TULANE STUDIES IN ZOOLOGY

Volume 8, Number 1 April 29, 1960

STUDIES ON THE BACKSWIMMERS OF COSTA RICA (HEMIPTERA; NOTONECTIDAE)

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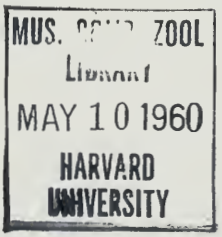


I. Introduction

Although Costa Rica has a rich fauna, studies of the insects are few. Some early naturalists (Calvert, 1917; Champion, 1897-1901; Picado, 1913; Pittier and Biolley, 1895; Pittier, 1942) published on various species but, with the exception of a recent work (Rosabal, 1954), there has not been any systematic attempt to study related forms at the generic or family levels.

The only records of the Costa Rican Notonectidae are by Champion (1897-1901), Hungerford (1933), and Truxal (1953). After Hungerford's studies on the taxonomic value of male genitalia in aquatic Hemiptera (1919b), Champion's work became obsolete as it was based on external morphology and pigmentation only. Hence, the only reliable information is that of Hungerford and Truxal who reported six forms from occasional collections. In the words of Hungerford: "...surely there are species not yet recognized and more intense collecting and closer scrutiny will prove fruitful indeed..."

In the course of this work, 2,357 specimens were studied, 697 specimens of the genus *Notonceta,* and 1,660 of *Buenoa.* In studying geographic variation in *Buenoa,* many series from various countries were examined. The material was obtained from the Francis Huntington Snow Entomological Collections (FHSC) at the University of Kansas, Museo Nacional de Costa Rica (MNCR), and the author's collection.

Areas studied.—Costa Rica, because of its geographic location, is the meeting place of the northern and southern faunas of the hemisphere. Several species common to North and South America have not been repoted in Costa Rica, but their presence is anticipated.

Most of the Costa Rican material studied was obtained from the Central Plateau and adjacent areas.

The Central Plateau is a valley about 1,000 M in altitude, bordered by mountains to the north and south, and by lowlands east and west.

The proximity of both Atlantic and Pacific Oceans provides a relatively homogeneous climate with such a minimum annual oscillation that the climate of the region has been classified as insular (Pittier, 1942). The monthly median temperature for San José, which is a good representation of the region, varies from 18.8°C in January to a median maximum of 20.5°C during May. The extremes range from 16.4°C to 28.1°C. As the annual curve of temperatures reaches just one maximum and one minimum, the climate is considered of tropical type.

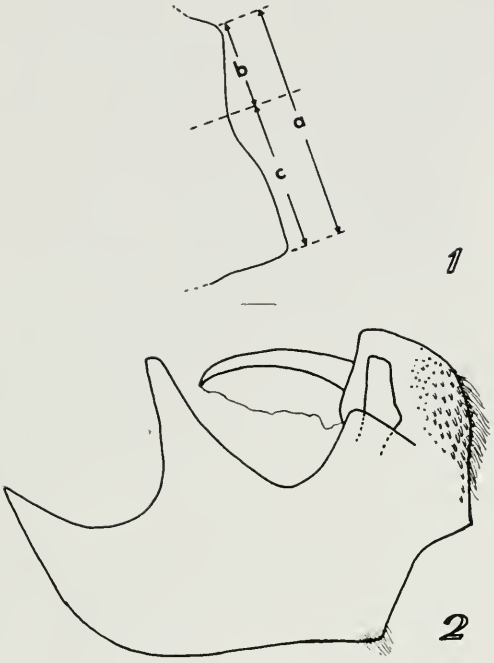
The hydrographic system of the Central Plateau area studied originates in the surrounding mountains, and runs through the plains of the west coast to the Pacific Ocean. The great majority of the rivers (Torres, María Aguilar, Tiribí, Carrizales, etc.) join to form a large stream bearing the name Rio Grande de Tarcoles. The rivers of the Plateau are not large and diminish during the dry season (December to May) but never become dry. During the rainy season (May to November) numerous temporary bodies of water are formed. These are important to the dispersal of the Notonectidae.

The other areas studied in this work (Rio Sucio, Sarapiqui) are in the lowlands north of the Central Plateau, and are irrigated by northward flowing streams that join the San Juan River which empties into the Atlantic Ocean. The high mountains of the Cordillera Volcanica separate this region from the Plateau, leaving a few narrow passages. And finally, the area of San Isidro de El General, in spite of being in the lowlands south of the Plateau, has climatic and hydrographic conditions very similar to the latter.

The vegetation of the Central Plateau is transitional between basal and subalpine. In the east and north, the Plateau is continued as lowland tropical rain forest; to the west it is replaced by grassland prairies which become deserts in the northwest part of the country. To the south the Plateau is continued in part by subtropical forest and grasslands.

Methods.—The methods and techniques used in the dissection and clearing of genitalia, study of appendages, measurements and identification, follow those recommended by Hungerford (1933) and Truxal (1953). Illustrations were made with the help of a camera lucida. Pubescence was omitted when it obscured characters of taxonomic importance.

All measurements were made using an ocular micrometer and reticule on a Bausch and Lomb stereoscopic microscope. In measuring the relative position of the curvature in the pronotum for *Notonecta ceres ceres,*



Figures 1-2. *Notonecta ceres ceres*. **1.** Measurements of pronotum: a = total length of side, b = distance from middle of curvature to anterior angle, c = distance from middle of curvature to posterior angle. **2.** Genital capsule, lateral view.

the scheme shown in Figure 1 was used. This computation is expressed in the graphs as a proportion which results from dividing the distance from the middle of the curvature to the anterior angle of the pronotum by the total length of the side of the pronotum.

Graph forms follow the methods of Hubbs and Hubbs (1953) with the exception of the small samples (less than 14) which were computed according to the method described by Cazier and Bacon (1949).

II. Key to the Males of the Costa Rican Notonectidae [1]

1. Hemelytral commissure without definite hair-lined pit at anterior end. Anterolateral margins of prothorax nonfoveate ..... (*Notonecta*) 2

   Hemelytral commissure with definite hair-lined pit at anterior end. Ventral abdominal keel extending onto last abdominal segment. Males with anterior tarsi two-segmented ..... (*Buenoa*) 5

2. Keel of fourth abdominal sternite bare, the hairs confined to the sides ..... *N. c. ceres*

   Keel of fourth abdominal sternite not bare 3

3. Pronotum broad in front, embracing the eyes, which are flattened and receding from the anterior margin of the vertex. Synthlipsis broad, one half the anterior margin of vertex as seen from above. Scutellum distinctly broader than long. Males with stout tubercle at angle of front trochanter ..... *N. ochrothoe*

   Pronotum not broad in front. Eyes not as above. Males without stout tubercle at angle of front trochanter 4

4. Synthlipsis distinctly less than one half anterior margin of vertex; head prominent ..... *N. indica*

   Synthlipsis wide, one half or more the anterior margin of vertex; head not prominent ..... *N. confusa*

5. Synthlipsis wide, one half or more the anterior margin of vertex 6

   Synthlipsis narrow, less than one half the anterior margin of vertex 10

6. Rostral prong with base originating laterally at or near distal end of third rostral segment 7

   Rostral prong with base not originating laterally at or near distal end of third rostral segment 8

7. Over 7 mm in length. Pronotum with its median length approximately three fifths its humeral width; disc almost unimpressed, not tricarinate ..... *B. crassipes*

   Less than 7 mm in length. Pronotum with its median length approximately two thirds its humeral width; disc with two elongate depressions toward the middle and a large subtriangular depression on each side, thus appearing distinctly tricarinate ..... *B. pallipes*

8. Posterior margin of hind femur with more than forty setae in ventral row ..... *B. pallens*

   Posterior margin of hind fe-

[1] This key was prepared by modification of Hungerford (1933) and Truxal's (1953) keys and includes forms that have not been reported for Costa Rica, but are anticipated because of their distribution north and south of Costa Rica.

mur with less than forty setae in ventral row 9

9. Pronotum almost unimpressed, not tricarinate; length of fore femur two times the width of apex; approximately twenty-five teeth in tibial comb ..... *B. ida*

Pronotum tricarinate; length of fore femur three times or more the width of apex; forty to fifty teeth in tibial comb ..... *B. antigone*

10. Fore femur narrowed at apex; length more than three times the width of apex, the stridulatory area consisting of six to nine sclerotized ridges. Rostral prong equal to or shorter than third rostral segment ..... *B. gracilis*

Fore femur widened at apex; length three times or less the width of apex, the stridulatory area consisting of eleven to fourteen sclerotized ridges. Rostral prong much longer than the third rostral segment ..... *B. platycnemis*

III. The Notonectidae of Costa Rica

A. *Notonecta ceres ceres* Kirkaldy, 1897

Synonymy.[2] — 1897. *N. mexicana* var. *ceres* Kirkaldy, Trans. Ento. Soc. London, p. 402; 1933. *N. ceres rogersi* Hungerford,

[2] For complete synonymy see: 1933. *N. c. ceres* Kirkaldy; Hungerford, Univ. Kansas Sci. Bull., 34(5) : p. 79.

Figure 3. Localities from which Costa Rican Notonectidae were examined. 1 = Sarapiqui, 2 = Rio Sucio, 3 = Laguna Zarcero, 4 = La Palma, 5 = Laguna San Isidro, 6 = San Jeronimo, Moravia, 7 = Rio Torres, 8 = San José, 9 = Escazu, 10 = Rio Virilla, 11 = Rio Maria Aguilar, 12 = Rio Tiribi, 13 = Desamparados, 14 = Carrizales, Escazu, 15 = San Isidro de El General.

Bull. Univ. Kansas, 34(5): p. 81.

The following description is modified from that of Hungerford (1933) to fit the ranges of variation found in the specimens that I studied.

Size.—Length, 10.4 mm to 12.7 mm; width of pronotum, 4.3 to 5.2 mm.

Color.—Red and black or tan and black for females; males are typically black but I have found specimens in which red was present in various degrees. Color variations are described in section below on statistical analysis. Anterior half of pronotum, head and limbs yellow or yellowish green; the middle and hind trochanters and femora with the dark stripe of the *N. mexicana* Amyot and Serville group.

Structural characters.—Head large; anterior outline of head viewed from above, flattened; vertex a little longer than its anterior width; anterior margin of vertex less convex and plainly shorter than the frontal margin of the eye; anterior breadth of vertex: synthlipsis :: 11 : 3. Pronotum nearly twice the length of head; lateral margins moderately concave and moderately divergent; the margin more concave in females than in males, as seen from the side, strongly curved, pronounced on anterior half; margin of prothorax shorter than the rear margin of the eye below it. Anterior lobe of membrane of hemelytra a little longer than the posterior one. Anterior trochanters of male with moderate hook. Mestotrochanters rounded. The carina of fourth abdominal sternite bare. The terminal abdominal sternite of female narrow, broader at the tip, and broadly incised. First pair of gonapophyses short. Male genital capsule as shown in Figure 2.

Location of types.—Kirkaldy collection at U. S. National Museum, Washington.

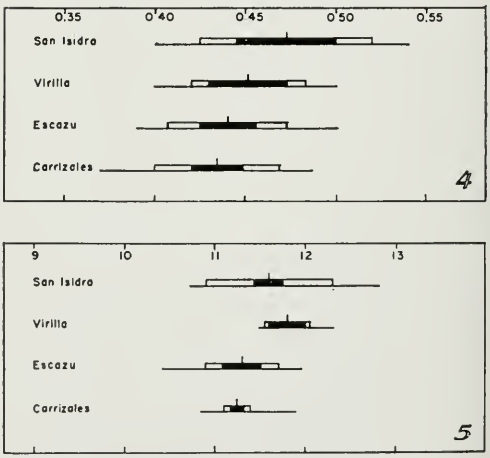
Comparative notes.—This subspecies was described by Hungerford (1933) as being different from *N. c. rogersi.* I have found that both are intergrades; a more detailed account is given in the statistical analysis.

Geographic distribution and specimens studied (fig. 3).—San José: Aug. 1905, P. Biolley, 1 female, 1 male (FHSC). Rio Virilla: Dec. 1931, H. Schmidt, 9 females, 3 males (FHSC). Rio Tiribi: Aug. 1956, J. De Abate, 2 females, 7 males, 6 nymphs (002);[3] July 1957, J. De Abate, 6 females, 3 males (009); Desamparados: Feb. 1958, S. Jimenez-Canossa, 13 females, 7 males, 42 nymphs (016). San Rafael Escazu: Jan. 1957, S. Jimenez-Canossa, 3 females, 6 nymphs (003). Carrizales, Escazu: Oct. 1957, S. Jimenez-Canossa, 3 females, 1 male, 4 nymphs (012); Nov. 1957, S. Jimenez-Canossa, 5 females, 8 males, 8 nymphs (013); Nov. 1957, S. Jimenez-Canossa, 26 females, 46 males, 205 nymphs (014); Dec. 1957, S. Jimenez-Canossa, 19 females, 26 males, 88 nymphs (015). San Jeronimo, Moravia: July 1956, J. De Abate and L. Mata, 1 females, 3 males (001). La Palma: date unknown, Tristan, 1 male (MNCR); date unknown, P. Biolley, 1 female, 3 males (FHSC). Laguna San Isidro, Heredia: July 1957, J. De Abate and L. Ferrero, 13 females, 13 males, 19 nymphs (008). Rio Sarapiqui: date unknown, H. Schmidt, 2 females, 2 males, 15 nymphs (FHSC). Rio Sucio: date unknown, H. Rogers, 1 female, 1 male (FHSC).

Besides *ceres* this species has another subspecies, *N. c. stirtoni,* which has been reported only for El Salvador.

1. *Statistical analysis*

In his monograph on the *Notonecta* of the World, Hungerford (1933) described a new subspecies, *N. c. rogersi.* The characters used in the description were: total



Figures 4-5. *Notonecta ceres ceres.* **4.** Position of the curvature at the side of pronotum. **5.** Total length variation in neighboring populations.

[3] Numbers in parenthesis indicate catalog number in writer's collection.

length, and relative position of the curvature at the sides of the pronotum.

With respect to total length Hungerford established the limit at 12 mm, calling *ceres* the individual which were 12 mm or less in total length and *rogersi* those exceeding that limit. For the other character he wrote: "...The lateral margins of the pronotum of female constricted in front of the middle: *rogersi*...". "...The lateral margins of the pronotum of female constricted near the middle: *ceres*...". However as his arbitrary limit for total length does not correspond to that found in nature, and the description "near the middle" is rather vague, I have analyzed statistically both characters to determine the validity of the subspecific status.

According to Hungerford's descriptions, only seven of the 64 specimens I studied for this purpose could be regarded as *ceres* and seven as *rogersi*. The rest (52 specimens) vary so much that they do not fit completely either description.

Four samples were used in the statistical analysis: 8 specimens from Rio Virilla, 13 specimens from San Isidro de Heredia, 24 from Carrizales de Escazú and 19 from Escazu. In all cases the data refer to adult females, which were selected because they have the curvature more pronounced, and to avoid the introduction of error by using both sexes.

Position of pronotal curvature.—The populations analyzed intergrade in such a manner that a subspecific status for this character becomes inconsistent (fig. 4). The samples from Rio Virilla, Escazu, and Carrizales appear to be more closely related to one another than to the one from San Isidro. This perhaps can be correlated with geographic distribution, since the first three areas are about two miles apart, whereas the latter is about ten miles away.

Total length.—Although total length is of little taxonomic significance, I attempted to find every possibility for segregation. Figure 5 shows an intergrading situation in which the Rio Virilla sample has higher values than the rest. This variance is not enough to justify a subspecific rank, and it is probably due to ontogenetic variation.

Figure 6 is a scatter-diagram in which the values for the position of the pronotal curvature and total length have been plotted for

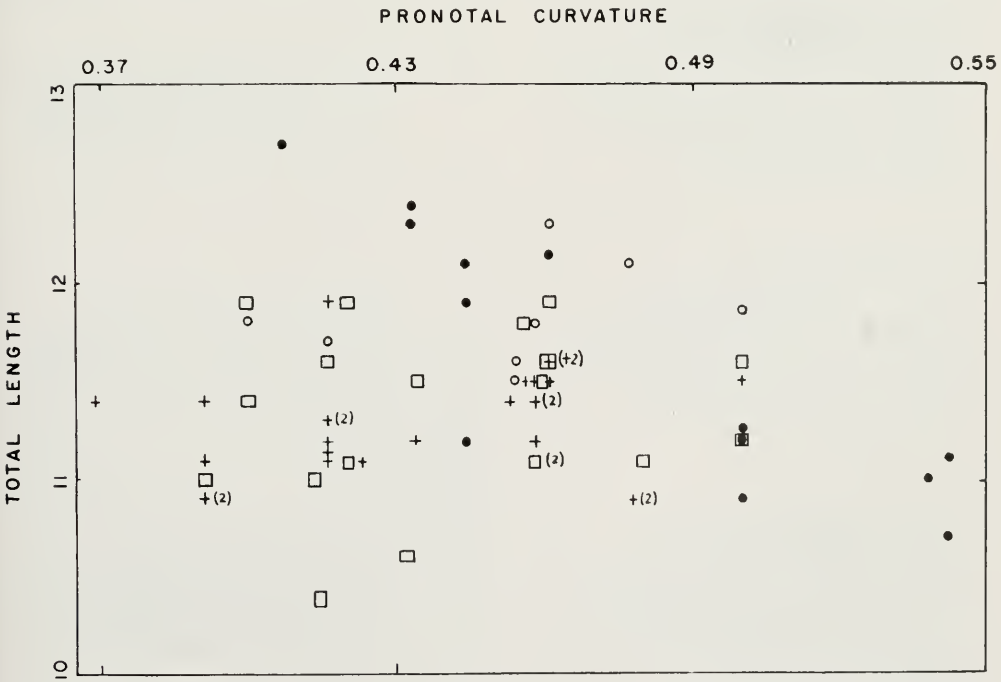


Figure 6. *Notonecta ceres ceres.* Total length compared with relative position of pronotal curvature. Crosses = Carrizales; squares = Escazú; small circles = Rio Virilla; black dots = San Isidro Heredia.

all four samples. Here again we can see that there is not enough segregation of individuals and that *N. c. ceres* has a wide range of variation.

Conclusions.—According to this analysis I feel that there is no reason for maintaining the subspecific status for *N. c. rogersi,* which I have relegated to synonymy with *N. c. ceres.*

Color variation.—In males there is a gradation in color ranging from the typical black to almost red. This variation concerns only the clavus and corium; the scutellum and membrane are always black.

The 114 specimens studied for this purpose were placed in five representative groups according to coloration (fig. 7). The incidence (by percent) in each group

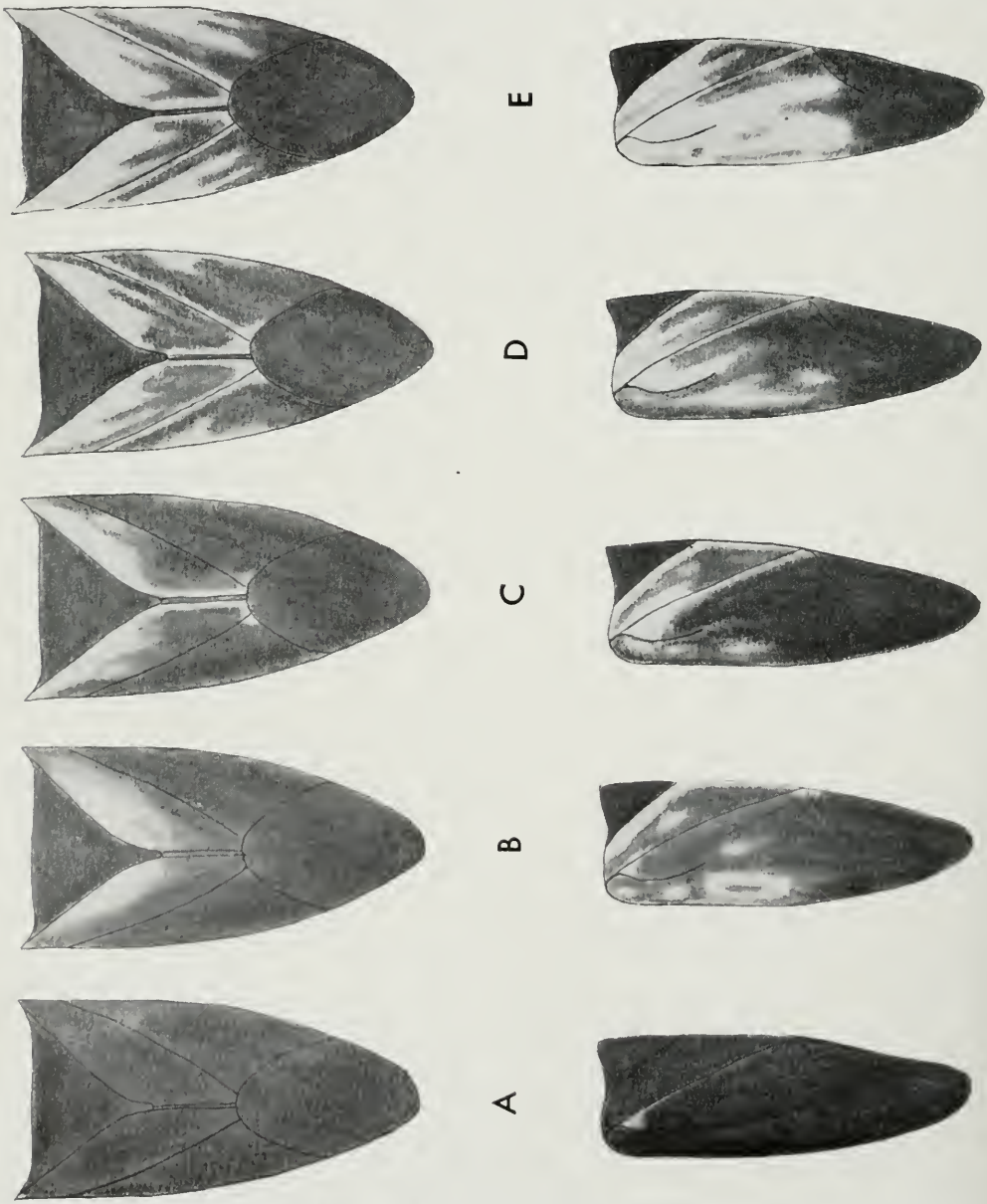


Figure 7. *Notonecta ceres ceres.* Color variation in male hemelytra; upper row, dorsal aspect; lower row, lateral aspect. Red areas shown in white.

is as follows:

A	B	C	D	E
42.1	30.7	6.1	12.8	8.7

No significance was found in color variation among different populations. I presume that nutrition and amount of sunlight are the main factors acting on this secondary sexual character. This presumption is based on the observation that male specimens reared in the laboratory are paler and have more red areas than those found in the field.

2. *Life history*

N. c. ceres has been reported only for Costa Rica, where it is abundant, but nothing has been published on its life cycle. During the summer of 1957, I had the opportunity to rear a sufficient number of specimens to observe the complete life history of this insect in the laboratory.

The insects used for this purpose were collected from San Isidro de Heredia and Rio Tiribi.

Duration

The life cycle from oviposition to the emergence of the adults requires an average of 65 days. This includes an average incubation period of 20 days at room temperature (23°C±3). The duration of each nymphal instar is from 9 to 11 days at the same temperature.

Eggs

Elongate oval in shape with ventral side flat (fig. 8). Average of 15 eggs measured were: length, 2.2 mm (2.05 to 2.30 mm); width, 0.99 mm (0.90 to 1.05 mm); height, 0.94 mm (0.75 to 1.0 mm). This is one of the largest *Notonecta* eggs known. During the first days the eggs are pearly white, becoming cream colored later. The only external sign of embryonic development is the appearance of two small red spots in dorsal cephalic position, which correspond to the eyes (fig. 8). At hatching the nymphs emerge from a dorsal slit in the egg. In the aquaria, eggs were glued to leaves and stems of *Elodea* sp. and to debris.

Figure 8. Eggs of *Notonecta ceres ceres* attached to stem of *Elodea* sp. Notice how close together the eggs were laid.

Nymphal instars

The nymphal instars are similar, the differences being mostly quantiative. As in the rest of the notonectids, there are five instars.

(I). *First instar* (figs. 9, 14, 19, 24).—Size: length, 3.0 to 3.25 mm; width of body, 1.35 to 1.7 mm; width of head, 1.02 to 1.27 mm; vertex, 0.55 to 0.85 mm; synthlipsis, 0.35 to 0.475 mm. Mean values are given in Table 1.

Color.—Limbs and abdomen transparent when newly hatched, becoming white hours later; hairs smoky; eyes red; sides of pronotium and abdomen testaceous; rostrum and antennae testaeceous dark; venter and abdomen light.

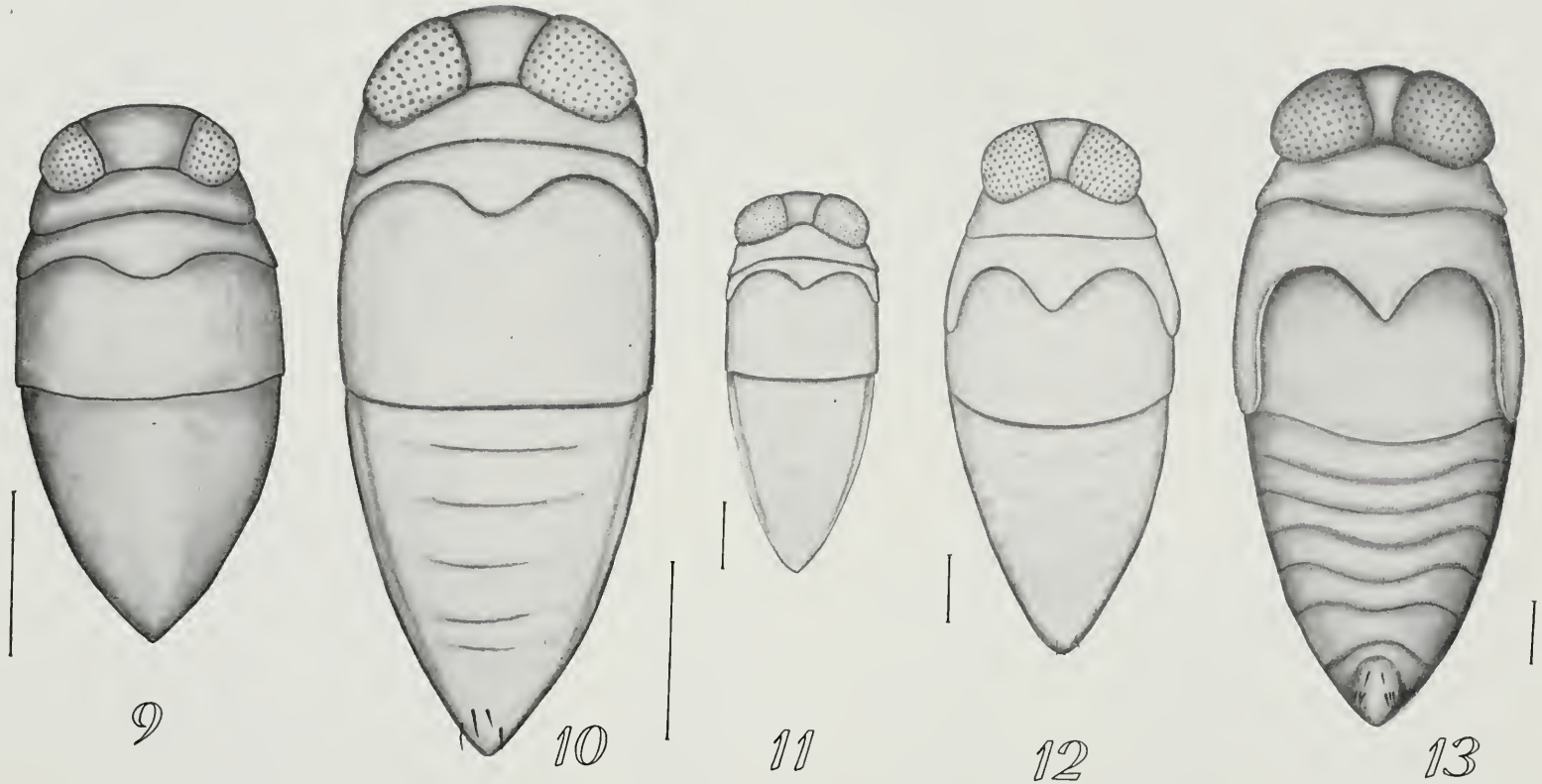
Structural characters.—Ventral abdominal carina absent as in all first instars of notonectids. Antennae directed downward, three-segmented, basal segment very short (fig. 19). Anteapical spine of intermediate femora not present (fig. 24). Tarsi one-segmented, ending in two large claws.

(II). *Second instar* (figs. 10, 15, 20, 25).—Size: length, 3.85 to 4.3 mm; body width, 1.35 to 2.25 mm; head width, 1.4 to 1.62 mm; vertex, 0.40 to 0.62 mm; synthlipsis, 0.20 to 0.325 mm. Mean values shown in Table 1.

Color.—General facies, white; eyes reddish brown; posterior femora with faint darker zone along the middle, corresponding to the stripe characteristic of the *N. mexicana* group.

Structural characters.—Ventral abdominal carina present and marginated with smoky hairs. Antennae three-segmented, oriented as in adults, with a structure as shown in fig. 20. Intermediate femora with anteapical spine moderately developed (fig. 24). Tarsi one-segmented, the posterior with two subequal claws.

(III). *Third instar* (figs. 11, 16, 21, 26).—Size: length, 5.15 to 5.85 mm; width of body, 2.2 to 2.7 mm; width of head, 1.8 to

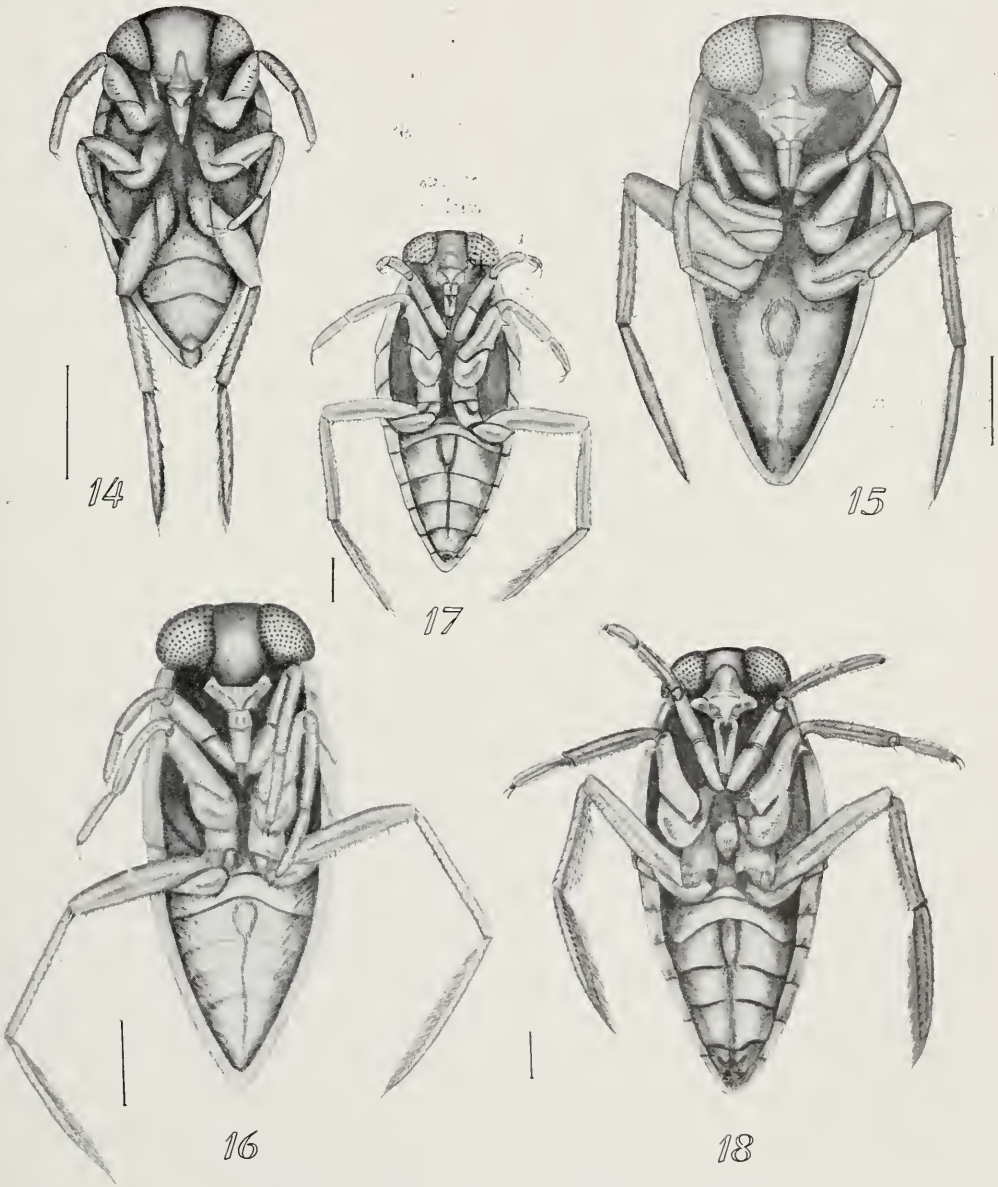


Figures 9-13. *Notonecta ceres ceres.* Dorsal aspect of nymphal instars. **9.** First instar. **10.** Second instar. **11.** Third instar. **12.** Fourth instar. **13.** Fifth instar. Vertical line beside each figure = 1 mm.

2.0 mm; vertex, 0.50 to 0.75 mm; synthlipsis, 0.225 to 0.375 mm. Mean values shown in Table 1.

Color.—General facies white; eyes reddish brown, dorsum of abdomen with lateral smoky bands poorly defined. Base of beak and beak dark testaceous. Limbs testaceous, middle trochanters, hind trochanters and femora with the typical markings of the *N. mexicana* group, but not as pronounced as in later instars.

Structural characters.—Ventral abdominal carina long, with the hairs darker than in the preceding stage. Antennae located as in adults and with structure as shown in figure 21. Intermediate femora with a hook-like



Figures 14-18. *Notonecta ceres ceres.* Ventral aspects of nymphal instars. **14.** First instar. **15.** Second instar. **16.** Third instar. **17.** Fourth instar. **18.** Fifth instar. Vertical line beside each figure = 1 mm.

TABLE 1.

N. ceres ceres: extreme ranges and mean values (bold face) for measurements in the nymphal instars.

Instar	Specimens Measured	Total Length	Body Length	Head Width	Vertex	Synthlipsis
1	5	3.0 -**3.16**-3.25	1.35-**1.54**-1.70	1.02-**1.19**-1.27	0.55-**0.675**-0.85	0.35 -**0.405**-0.475
2	15	3.85-**4.11**-4.3	1.35-**1.84** 2.25	1.40-**1.52**-1.62	0.40-**0.482**-0.62	0.20 -**0.27** -0.325
3	15	3.15-**5.49**-5.85	2.2 -**2.46**-2.7	1.8 -**1.90**-2.0	0.50-**0.604**-0.75	0.225-**0.308**-0.375
4	15	7.25 **7.56**-1.85	3.2 -**3.38**-3.5	2.25-**2.38**-2.50	0.65-**0.756**-0.87	0.30 -**0.356**-0.45
5	15	9.2 -**9.73**-10.2	4.2 -**4.57**-5.1	2.9 -**3.0** -3.1	0.80-**0.857**-0.95	0.30 -**0.36** -0.45

anteapical process (fig. 26). Tarsi one-segmented. Wing pads as shown in figure 14.

(IV). *Fourth instar* (figs. 12, 17, 22, 27).—Size: length, 7.25 to 7.85 mm; width of body, 3.2 to 3.5 mm; width of head, 2.25 to 2.50 mm; vertex, 0.65 to 0.87 mm; synthlipsis, 0.30 to 0.45 mm. Mean values shown in Table 1.

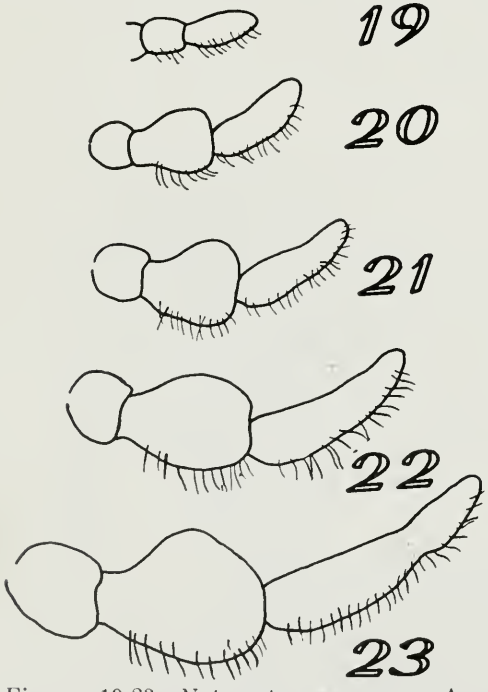
Color.—White. Eyes dark brown. Dorsum of abdomen with lateral markings as in third instar. Base of beak and beak testaceous, clypeus darker. Limbs testaceous, all trochanters with median longitudinal stripe; anterior, middle and posterior femora also with the typical stripe of the *N. mexicana* group.

Structural characters.—Carina as in third instar. Antennae located as in the preceding stage, with srtucture as shown in figure 22. Intermediate femora with anteapical process straight and well developed, and with a small tubercular process in the middle of the posterior margin (fig. 27). Tarsi as in third instar. Wing pads well developed (fig. 12).

(V). *Fifth instar* (figs. 13, 18, 23, 28). —Size: length, 9.2 to 10.2 mm; width of body, 4.2 to 5.1 mm; width of head, 2.9 to 3.1 mm; vertex, 0.80 to 0.95 mm; synthlipsis, 0.30 to 0.45 mm. Mean values shown in Table 1.

Color.—White. Eyes dark brown. Dorsal abdominal markings as in the preceding instar but more distinct. Beak and base of beak as in fourth instar. Ventral aspect darker than in the preceding instars. Limbs as in fourth instar but with darker markings.

Structural characters.—Ventral abdominal carina as in the two preceding instars but more pronounced. Eyes strongly confluent posteriorly (fig. 13). Intermediate femora as in fourth instar but with processes more pronounced (fig. 28). Tubercular process in the middle of posterior margin more developed than in the preceding instar. Antennae located as in adults with a constriction in distal third of the third segment. In cleared and mounted antennae, a thin transverse septum can be seen near the level of the constriction (fig. 22) which will become the division between the third and fourth antennal segments of the adult. Wing pads extending beyond posterior thoracic border (fig. 13).



Figures 19-23. *Notonecta ceres ceres.* Antennae of nymphal instars. **19.** First instar. **20.** Second instar. **21.** Third instar. **22.** Fourth instar. **23.** Fifth instar.

Mating

When collected, many individuals were mating and they continued doing so after transferal to aquaria. This species is able to copulate three times per day, sometimes for periods of three continuous hours (maxi-

TABLE 2.
N. c. ceres: monthly incidence of the various instars.

		Months											
		J	F	M	A	M	J	J	A	S	O	N	D
Instars	1		+				+		+	+		+	+
	2		+	+	+				+		+	+	+
	3		+		+	+	+		+	+	+	+	+
	4		+	+		+	+	+	+	+	+	+	+
	5	+	+	+	+	+	+	+	+	+		+	+
	Ad.	+	+	+	+	+	+	+	+	+	+	+	+

mum mating time observed was 3 hrs., 20 min.).

For *N. borealis* Rice (1954) reported that, after mating, there is a preoviposition period. Nothing of this sort was observed in *N. c. ceres,* as females were actively mating during the oviposition period, sometimes laying eggs just a few minutes after copulation.

Seasonal activity

In all months when collections were made, both adults and nymphs of various instars were found. The stages found and the months involved are given in Table 2. I presume that, due to the favorable climatic conditions of Costa Rica, *N. c. ceres* is able to breed the year around.

Oviposition

My laboratory notes read as follows "... A gummy substance is secreted on the surface where the eggs is going to be laid. The egg is held by ovopositor against the gummy substance until it is secure. All the process takes about 25 seconds for each egg...".

Eggs are laid in an irregular manner. One isolated female laid 37 eggs in 13 days; that is, an average of 2.8 eggs per day. Four other females laid 76 eggs in 17 dags.

3. *Growth*

To obtain estimates of growth rates, nymphs of the five instars were used. The distinct size groups corresponding to each instar are given in Table 1. For every measurement the mean, maximum, and minimum ranges of variation are given. For total length, body width, and head width there is a close isometric relationship. This is not true for the vertex and synthlipsis values where an apparent decrease in growth is detectable at the second instar. This can be explained not as a reduction of vertex and synthlipsis, but as a rapid growth of the eyes in molting to the second instar. The relative size of the eyes can be seen in figures 9, 10, 14, 15. Differential growth between males and females is not given, as sexual determination is difficult during the nymphal instars and the technic involved destroys the specimens.

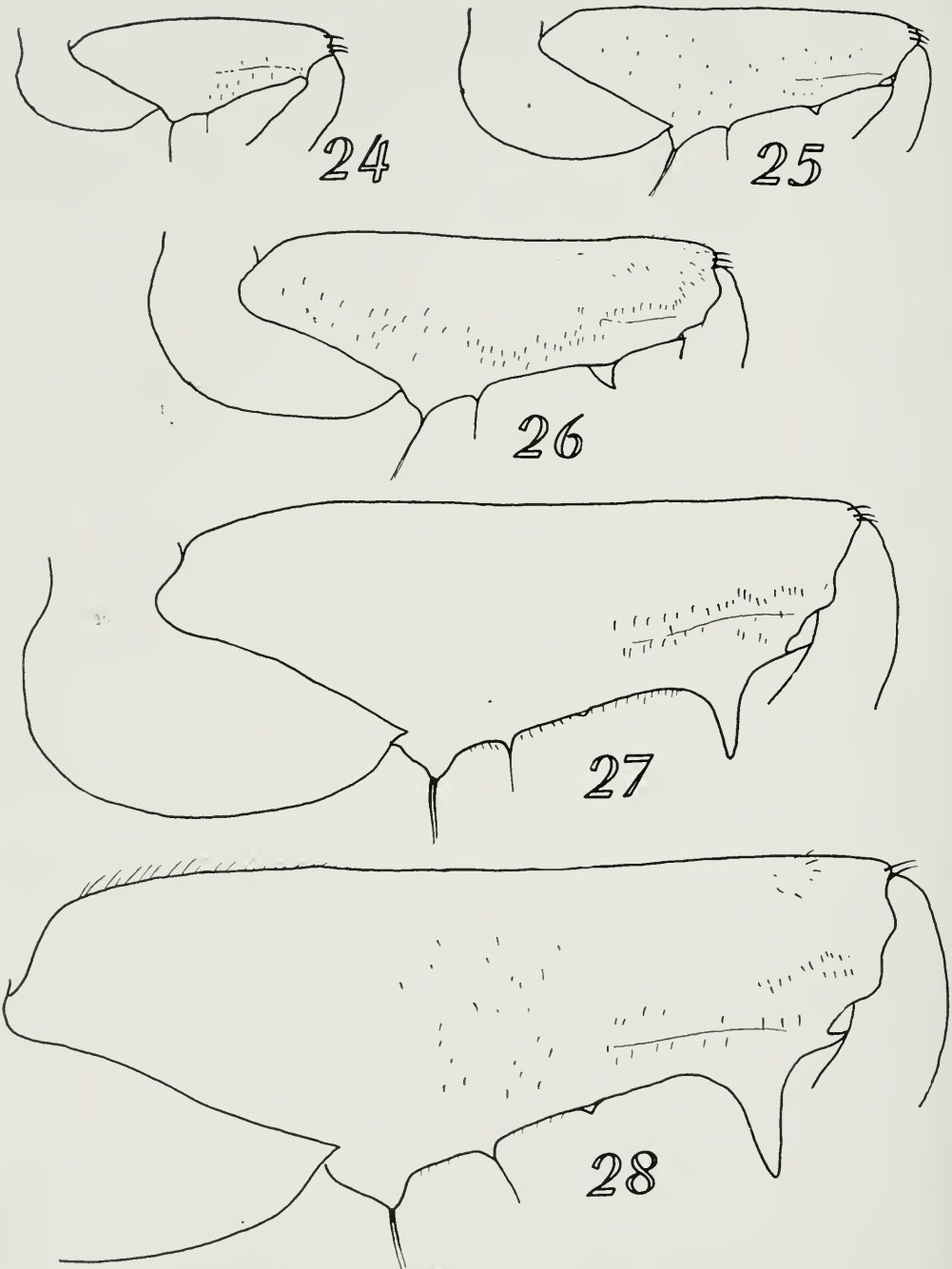
In checking Dyar's Law (1890) in an attempt to establish a definite growth rate for *N. c. ceres,* I found that if a measurement of the first nymphal instar was multiplied successively by 1.3, and again this number by 1.3 a series of figures was obtained that corresponded closely to the values for that particular measurement in the different instars. Table 3 shows these theoretical values compared with the actual averages (taken from Table 1). In all cases the theoretical figures follow closely the actual values.

Knowing the first instar, the measurements of other instars can be foreseen by using the equation:

$$Y = M(1.3)^{N-1}$$

Where Y = the measurement of the nymphal instar sought; M = same measurement in the first instar; 1.3 = the growth factor; and, N = the number of the instar sought in Y.

A further attempt was made to determine the possibility of a unique growth rate, of the measurements studied for all notonectids. For this, data of head width published by Hungerford (1919a) for *N. undulata, N. irrorata* and *Buenoa margaritacea* were used. Also data for *N. insulata, N. borealis, N. raleighi* and *B. limnocastoris* were taken from Rice (1942, 1954). Actual values were compared with the corresponding theoretical figures (Tables 4, 5), and here again the growth rate factor of 1.3 is appropriate. Plotting these figures (figs. 29-32) shows that the theoretical figures follow closely the



Figures 24-28. *Notonecta ceres ceres.* Middle femora of nymphal instars. **24.** First instar. **25.** Second instar. **26.** Third instar. **27.** Fourth instar. **28.** Fifth instar.

actual values for *N. c. ceres, N. insulata, N. undulata, N. irrorata* and *B. margaritacea.* This is not so for the rest of the species studied. For *N. raleighi* the values for third and fifth instars are very close, but not those for the second and fourth. In *N. borealis* and appreciable difference of values can be seen in the fourth instar. And finally,

Table 3.

N. c. ceres: the actual and theoretical values of growth rate for body parts.

Instar	Body Length		Body Width		Head Width	
	Actual	1.3	Actual	1.3	Actual	1.3
1	3.16		1.54		1.19	
2	4.11	4.11	1.84	2.0	1.52	1.55
3	5.49	5.34	2.46	2.60	1.9	2.01
4	7.56	6.94	3.38	3.38	2.38	2.61
5	9.73	9.03	4.57	4.41	3.0	3.40

Table 4.

Head width: theoretical and actual growth rate values in five species of Notonecta.

Instar	*N. undulata*		*N. irrorata*		*N. borealis*		*N. insulata*		*N. raleighi*	
	Actual	1.3	Actual	1.3	Actual	1.3	Actual	1.3	Actual	1.3
1	0.833		0.91		1.045		1.092		0.532	
2	1.06	1.083	1.2	1.18	1.375	1.358	?	1.419	0.95	0.691
3	1.4	1.41	1.56	1.54	1.815	1.766	1.85	1.845	0.97	0.899
4	1.87	1.833	2.08	2.0	1.935*	2.295	2.3	2.399	1.3	1.169
5	2.5	2.382	2.86	2.6	2.805	2.984	2.86	3.118	1.5	1.519

* In Rice (1954) this value is reported as ".935", and is probably an error.

for *B. limnocastoris* a considerable difference is noted in the figures for second and fourth instars.

In the last three cases Rice, who probably obtained the material from field collections and not from laboratory rearing, must have confused some nymphal instars, introducing variations of such magnitude as shown in the curves (figs. 30-32).

Clark and Hersh (1939) studied the growth of *N. undulata:* theirs is a thorough study referring, specially, to growth centers and growth gradients. Applying the 1.3 growth rate factor to their data on head width and body length I found that it corresponded with deviations comparable to those cited in Table 4.

Based on these data, I postulate that the growth rate of body length and head width is very close for all notonectids, if not the same. Further investigation of other species is necessary to establish a generalization in this respect.

Food.—*N. c. ceres,* as the rest of the notonectids, has predaceous habits and probably feeds on a great variety of animal forms. In nature I have seen it feeding on *Buenoa* and ostracods. In the laboratory it was fed on muscid flies (*Musca* sp.), tabanid flies (Tabanidae), mosquito larvae (*Culex* sp.), stingless bees (Meliponidae), leaf hoppers (Jassidae) and on small snails (*Tropicorbis* sp.), all of which were accepted eagerly. I also observed that this species attacks and feeds on small fishes (*Rivulus* sp.) and tadpoles (*Hyla* sp.). When specimens were starved, cannibalism was observed.

Behavior.—Adults are clumsy swimmers and spend most of the time "hanging" from the surface of the water. When feeding they hold their prey with their front legs, the middle legs hanging with claws just reaching the water surface, and the hind legs with femur and tibia at an angle of about 90° to each other.

When attached to objects under water, they come to the surface to replenish air periodically. Air is stored under the hemelytra and in the ventral abdominal pubescence. The average submergence time, taken from 20 observations, was 4 min., 15 sec., (26 sec. to 4 min., 35 sec.), although Edwards (1953) reported that *Notonecta* are able to remain submerged up to six hours depending on the metabolic rate.

Ecology.—In all cases *N. c. ceres* was collected in fresh water. This species was found most commonly in clear, slow-running, permanent, shaded water. In most of the cases, the vegetation was moderate and a sandy-mud bottom was present. For the

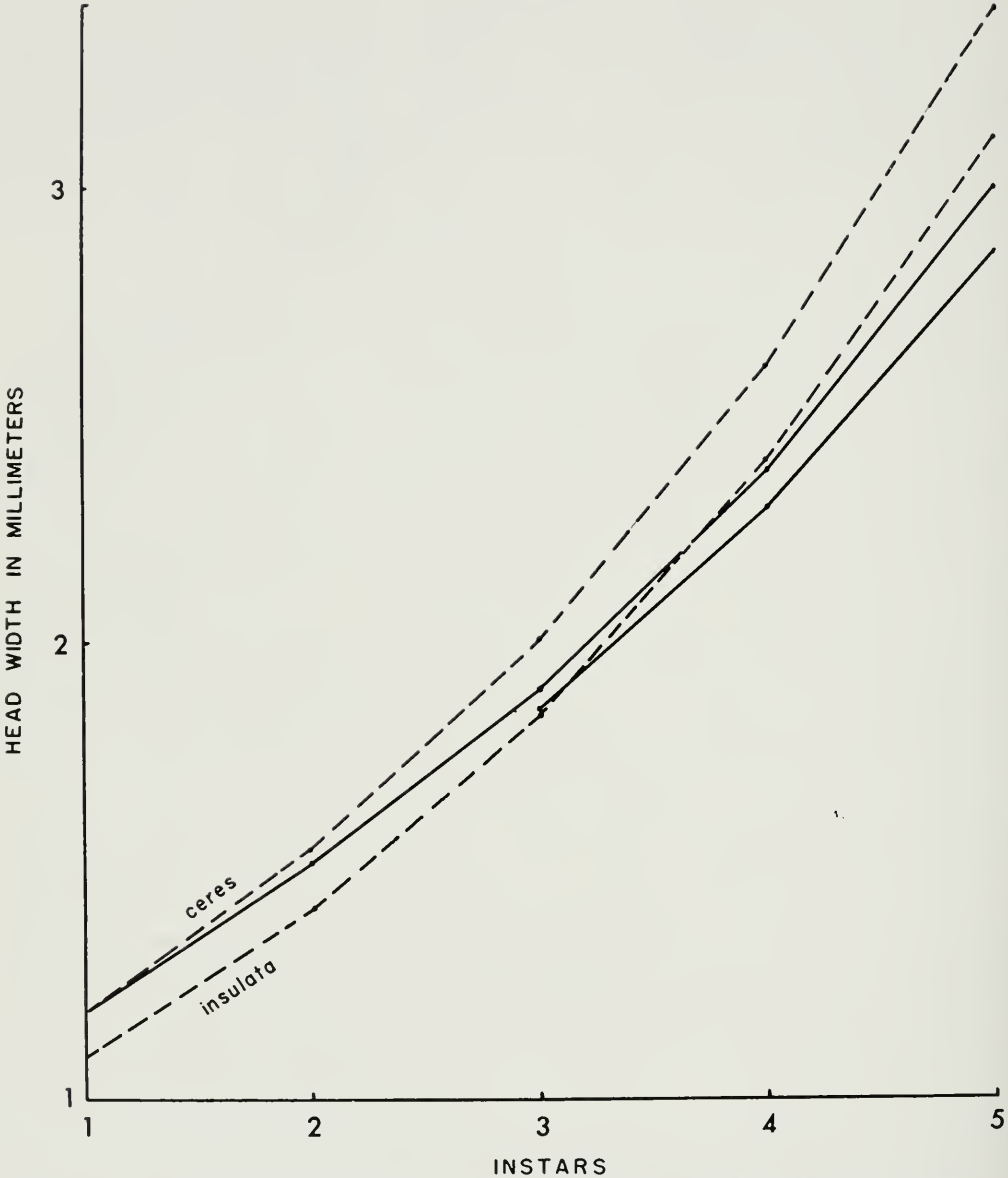


Figure 29. Theoretical and actual growth rates for *Notonecta ceres ceres* and *Notonecta insulata*. Solid lines = actual values; broken lines = theoretical values. Actual data for second instar of *N. insulata* were unavailable.

numerical incidence of each ecological situation see Table 6.

In respect to the fauna, Gerridae, Belostomatidae, ostracods and small fishes and tadpoles were present in various numbers, and I assume that they play an important role in the biology of the notonectids.

Notonetca indica Linne, 1771

Synonymy.[4]—1771. *N. indica* Linnaeus. Mantissa Plantarum, II, p. 534.

Size.—Length, 10 mm to 11 mm, width

[4] For complete synonymy see: 1933. *Notonecta indica* Linne; Hungerford, Univ. Kansas Sci. Bull., 21(9): p. 113.

of pronotum, 3.36 to 3.75 mm.

Color.—Luteous to almost black, hemelytra usually white with base of clavus black or tan. Scutellum black, often pale at the tip and basal angles.

Structural characters. — Head prominent, more than one half length of pronotum. Anterior margin of vertex straight; width of vertex: synthlipsis :: 5 : 2. Synthlipsis less than one half the anterior margin of the eye. Anterior angles of pronotum embracing the eyes. Anterior trochanter of male with a stout hook. Mesotrochanters rounded or nearly so. Male genital capsule not digitate and with claspers broad; incised at the tip.

Geographic distribution. — This species has never before been reported for Costa

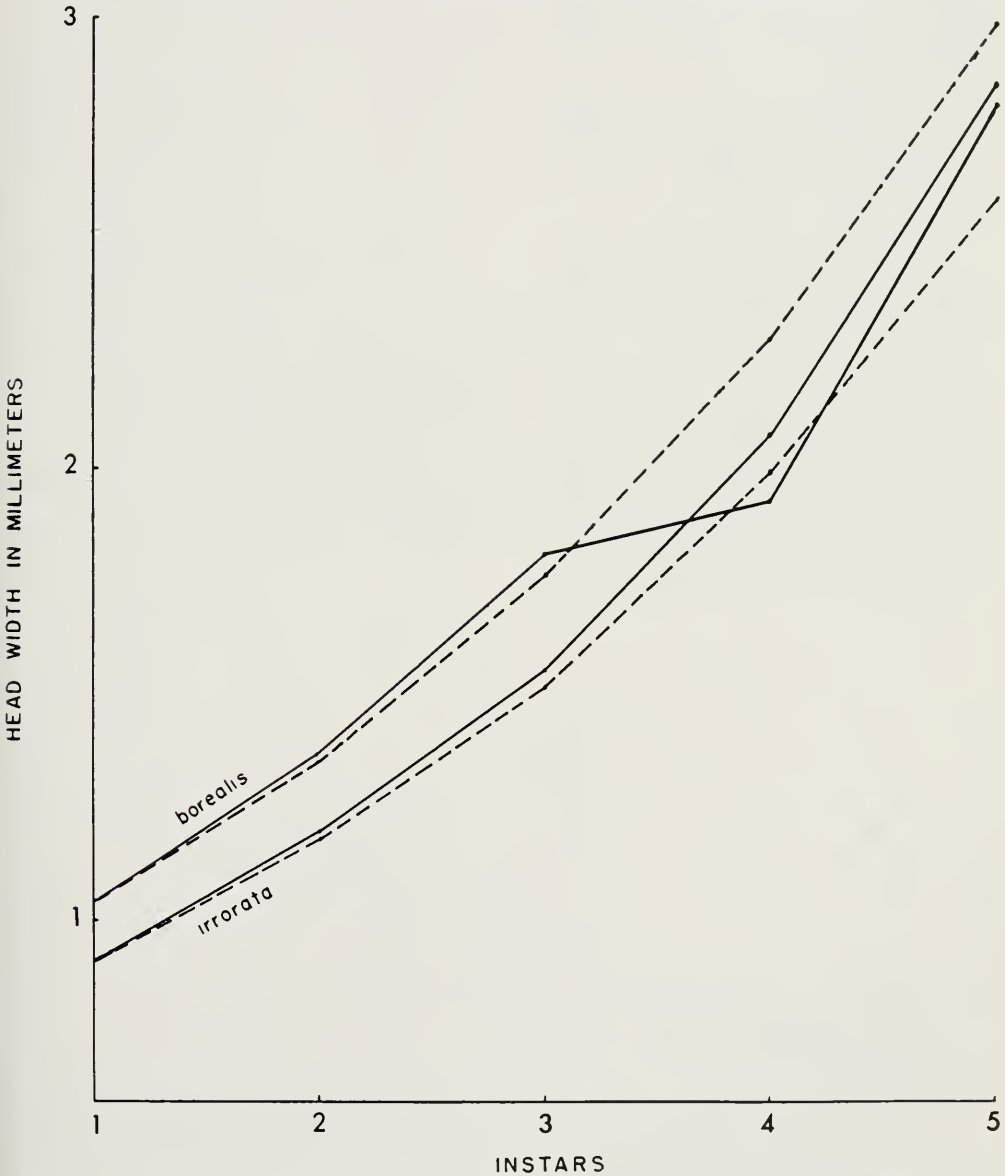


Figure 30. Theoretical and actual growth rates for *Notonecta borealis* and *Notonecta irrorata*. Observe how closely the theoretical values follow the actual values, except for the fourth instar of *N. borealis*. Symbols as in figure 29.

Rica. I collected one male specimen in the San Isidro Heredia Lagoon. In spite of a careful search, I was not able to find another specimen.

Reports on the geographic distribution of this species give a range from 37° latitude in the United States to Brazil in South America. The reports for localities are as follows: United States, Mexico, Guatemala, Colombia, Brazil, and the islands of Cuba, Jamaica, St. Croix, St. Thomas and Puerto Rico. The Costa Rican specimen bears the following data:

Costa Rica: Heredia, Laguna de San Isidro, J. De Abate and L. Ferrero, 1 male (008). This specimen was collected in fresh still water, in a shady area where vegetation was abundant.

C. *Notonecta confusa* Hungerford, 1930

Synonymy.—1930. *N. confusa* Hungerford. Bull. Brooklyn Ent. Soc. XXV, p. 140; 1933 *N. confusa* Hungerford; Univ. Kansas Sci. Bull. 34(5): 1-195.

Size.—Length, 12 mm; width of thorax, 4 mm.

Color.—Pale yellow. Hungerford (1933) stated that the typical color is probably black and white.

Structural characters.—This species is very similar to *N. undulata* Say, from which it differs in having the mesotrochanter feebly angulate and the male genital claspers bifurcate. This species was described from a single specimen.

Geographic distribution.—The type locality is "South America"; another specimen was reported also from Cuba; I suspect that this species is present in Costa Rica.

D. *Notonecta ochrothoe* Kirkaldy, 1897

Synonymy. — 1897. *N. shooterii* var. *ochrothoe* Kirkaldy, Trans. Ent. Soc. London, p. 407; 1905. *N. shooterii* var. *ochrothoe* Kirkaldy; Bueno, J. N. Y. Ent. Soc., xiii, p. 161; 1933. *N. ochrothoe Kirkaldy:* Hungerford, Univ. Kansas Sci. Bull., 34(5), p. 99.

Size.—Length, 10.8 to 11.4 mm; width of pronotum, 4.0 to 4.4 mm.

Color.—Luteous or pale luteous.

Structural characters.—Anterior outline of the head viewed from above, convex; anterior width of vertex: synthlipsis :: 3 : 2. Pronotum more than twice the length of head; anterolateral margins acute and embracing the eyes. Anterior trochanter of male with stout hook and tuberculate projection on the basal angle. Mesotrochanters rounded. Male genital capsule with a thickened protuberance on keel.

Geographic distribution. — This species hss not been reported for Costa Rica, but

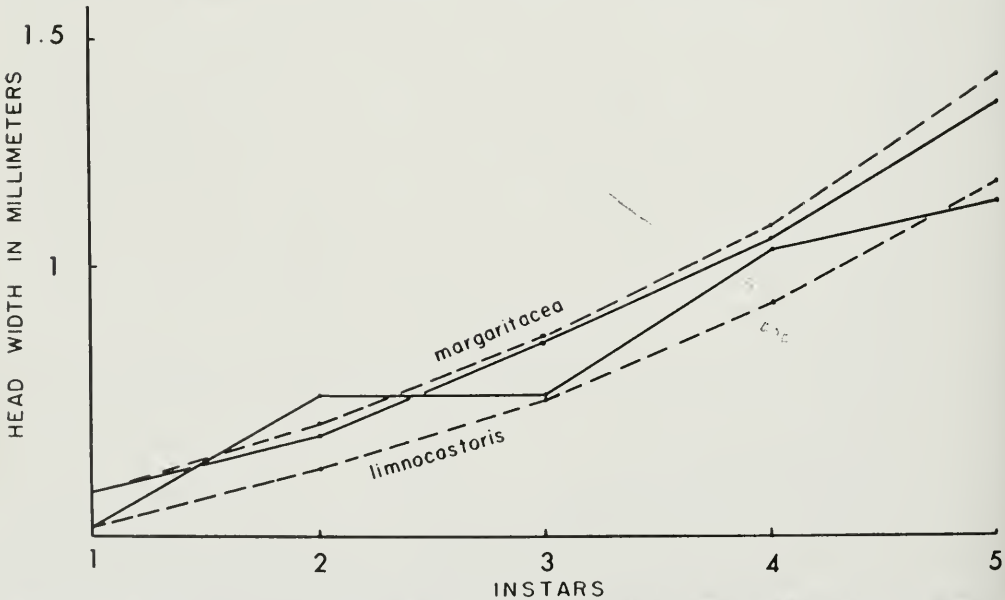


Figure 31. Theoretical and actual growth rates for *Buenoa margaritacea* and *Buenoa limnocastoris*. Compare the closely similar rates in *B. margaritacea* with deviations in *B. limnocastoris*. Symbols as in figure 29.

its presence is anticipated. It has been reported from Colombia, S. A. and California, U. S. A.

E. *Buenoa crassipes* (Champion) Kirkaldy, 1904

Synonymy.[5] — 1901. *Anisops crassipes* Champion. Biologia Centrali - Americana, Heteroptera, vol. II, p. 374.

Size.—Male, length 7.0 to 8.4 mm; head width, 1.75 to 2.2 mm; vertex 0.26 to 0.35 mm; synthlipsis, 0.10 to 0.21 mm. For the female Truxal (1953) reports the following figures: length, 5.98 to 7.5 mm; greatest body width, 1.75 to 2.01 mm.

Color.—General facies testaceous to nigro-violaceous. Head, pronotum, venter and limbs testaceous. Keel and portions of conexivum testaceous. This species is variable in color.

Male structural characters.—Viewed from above, head is laterally rounded with vertex indented. Greatest width of head from six to seven times the width of vertex. Synthlipsis approximately half the width of vertex. Tylus slightly inflated. Rostral prong with apex rounded, its origin near the distal end of third rostral segment. Fore femur with triangular and subtriangular stridulatory area formed by ten to eighteen ridges. Genital claspers normal.

Female structural characters.—Head shaped as in males, five and one half times the width of vertex. Synthlipsis approximately one half the width of vertex. Scutellum with median length greater than that of pronotum. Ovipositor normal in shape, with teeth arranged in two longitudinal rows. The inner row with large teeth, the outer row with smaller teeth.

TABLE 5.

Head width: theoretical and actual growth rate values in two species of Buenoa.

Instar	*B. limnocastoris* Actual	1.3	*B. margaritacea* Actual	1.3
1	0.45		0.5	
2	0.715	0.546	0.625	0.65
3	0.715	0.709	0.832	0.845
4	1.04	0.923	1.063	1.098
5	1.15	1.199	1.365	1.428

Geographic distribution. — This species has been reported for Guatemala, Costa Rica, Ecuador and Brazil. Specimens from the following localities were studied:

Costa Rica: Heredia, Laguna Zarcero La Peña: Jan. 1957, J. Vieto, 6 females, 14 males, 5 nymphs (004); Laguna San Isidro, Aug. 1957, J. De Abate, 2 females, 10 males, 27 nymphs (008). San José; purchased June 1931, H. Schmidt, 20 females, 6 males (FHSC); June and July 1931, H. Schmidt, 11 females, 10 males (FHSC); purchased 1932, H. Schmidt, 82 females, 58 males (FHSC); Rio Virilla, Dec. 1931, H. Schmidt, 33 females, 21 males (FHSC); Rio Torres, Feb. 1932, H. Schmidt, 1 female, 1 male, 1 nymph (FHSC); Heredia, Rio Sarapiqui, H. Schmidt, 8 females, 8 males (FHSC).

Brazil: Sta. Catarina, Nova Teutonia, Dec. 1946, F. Plaumann, 20 females, 34 males (FHSC); Nova Teutonia, May 1948, F. Plaumann, 42 females, 23 males (FHSC).

Ecology.—*B. crassipes* was found in fresh, clear, static, permanent, exposed waters. The incidence of this species in waters completely exposed to the sun perhaps can be explained studying their behavior. These notonectids spend most of their time swimming gracefully or resting about four inches below the water surface, thus posibly having protection from the sun.

F. *Buenoa pallens* (Champion) Kirkaldy, 1904

Synonymy.[6] — 1901. *Anisops pallens* Champion. Biologia Centrali - Americana, Heteroptera, Vol. II, p. 374.

Size.—Male: total length, 5.6 to 7.3 mm; head width, 1.4 to 1.9 mm; vertex, 0.23 to 0.37 mm. Truxal (1953) reports the following figures for the female: length, 5.98 to 7.15 mm; greatest body width, 1.75 to 2.01 mm.

Color.—Pale testaceous to nigro-violaceous. Light specimens with ventral keel and last two segments testaceous. Dark specimens with head, anterior pronotum, venter and limbs testaceous. Scutellum usually black with apex testaceous or sordid white. This species is variable in color.

Male structural characters.—Viewed from

[5] For complete synonymy see: 1953. *Buenoa crassipes* (Champion); Truxal, Univ. Kansas Sci. Bull., 35(11): p. 1385.

[6] For complete synonymy see: 1953: *Buenoa pallens* (Champion); Truxal. Univ. Kansas Sci. Bull., 35(11); p. 1414.

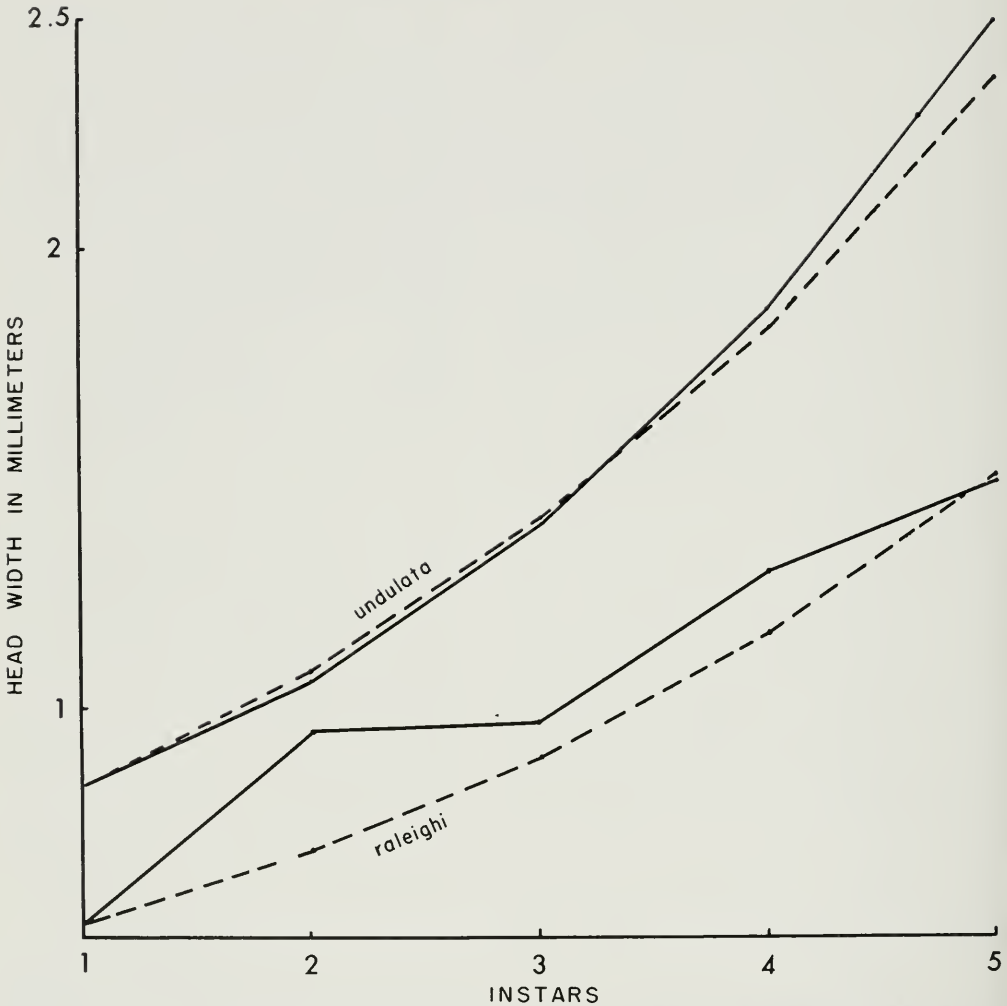


Figure 32. Theoretical and actual growth rates for *Notonecta undulata* and *Notonecta raleighi*. Observe closely similar actual and theoretical rates for *N. undulata;* note the discrepencies in second and fourth instars of *N. raleighi*. Symbols as in figure 29.

above, head laterally rounded with vertex indented. Greatest width of head less than seven times the width of vertex. Synthlipsis narrow, about three fifths the anterior width of vertex. Tylus slightly inflated; rostral prong variable in shape, its origin not at the distal end of the third rostral segment. Fore femur with triangular or subtriangular stridulatory area formed by sixteen to twenty-two ridges. Genital claspers normal.

Female structural characters.—Head shaped as in males, its width approximately five and one-half times the width of vertex. Synthlipsis approximately one-half the width of vertex. Scutellum large, with median length greater than the length of pronotum. Ovipositor normal in shape, with the teeth arranged in two rows. The inner row of few large teeth; the outer row of smaller teeth.

Geographic distribution.—*B. pallens* has been recorded for Mexico, Guatemala, Costa Rica, St. Thomas, St. Croix, Guadeloupe, Dominica, Grenada, Trinidad, Colombia, Ecuador, Brazil, Peru and Chile. Specimens from the following localities were studied:

Mexico: Morelos, Cuernavaca, Oct. 1936, H. D. Thomas, 126 females, 40 males (FHSC). Oaxaca, Aug. 1937, H. D. Thomas,

30 females, 11 males (FHSC).

Costa Rica: San José, Maria Aguilar, Oct. 1957, S. Jimenez-Canossa, 7 females, 8 males, 1 nymph (011); Carrizales, Escazu, Oct. 1957, S. Jimenez-Canossa, 31 females, 26 males, 22 nymphs (012); Carrizales, Escazu, Oct. 1957, S. Jimenez-Canossa, 6 females, 3 males, 4 nymphs (0.14); Carrizales, Escazu, Dec. 1957, S. Jimenez-Canossa, 4 females (015).

St. Croix: Christiansted, June 1941, H. A. Beatty, 1 female, 3 males (FHSC).

Peru: Cajamarca, Celendin, May and June 1936, F. Woytkowsky, 127 females, 117 males (FHSC); Amazonas, Chachapoyas, Aug. 1936, F. Woytkowsky, 36 females, 44 males (FHSC).

Ecology.—Specimens of this species were found more commonly in fresh, clear, static, permanent, shaded waters. For the numerical incidence of each ecological character see Table 4

G. *Buenoa pallipes* (Fabricius) Kirkaldy, 1904

Synonymy.[7] — 1803. *Notonecta pallipes* Fabricius. Systema Rhyngotorum, p. 103.

Size.—Male: total length, 5.3 to 6.8 mm; head width, 1.4 to 1.7 mm; vertex, 0.20 to 0.30 mm; synthlipsis, 0.09 to 0.15 mm. For the female Truxal (1953) gives the following figures: length, 5.62 to 6.50 mm; greatest body width, 1.69 to 1.95 mm.

Color.—Sordid white to black. Pronotum usually fuscous; scutellum black or fuscous, with apex testaceous. Abdomen black except for ventral keel and portions of conexivum. This species is variable in color, a wide color gradation being found within a single population.

Male structural characters.—Viewed from above, outline of head laterally rounded, its width six times the width of vertex. Synthlipsis narrow, approximately one-half the width of vertex. Tylus inflated; rostal prong with posterior margin almost straight, its base originating at distal end of third rostral segment. Fore femur with a subtriangular stridulatory area consisting of approximately seventeen ridges. Male genital claspers normal.

Female structural characters.—Head shaped as in males, its width about six times the width of vertex. Synthlipsis as in males. Scutellum large, its median length greater than that of pronotum. Ovipositor normal in shape, with teeth arranged in two lateral rows. The inner row with large teeth, the outer row with smaller teeth.

Geographic distribution.—*B. pallipes* has been reported for Hawaii, Mexico, Honduras, Costa Rica, Panama, Jamaica, Puerto Rico, St. Thomas, Guadeloupe, St. Vincent, Colombia, Peru and Paraguay. I had the opportunity of studying specimens from the following localities:

Honduras: Tela, Apr. 1923, J. Deal, 93 females, 76 males (FHSC).

Jamaica: Montego Bay, Lumsden Tydenham, St. Ann, Feb. 1928, L. G. Perkins, 7 females, 3 males (FHSC); Baron Hill Trelawny, Feb. 1928, L. G. Perkins, 1 female, 1 male (FHSC); Bath St. Thomas, Mar. 1937, Ch. Roys, 19 females, 8 males (FHSC).

Costa Rica: Cartago, San Isidro de El General, Feb. 1939, D. L. Rounds, 1 female, 1 male (FHSC).

Peru: Amazonas, Guayabamba, Aug. 1936, F. Woytkowsky, 70 females, 67 males (FHSC).

Paraguay: Villarrica, Dec. 1924, F. Schade, 28 males (FHSC).

Ecology.—No data on the ecology of this species is available. I have not been able to collect it although it was recorded from Costa Rica by Truxal (1953).

H. *Buenoa platycnemis* (Fieber) Truxal, 1953

Synonymy.[8]—1851. *Anisops platycnemis* Fieber. Abhandlungen Kongl. Bohmishen Gesellschaft Wissenschaften, Vol. VII, Series 5, p. 485.

Size.—Male: total length, 4.4 to 5.8 mm; head width, 1.1 to 1.4 mm; vertex, 0.19 to 0.28 mm; synthlipsis, 0.06 to 0.14 mm. Truxal (1953) reported the following measurements for the female: length, 5.00 to 5.43 mm; greatest body width, 1.49 to 1.75 mm.

Color.—Sordid white to black. Head, parts of pronotum, thoracic venter and limbs sordid white to testaceous. Scutellum usually

[7] For complete synonymy see: 1953. *Buenoa pallipes* (Fabricius); Truxal, Univ. Kansas Sci. Bull., 35(11): p. 1418.

[8] For complete synonymy see: 1953. *Buenoa platycnemis* (Fieber); Truxal, Univ. Kansas Sci. Bull., 35 (11): p. 1421.

testaceous or black with apex lighter. Abdominal venter black with keel and parts of conexivum testaceous.

Male structural characters.—Viewed from above, head laterally rounded. Greatest width of head five to six times the width of vertex. Synthlipsis narrow, less than one-half the width of vertex. Tylus moderately inflated; rostral prong longer than third rostral segment and originating at distal end of the third rostral segment. Fore femur with subtriangular stridulatory area formed by eleven to fourteen ridges. Genital claspers normal.

Female structural characters.—Head shaped as in males, its width five to five and one half times the width of vertex. Synthlipsis less than half the width of vertex. Scutellum large with median length greater than that of pronotum. Ovipositor of normal shape with teeth arranged in two rows; the inner row of large teeth, the outer row of small ones.

Geographic distribution. — This species has been reported for the United States (Texas and Florida), Mexico, Cuba, Grand Cayman, Haiti, Jamaica, Mona, Puerto Rico, St. Thomas, St. Croix, Martinique, Costa Rica, Panama, Colombia, Venezuela, Brazil and Peru. Specimens from the following localities were studied:

Mexico: Sonora, Rio Mayo, Feb. 1935, H. E. Gentry, 19 females, 8 males (FHSC). Michoacan, El Sabino Uruapan, July 1936, H. D. Thomas, 19 females, 19 males (FHSC). Campeche, Hda. Encarnacion, Oct. 1936, H. D. Thomas, 5 females, 6 Males (FHSC).

U. S. A.: Texas, Mc Allen, Nov. 1932, L. D. Tuthill, 4 females, 6 males, (FHSC); Star Co., July 1938, R. I. Sailer, 5 females, 7 males (FHSC); Falfurrias, Jan. 1946, L. D. Beamer, 2 females, 2 males (FHSC).

Florida: L. Matecumba Key, Mar. 1947, R. H. Beamer and L. D. Beamer, 6 females, 5 males (FHSC).

Grand Cayman: Cow well near Pedro Castle, Oxford Univ. Biol. Exp., Aug. 1928, Lewis and Thompson, 11 females, 11 males (FHSC).

Cuba: Habana Bot. Garden, Jan. 1932, P. J. Bermudez, 8 females, 6 males (FHSC); Habana, 1933, P. J. Bermudez, 14 females, 31 males (FHSC).

Puerto Rico: Luquillo July 1932, J. Blanch, 1 female, 2 males (FHSC); Quebrada, Feb. 1935, J. G. Diaz, 2 females, 1 male (FHSC); Florida Road, Feb. 1935, J. G. Diaz, 10 females, 5 males (FHSC);

TABLE 6.
Ecological data.

		N. c. ceres	*Buenoa crassipes*	*Buenoa pallens*	*N. indica*
	Number of collection sites	15	2	5	1
Vegetation	Abundant	20%	100%	20%	
	Moderate	80%		80%	100%
Bottom	Sand	13.3%	50%		
	Mud	20 %		20%	
	Sandy mud	66.6%	50%	80%	100%
Water	Dark	20%		20%	
	Clear	80%	100%	80%	100%
	Flowing	53.3%		40%	
	Static	46.7%	100%	60%	100%
	Temporary	26.7%		40%	
	Permanent	73.3%	100%	60%	100%
	Shaded	73.3%		60%	
	Exposed	26.6%	100%	40%	100%

Almirante Road, March 1935, J. G. Diaz, 8 females, 5 males (FHSC); Tortuguera L., Mar. 1935, J. G. Diaz, 8 females, 3 males (FHSC); Near Isabela, May 1935, J. G. Diaz, 2 females, 7 males (FHSC); Luquillo Mts., Nov. 1935, J. G. Diaz, 8 females, 4 males (FHSC).

Costa Rica: Cartago, San Isidro de El General, Feb. 1939, D. L. Rounds, 1 female, 4 males (FHSC).

Colombia: Villavieja, 1944, R. A. Stirton, 26 females, 22 males (FHSC).

Peru: Amazonas, Vic. Guyabamba, Aug. 1936, F. Woytkowsky, 23 females, 28 males (FHSC); San Martin, Vic. Rioja, Sept. and Oct. 1936, F. Woytkowsky, 11 females, 11 males (FHSC).

Ecology.—There are no reports on the ecology of this species. Only five specimens have been collected in Costa Rica and they bear no ecological data. I have not been able to collect this species.

I. *Buenoa antigone antigone* (Kirkaldy) Truxal, 1953

Synonymy.[9] — 1899. *Anisops antigone* Kirkaldy, G. W. The Entomologist, vol. XXXII, p. 30.

Size.—Male: length, 7.80 to 7.99 mm; greatest body width, 2.46 to 2.60 mm; female: length, 8.25 to 8.51 mm; greatest body width, 2.60 to 2.79 mm.

Color. — Testaceous; scutellum usually ochraceous, brown at the base. Ventral abdomen brown or black with conexivum testaceous.

Male structural characters.—Head laterally rounded when viewed from above, its width more than six times the width of vertex. Synthlipsis one half to two thirds the width of vertex. Rostral prong originating laterally at proximal end of third rostral segment. Fore femur with triangular stridulatory area consisting of fifteen to twenty-three ridges. Genital claspers normal.

Females structural characters.—Head as in males. Synthlipsis more than half the width of vertex. Ovipositor with two rows of teeth all small except for the apical four in the outer row.

Geographic distribution.—Recorded from Mexico, Guatemala, Cuba, Grand Cayman, Haiti, Jamaica, Puerto Rico, St. Croix, Brazil, Ecuador, Peru, Bolivia, Paraguay and Argentina. Because of the recorded geographic distribution, the presence of this species in Costa Rica is expected.

J. *Buenoa gracilis* Truxal, 1953

Synonymy.—1953. *Buenoa gracilis* Truxal, Univ. Kansas Sci. Bull. XXXV(11), p. 1439.

Size.—Male: length, 5.39 to 6.04 mm; greatest body width, 1.30 to 1.49 mm; female: length, 5.52 to 6.11 mm; greatest body width, 1.36 to 1.69 mm.

Color.—Sordid white. Abdominal venter black except keel and portions of conexivum, sordid white to pale testaceous.

Male structural characters.—Viewed from above, outline of head laterally rounded; greatest width of head, six to six and one half times the width of vertex. Synthlipsis narrow, approximately one-fourth the width of vertex. Tylus inflated; rostral prong originating near the proximal end of third rostral segment. Fore femur with subtriangular stridulatory area consisting of about six to nine ridges. Male genital claspers normal.

Female structural characters.—Head shaped as in males, its width approximately five times the width of vertex. Pronotum faintly tricarinate; scutellum with median length greater than that of pronotum. Ovipositor normal in shape, with two rows of teeth; the inner row of large teeth and the outer row of smaller teeth.

Geographic distribution.—Reported from Mexico, Honduras, Panama, Cuba, Jamaica, Puerto Rico, St. Croix, Grenada, and Peru. This species is probably present also in Costa Rica.

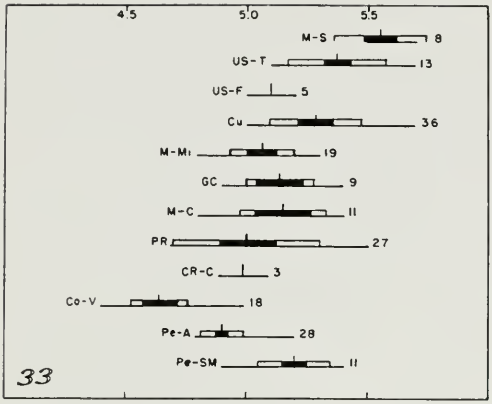
K. *Buenoa ida* Kirkaldy

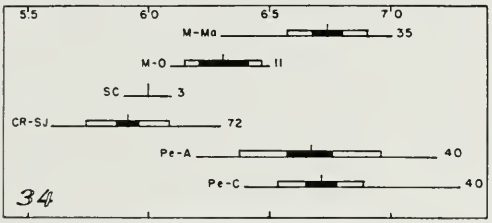
Synonymy.—1904. *Buenoa ida* Kirkaldy, G. W., Wiener Ziet., Vol. XXIII, pp. 121, 122 and 134; 1909. *Buenoa ida* Kirkaldy, G. W. and Torre-Bueno, J. R. de la. Proc. Ent. Soc. Washington, vol. X, p. 200. (catalogue); 1953. *Buenoa ida* Kirkaldy; Truxal. Univ. Kansas Sci. Bull., 35(11), p. 1383.

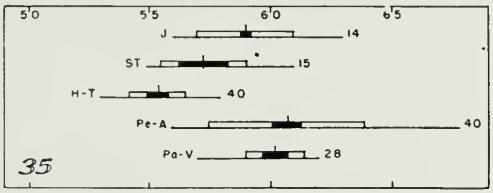
Size.—Male: length, 9.16 to 9.62 mm; greatest body width, 2.73 to 2.82 mm; female: length, 9.29 to 9.94 mm, greatest body width, 3.12 to 3.25 mm.

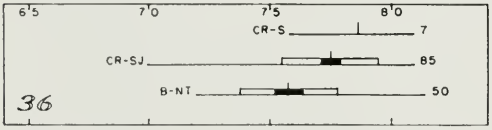
Color.—Fuscous; head, pronotum, thoracic

[9] For complete synonymy see: 1953. *Buenoa antigone antigone* (Kirkaldy); Truxal, Univ. Kansas Sci. Bull., 35 (11): p. 1376.









Figures 33-36. North to south variation in total length. **33.** *Buenoa platycnemis.* **34.** *Buenoa pallens.* **35.** *Buenoa pallipes.* **36.** *Buenoa crassipes.* Abbreviations for localities (at left of each bar): B-NT = Brazil: Nova Teutonia; Co-V = Colombia: Villavieja; CR-C = Costa Rica: Cartago; CR-S = Costa Rica: Sarapiqui; CR-SJ = Costa Rica: San José; Cu = Cuba; GC = Grand Cayman; H-T = Honduras: Tela; J = Jamaica; M-C = Mexico: Campeche; M-Mi = Mexico: Michoacan; M-Mo = Mexico: Morelos; M-O = Mexico: Oaxaca; M-S = Mexico: Sonora; Pa-V = Paraguay: Villarrica; Pe-A = Peru: Amazonas; Pe-C = Peru: Cajamarca; Pe-SM = Peru: St. Martin; PR = Puerto Rico; SC = St. Croix; ST = St. Thomas; US-F = United States: Florida; US-T = United States: Texas. Numbers at right of each bar indicate the number of specimens studied.

venter and limbs testaceous. Scutellum brown to black with apex light. Abdomen black, except for ventral keel and portions of conexivum.

Male structural characters. — Outline of head laterally rounded when viewed from above. Greatest width of head about five times the width of vertex. Synthlipsis approximately one-half the width of vertex. Tylus not inflated; rostral prong originating at basal portion of third rostral segment. Fore femur thickened at apex and with a triangular stridulatory area consisting of about thirty-five ridges. Genital claspers normal.

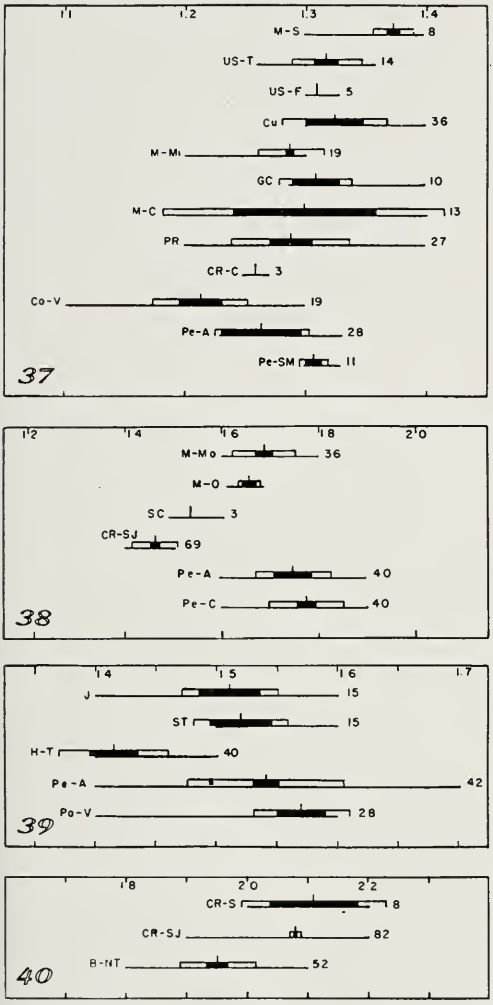
Female structural characters.—Head shaped as in males, about five and one-half times width of vertex. Synthlipsis as in males. Pronotum with disc unimpressed. Scutellum large, with median length greater than that of pronotum. Ovipositor normal in shape, with teeth in two rows, and inner one of few large teeth and an outer one of smaller teeth.

Geographic distribution. — This species has not been reported for Costa Rica, although the recorded geographic distribution suggests its presence. It has been reported for Mexico, Guatemala, and Uruguay.

IV. Geographic Variation in *Buenoa*

In his revision of the Genus *Buenoa,* Truxal (1953) wrote: "...It is interesting to note that in spite of wide ranges, a striking feature in *Buenoa* is the lack of geographic variation in most specimens studied. There are only three good examples that are obvious. One case is primarily an example of size variation...". He points out that for *B. limnocastoris* and *B. confusa,* there is size variation from a large northern form to a small southern form. This type of clinal variation, known as Bergman's rule, was first reported for mammals (Bergman, 1847). Some other insects have been found to follow this pattern of geographic variation (Hubbell, 1956), but the number of forms studied and their geographic ranges are too small to permit generalizations in this respect.

The geographic range studied by Truxal is from Manitoba in Canada to Florida. Although his studies seem to be conclusive there were questions not yet answered: Is this north-to-south variation true for neo-



Figures 37-40. North to south variation in head width. **37.** *Buenoa platycnemis.* **38.** *Buenoa pallens.* **39.** *Buenoa pallipes.* **40.** *Buenoa crassipes.* Abbreviations same as in figures 33-36.

tropical forms? Is it also true for measurements other than total length? There is also another question that, as far as I know, has not been answered for insects: Is a reversal of this rule expected once the equator is reached? A report (Hesse et al, 1937) on variations of penguins south of the equator, gives weight to this presumption since birds also follow Bergman's rule.

To answer these questions, 717 specimens of four species of *Buenoa,* which are represented in Costa Rica, were selected for study because of their wide geographic distribution. The species are: *B. pallens* (ranging from Oaxaca, Mexico to Celendin, Peru), *B. pallipes* (from St. Thomas to Villarica, Paraguay), *B. platycnemis* (from Sonora, Mexico to San Martin, Peru) and, *B. crassipes* (from Heredia, Costa Rica to Nova Teutonia, Brazil).

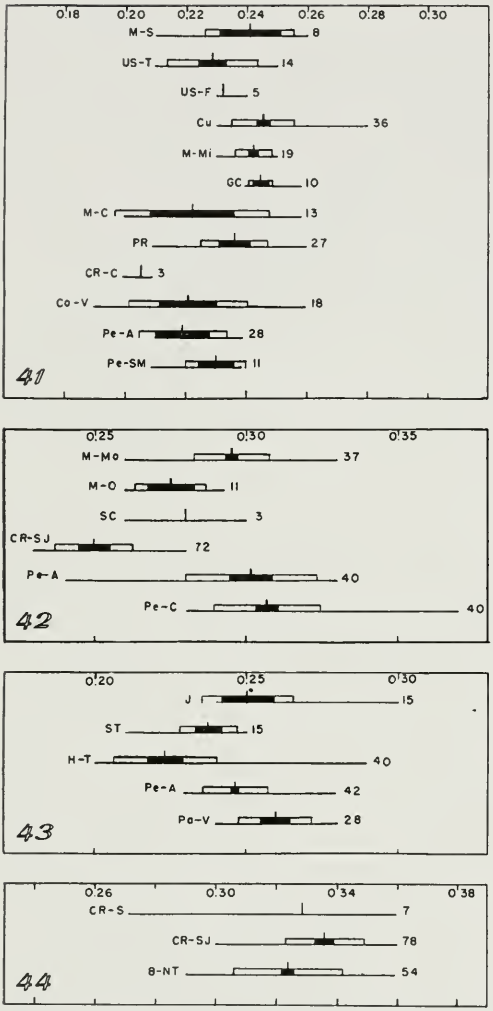
In all specimens, four measurements were taken: total length, head width, vertex width, and width of synthlipsis. These measurements are used in the taxonomy of the group, hence checking their variability was of great interest. The populations studied were grouped according to the states or provinces of origin, except for the island countries where the reduced territorial extension and environmental homogeinity did not justify territorial subdivisions.

Total length.—Figures 33-36 show variation in total length for the four species studied. *B. platycnemis* (fig. 33) has a tendency to diminish in size from north to south, with a clear inversion of this trend once the equator is passed. Except for the populations from Florida and Michoacan, there is no variation to be expected. *B. pallens* (fig. 34) follows the rule without any deviation, showing also inversion south of the equator. In *B. pallipes* (fig. 35), there is also a reduction in size from north to south. The inversion south of the equator is not evident in one case: Villarica, Paraguay. The same is also true for *B. crassipes* (fig. 36), with one population south of the equator not following the expected trend.

Head width.—For *B. platycnemis* (fig. 37) the expected comes true, with inversion south of the equator. The few deviations are not significant. *B. pallens* (fig. 38) and *B. pallipes* (fig. 39) also follow the expected pattern, showing inversion below the equator. And again, *B. crassipes* (fig. 40) is the one that, although with a clear north to south variation, does not follow the south of the equator inversion.

Vertex width.—*B. platycnemis* (fig. 41), *B. pallens* (fig. 42), *B. pallipes* (fig. 43) and *B. crassipes* (fig. 44), show reduction in size of head width from north to south. There is only one minor, insignificant, deviation for *B. pallens.* The inversion south of the equator is also clear in all cases but *B. crassipes.*

Synthlipsis width.—*B. platycnemis* (fig. 45) has a general trend in diminishing this

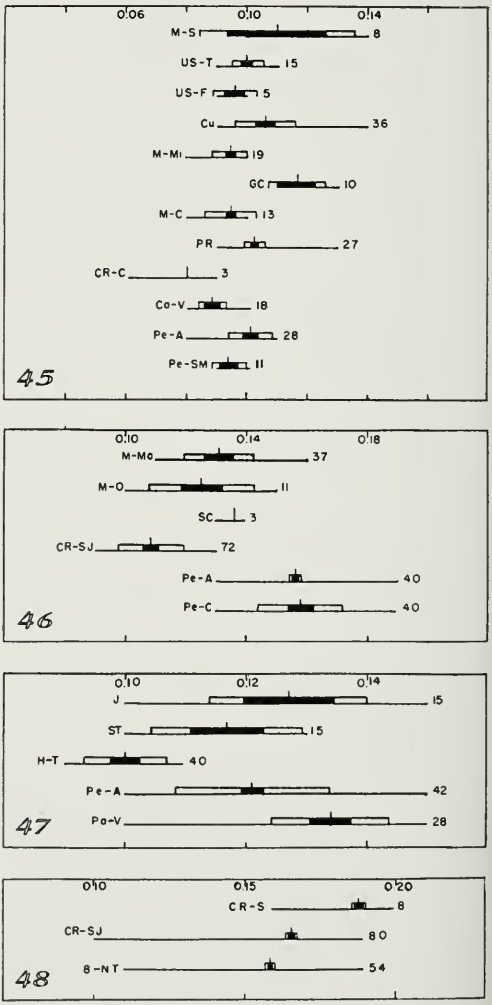


Figures 41-44. North to south variation in vertex width. **41.** *Buenoa platycnemis.* **42.** *Buenoa pallens.* **43.** *Buenoa pallipes.* **44.** *Buenoa crassipes.* Abbreviations same as in figures 33-36.

measurement from north to south, but shows deviations for three island populations: Cuba, Grand Cayman, and Puerto Rico. *B. pallens* (fig. 46) follows the expected variation, except for an island population (St. Croix), also showing inversion south of the equator. *B. pallipes* (fig. 47) and *B. crassipes* (fig. 48) are clear in their north to south variation, but the latter does not have inversion below the equatorial line.

Discussion and conclusions.—Clearly, there is a reduction in measurements from north to south, with inversion once the equator is passed. This geographic clinal variation is due to temperature and therefore could be affected by such other factors as seasonal and altitudinal variations. Compensation for these possibilities is not included in the graphs, but should be borne in mind.

For total length, north to south clinal variation is consistent, the exceptions being populations from Florida and Michoacan (*B. platycnemis*). In the first case the sample is too small to be statistically conclusive. The case of Michoacan, I can explain only as a case of seasonal variation.



Figures 45-48. North to south variation in synthlipsis width. **45.** *Buenoa platycnemis.* **46.** *Buenoa pallens.* **47.** *Buenoa pallipes.* **48.** *Buenoa crassipes.* Abbreviations same as in figures 33-36.

The specimens studied were collected during late summer, which could account for their reduced size in spite of the high latitude of Michoacan.

Equatorial inversion for total length is also consistent. Two deviations were found to this: the Paraguay sample for *B. pallipes* and Nova Teutonia, Brazil sample for *B. crassipes*. In both cases the altitude probably caused the deviations; both localities, in spite of being far south of the equator (26° and 27° latitude) are in lowlands with a climate of tropical type similar to the equatorial one.

For head width and vertex width, the actual results were as expected, with the exception of the samples of *B. platycnemis* from three island populations. For these populations, the mean values are above the expected. Local variation, preserved and accentuated by geographic isolation, is the only answer I can give to explain this deviation. Inversion south of the equator is also true except in one case, San Martin, Peru (*B. platycnemis*). I do not have any data on the altitude of this locality and presume it is in lowlands of equatorial type, which would explain the deviation.

More studies on the geographic, altitudinal and seasonal variations are desirable. Our knowledge on the evolution of the notonectids is slight and no doubt the comparative study of populations will be critical in this respect. To date this has not been attempted.

V. Acknowledgements

I wish to express my appreciation to Dr. George H. Penn, under whose direction this paper was prepared, for his helpful criticism and suggestions. I want to thank also Mr. Pedro L. Vieto, Mr. Leonardo Mata, and Mr. Luis Ferrero who helped to collect specimens, and very special thanks are due to Dr. Salvador Jiménez-Canossa who did a great deal of collecting for me. I am also grateful to Dr. George Byers, Curator of the Snow Entomological Museum at the University of Kansas, and to Mr. Alfonso Jiménez, Curator of the Museo Nacional de Costa Rica, who loaned material. To each of them, I express my deep gratitude.

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Abstract

The Notonectidae of the Central Plateau of Costa Rica were studied. Six species are reported (*Notonecta c. ceres, N. indica, Buenoa crassipes, B. pallens, B. pallipes, B. platycnemis*), one of them (*N. indica*) is a first record for Costa Rica; five other species (*N. confusa, N. ochrothoe, B. antigone, B. gracilis, B. ida*) from neighboring areas are anticipated. All are included in a key to the Costa Rican species. The life cycle of *N. c. ceres* is described and illustrated. A taxonomic analysis of four populations of *N. c. rogersi* was made showing that this subspecies intergrades with *N. c. ceres* and is here considered synonymous. Growth rates were studied for eight notonectids, the factor 1.3 being considered as the possible growth rate factor for all the members of the family. North to south variation was studied in samples of twenty-six populations of four species of *Buenoa*. Reduction in body measurements was observed from north to south (Bergman's rule), and inversion of this trend was found in populations south of the equator.