1990

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The morphometrics of *Xiphinema americanum sensu lato* in California [(1)]

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SUMMARY

Ten populations of *Xiphinema americanum sensu lato (s. l.)* from California and two from the eastern United States were studied in a morphometric comparison. Morphometrics were generated by descriptive statistics and a stepwise discriminant analysis (SDA) from nine California field populations, and voucher specimens from a previous California vector study (Hoy, Mircetich & Lownsbery, 1984); identified as *X. californicum.* Also included were greenhouse populations of *X. americanum* Cobb, 1913 *sensu stricto (s. s.)* from New York (NY) and *X. rivesi* Dalmasso, 1969 from Pennsylvania (Pa). SDA canonical plots of individual specimens showed the *X. rivesi* population to be well separated from the other populations with no overlap. All other groups overlapped to varing degrees. NY *X. americanum s. s.,* Hoy's *X. californicum,* and four field populations showed close alignment, and their high degree of similarity to the neotype and the populations in a redescription of *X. americanum s. s.* (Lamberti & Golden, 1984) show that *X. americanum s. s.* occurs in California. Two other California populations are judged through descriptive statistics and comparison with paratypes to match the description of *X. californicum.* SDA fails to separate them from *X. americanum s. s.* as it did *X. rivesi* and in fact these two populations frequently overlap the type species. These SDA data show that *X. californicum* is not separable from *X. americanum s. s.* and is therefore considered a junior synonym of *X. americanum s. s.*

RÉSUMÉ

Morphométrie de Xiphinema americanum sensu lato *en Californie*

Une étude de morphométrie comparative a porté sur douze populations de *Xiphinema americanum sensu lato (s. l.),* dix provenant de Californie et deux de l'est des USA. Les données morphométriques ont été recueillies à partir d'une procédure statistique descriptive et d'une analyse discriminante pas-à-pas (ADP) portant sur neuf populations naturelles de Californie et des spécimens tests provenant d'une étude précédente de vection (Hoy, Mircetich & Lownsbery, 1984), l'ensemble étant identifié comme *X. californicum* Lamberti & Bleve-Zacheo, 1979. Sont comprises également dans cette étude des populations maintenues en serre de *X. americanum* Cobb, 1913 *sensu stricto (s. s.)* provenant de New York (NY) et de *X. rivesi* Dalmasso, 1969 provenant de Pennsylvanie (Pa). Les diagrammes canoniques issus de l'ADP relatifs aux données individuelles montrent que la population de *X. rivesi* est bien séparée des autres populations, aucun recouvrement n'apparaissant. Tous les autres groupes montrent des recouvrements d'importance variable. *X. americanum s. s.* pop. NY, *X. californicum* pop. Hoy et quatre populations naturelles sont en alignement étroit; leur degré élevé de similarité avec le néotype et les populations utilisées dans la redescription de *X. americanum s. s.* (Lamberti & Golden, 1984) démontrent que *X. americanum s. s.* est présent en Californie. Deux autres populations provenant de Californie correspondent, d'après l'étude des paratypes et les résultats de la statistique descriptive, à *X. californicum.* Toutefois, l'ADP est impuissante à les séparer de *X. americanum,* à l'inverse de ce qui est observé avec *X. rivesi;* en réalité les données relatives à ces deux populations recouvrent fréquemment celles de l'espèce type. Les données provenant de l'ADP montrent que *X. californicum* ne peut être séparé de *X. americanum s. s.* et par conséquent la première espèce est considérée comme un synonyme mineur de la seconde.

Since the original description of the genus and the type species *Xiphinema americanum* Cobb, 1913, the genus has been expanded to include over 150 nominal species. Cobb was aware of the diversity, and in 1913 he said of the genus " *Xiphinema* contains dozens and possibly hundreds of species ". Taxonomists since Cobb have noted this variation, especially regarding the type species, which is now considered by many to form the *X. americanum* group. Lima (1965), Tarjan (1969), Lamberti and Bleve-Zacheo (1979), and Kruger and Heyns (1986) have commented on this proposition. Some nematologists have expressed doubts on the necessity

(1) Part of a Ph. D. dissertation submitted by the senior author to the University of California, Davis, USA.

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and validity of the plethora of proposed species, in the absence of other than morphometric data (Thorne, 1961; Cohn & Sher, 1972; McHenry, 1987).

In recent years, publications by Hoy, Mercetich and Lownsbery, 1984, Lownsbery and Lownsbery (1985), Jaffee *et al.* (1987), Stace-Smith and Ramsdell (1987) and Georgi (1988) have used the designation *X. californicum* Lamberti & Bleve-Zacheo, 1979 for some relatively thinner and longer populations in California and the east coast of the United States. The use of the new taxon has become a problem for many regulatory agencies which must exclude potential vectors and pathogens, yet can not identify the species with certainty (McHenry, 1987), and also creates a dilemma for biologists and ecologists who must question the validity of previous works as a result of the species proposals and the increasing frequency of their use in the literature.

This study examines the morphological variation of ten *X. americanum sensu lato (s. l.)* populations from perennials in the state of California, and compares their features with one population each of *X. americanum sensu stricto (s. s.)* from New York (NY) and *X. rivesi* Dalmasso, 1969 from Pennsylvania (Pa). Morphometric variation is assessed through both standard descriptive statistics of standard characters and through stepwise

Fig. 1. California collection sites of *Xiphinema americanum sensu lato.* 1, Reedley; 2, Freedom; 3, Camino; 4, Durham; 5, Linden; 6, Winters; 7, Calistoga; 8, Parlier; 9, San Luis Obispo.

discriminant analysis (SDA) of the same characters. SDA, developped by R. A. Fisher, is an analysis that essentially magnifies small differences in morphometrics between groups and has been used previously to examine species in the genus *Xiphinema* (Lima, 1965; Luc & Southey, 1980; Brown & Topham, 1985; Georgi, 1988). SDA separation, or lack of it, can then be used to assist in the classification of very similar species.

Materials and methods

Nine field populations were collected from northern and central California (Fig. 1) for a morphometric analysis. The plant host genera were chosen for their ability to support large populations of nematodes (California Extension Service Nematology records, unpub.). Three populations were collected per host and included : *Malus* (Camino, Freedom and Reedley, Ca.); *Prunus* (Durham, Winters and Linden, Ca.) and *Vitis* (Calistoga, Parlier and San Luis Obispo, Ca.). Additionally, preserved greenhouse populations of *X. rivesi* from Pennsylvania and *X. americanum s. s.* from New York were included to provide taxonomic « standards » of eastern species. Also included in the morphometrics are voucher specimens from Sonoma (Hoy, 1983), for comparison against the other populations, as an experimentally proven nepovirus vector.

Specimens for the morphometric analyses from the field populations were extracted from soil by seiving on a 100 mesh screen and placing the residual on a Baerman funnel in a mist chamber for 18-24 hours. Approximately 100 *Xiphinema* were hand picked and placed in hot Seinhorst's fixative and transferred to anhydrous glycerin via the method of De Grisse and Choi (1971). Twelve females per population were picked at random and placed on permanent slides. Voucher specimens were placed in the U. C. Davis nematode collection.

Measurements recorded were total body (L) and esophageal length (eso), guide ring (gr) and vulval distance from the anterior extremity, length of the odontostyle (os), odontophore (op) and tail, and the body width at the vulva (Wv) and the anus (Wa). The ratios a, b, c, c′ and V, were generated within the routine. Standard descriptive statistics and histograms were calculated with BMDP 7D (Dixon, 1988), and a stepwise discriminant analysis (SDA) selecting sets of morphometric variables to maximize the separation between the populations were calculated with BMDP 7M. Additionally, two-dimensional canonical plots of both population centroids and maximum convex polygonals of all individuals per population are presented.

The claim of Lima (1965) and Lamberti and Bleve-Zacheo (1979) that lip region morphology and tail shape are diagnostic characteristics that can be used to separate species is examined. Populations with small overall variability determined by the discriminant analysis (and

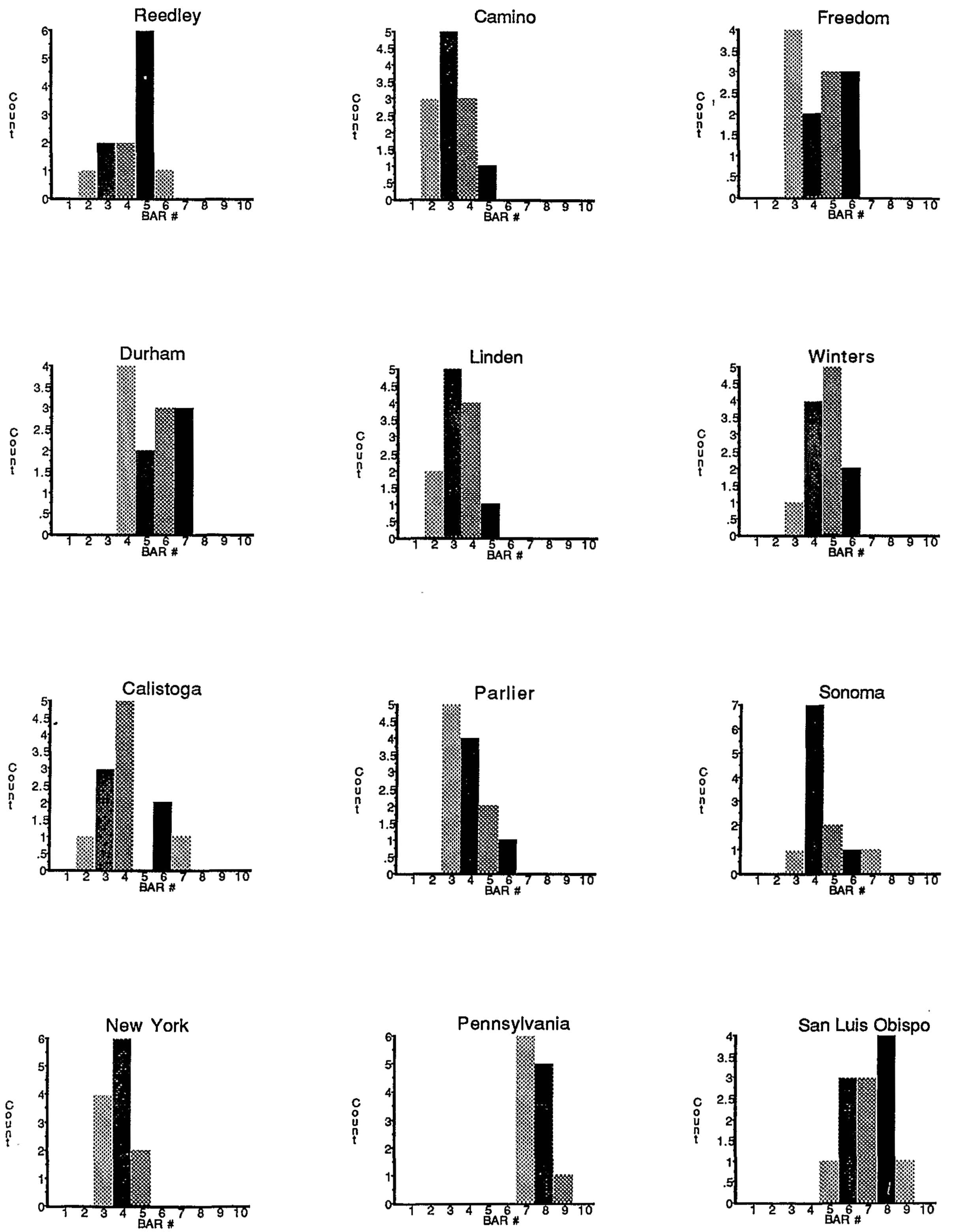

Fig. 2. Frequency distribution of study populations by total length. Bar numbers (1-10) represent 0.1 mm increments, with bar number one equal to 1.4 mm, bar number two equal to 1.5 mm, etc.

therefore isomorphic) were photographed with a Leica DBP camera mounted on a Leitz Ortholux 1 compound microscope, to assess the degree of variability of the head and tail regions in relation to the standard morphometrics.

Results

To examine the possibility of more than one species existing in each field collected population, frequency distributions of each morphological characteristic including ratios were plotted for each population. No populations displayed an obvious bimodality, and most approached a normal distribution for many of the characteristics and were assumed to be monospecific. To save space, only the total length histograms are reported here (Fig. 2). Again, for total length, most populations approach a bell-shaped distribution. Three populations, Freedom, Durham and Parlier express skewed distributions for length, yet other distributions such as width at the vulva or odontostyle length approached a normal distribution.

Morphometric analysis provided by the BMDP 7D program is displayed in Table 1. Of the twelve populations analyzed, the group that showed the most divergence from all other groups in the measurements recorded was *X. rivesi.* This was accessed by comparing the range of measurements for a given morphological variable of a given population against the grand mean of that variable for all populations. This approach only points out divergence and is not a variance test. For *X. rivesi* the total range of measurements for a specific morphological variable of the population were apart, or outwith one standard deviation from the grand mean (mean of all populations) for seven of fourteen variables including L, op, os, gr, Wv, Wa, and c′. Three populations had three variables diverging from the grand mean including; San Luis Obispo, L, eso and gr; *X. americanum* (NY), os, gr, and a; Sonoma, eso, b and c. Five populations had one or two characters diverging as follows; Calistoga, c′; Reedley, Vw and a; Camino, eso; Linden, L; and Durham, c′. All the Parlier, Winters and Freedom variables varied less than one standard deviation from the grand mean for all morphometrics recorded.

Although only one *X. rivesi* population was used in the study, the measurements closely matched the holotype (Dalmasso, 1969), and were similar to the values from two other studies (Lamberti & Bleve-Zacheo, 1979; Wojtowicz *et al.*, 1982). From the comparison of the morphometrics of the seven populations used in the above three studies, the variation of the species appears small, and the use of one population as an outgroup is justified.

The stepwise discriminant analysis supplied a graphic separation by both population centriod (Pantone, Griesbach & Maggenti, 1987) and individual plotting of the canonical variables generated by multiplying constants and the morphometric measurements. The measurements the analysis chose for separating the populations included (in decreasing significance) body length, vulval width, odontostyle, tail length, anal body diameter, and the ratios a, b, and c′ (Table 1). It should not be surprising that these parameters are generally the same ones that are used by taxonomists in this field. However, it is surprising that the ratio c′ is of least significant value to the separation of at least these populations based on canonical correlation (Table 3), especially in view of the weight many of these workers have given this ratio.

Two dimensional canonical plots of the populations centroids or arithmetic means show that the *X. rivesi (Xr)* population is quite distinct from a major clustering of all other populations (Fig. 3). The *X. americanum* (NY), Sonoma (Hoy), Camino, Linden and Parlier populations were plotted in close proximity to one another. Canoni-

Table 1

Summary of canonical variables ranked by canonical correlation.

Variable	*Correlation*
length	0.861
width	0.786
odontostyle	0.670
tail	0.585
abd	0.572
a	0.429
b	0.248
c′	0.165

Table 2

Classification table with the percent of specimens correctly classified by each populations descriminant function.

Population	*Correctly placed (%)*
X. rivesi	100.0
X. americanum	83.3
San Luis Obispo	83.3
Sonoma	75.0
Calistoga	66.7
Reedley	58.3
Winters	58.3
Freedom	50.0
Linden	41.7
Parlier	41.7
Camino	8.3
Durham	0.0
Expected random	8.3

cal plotting of all the individuals (n = 144) is made visually simple with the use of maximum convex polygonals (Fig. 4). Maximum convex polygonals are generated by encompassing the widest outlying members of a given population (Pantone, Griesbach & Maggenti, 1987). Maximum rather than minimum polygonals were used to insert an error range about the population areas. The figure is at first hard to read because there is a great amount of overlap, except for *X. rivesi* population. *X. rivesi* specimens do not overlap any other population. The other populations, including *X. americanum* from New York and ten California populations, express considerable overlap. Some populations such as Reedley and Durham exhibiting a high degree of variability as demonstrated by a large polygonal. Other groups including Winters, Linden and the *X. americanum* populations have relativly small areas, expressing minimal morphometric diversity as described by the canonical variates.

New York *X. americanum*, Hoy's *X. californicum* (Sonoma) and the Linden and Camino populations show a great amount of overlap and therefore nonseparability in the analysis. The variable Reedley and Parlier specimens also have representatives in the lower right region of the canonical plot showing that they overlap with and thus can not be separated from *X. americanum.*

To test the robustness of the discriminant functions, the BMDP 7M produced a classification matrix where individuals are placed in the group predicted by the function. For a SDA of twelve populations, each with twelve specimens, we would expect one specimen in each group at random. If this happened, it would indicate that the discriminant function was useless and in this case would have a correctness of about 1 in 12. The function was able to identify correctly and place specimens of the *X. rivesi* deme a perfect 12 of 12 (Table 2). Members of the San Luis Obispo and New York populations were correctly identified 10 of 12 times. Durham, 0 of 12 (0 %) and Camino 1 of 12 were not well characterized by discriminant functions.

The similarity between populations was calculated by an F-matrix (Table 3). The estimated significant F value for the matrix was 7.964 (df 8, 125). Groups above this value were morphometrically separable, but whether this denoted a species difference or just phenotypic plasticity is arguable. Certainly the large F value differences that the *X. rivesi* population expressed supports species status. The mean F value difference *X. rivesi* expressed versus the other populations was F = 20.0.

Neotypes and paratypes of *X. americanum* and *X. californicum*, obtained from A. M. Golden (USDA) along with the specimens from two eastern US populations, Hoy's Sonoma population and the assembled California populations were studied for a comparison of the less quantifiable features such as body shape assumed upon fixation, lip region morphology and the tail shape. One is immediately aware of the high degree of diversity within populations for the features some authors use in their differential diagnosis. For example, the Winters population, which closely fits the morphometrics of the proposed *X. californicum* and which has small variation in its standard morphometrics (Table 4, Fig. 4), shows variation in the lip region morphology from being distinctly set off to being nearly continuous (Fig. 5). This deme also showed a range of tail shapes (Fig. 5) attributed to the *X. americanum* and *X. californicum.* Similarly, the Camino group that has only minor morphometric variation expresses dramatic variation in the tail shape (Fig. 5).

Discussion

Table 5 presents a comparison of the morphometrics of five different populations including Cobb's Falls Church specimens, Lamberti's topotypes (Lamberti &

Table 3

F matrix, showing the differences between study populations.

	Reedley	*Freedom*	*Camino*	*Durham*	*Linden*	*Winters*	*Calistoga*	*Parlier*	*Sonoma*	X. american.	X. rivesi
Freedom	6.94										
Camino	14.25	4.58									
Durham	10.59	4.46	8.57								
Linden	11.74	2.35	1.81	7.91							
Winters	6.75	2.25	6.82	1.78	5.65						
Calistoga	11.13	3.82	6.02	2.41	4.27	1.42					
Parlier	10.15	2.21	8.59	8.24	2.99	5.02	4.52				
Sonoma	16.2	4.85	2.71	10.45	4.89	9.58	11.39	11.32			
X. americanum	19.15	5.97	9.28	12.09	4.81	11.76	9.84	5.16	10.76		
X. rivesi	30.78	18.51	24.92	6.91	25.59	13.92	15.16	25.26	22.81	25.64	
S. Luis Obispo	13.97	8.83	17.67	6.38	14.58	6.11	10.03	11.97	18.68	16.55	9.77

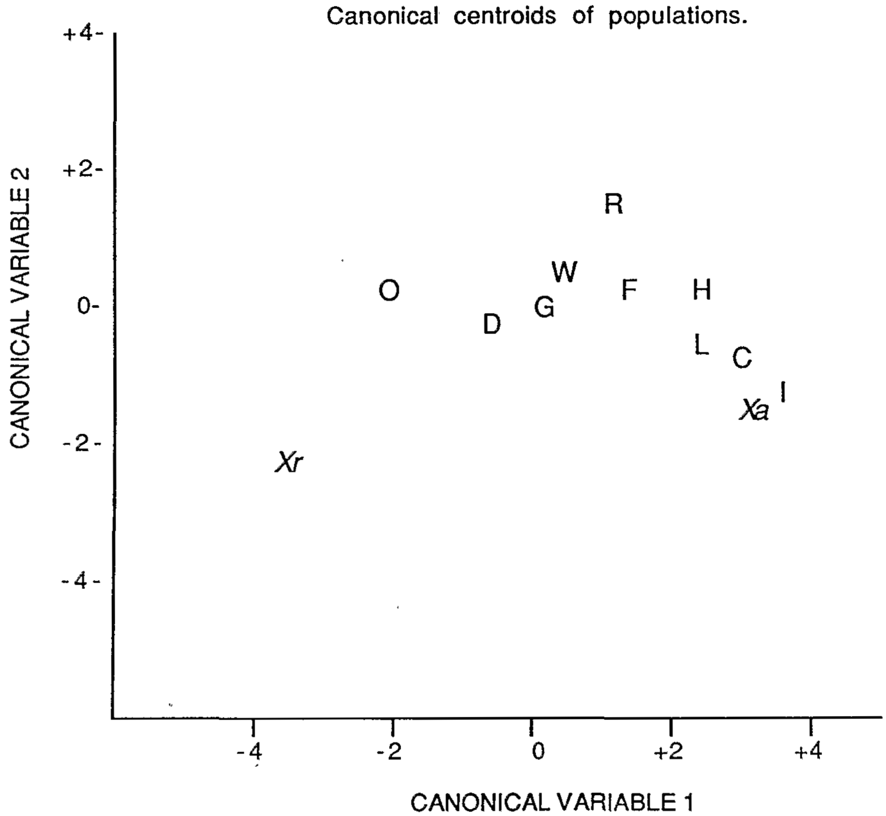

Fig. 3. Canonical centroids of populations. The centroid, or arithmetic mean of each population is plotted by the canonical variables (CV). Populations are : *X. rivesi*, Xr; *X. americanum* (NY), Xa; Camino, C; Durham, D; Freedom, F; Calistoga, G; Parlier, H; Sonoma (Hoy, Mercetich & Lownsbery, 1984), I; Linden, L; San Luis Obispo, O; Reedley, R and Winters, W.

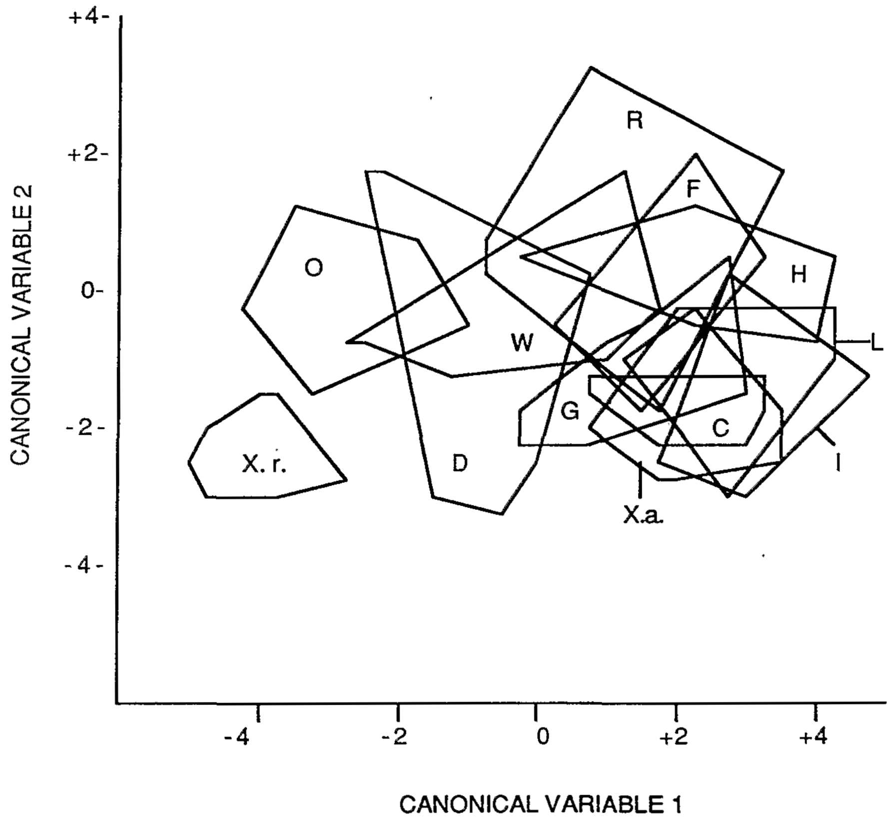

Fig. 4. Canonical plots of cohorts with maximum convex polygonals. Maximum convex polygonals of each population are constructed by connecting maximally outlying plotted individuals. All populations overlap to some degree except *X. rivesi*. *X. americanum* (NY), Sonoma (Hoy, Mercetich & Lownsbery, 1984), Linden and Camino populations all overlap to a great degree, therefore non-separable by this analysis. Populations are : *X. rivesi*, Xr; *X. americanum* (NY), Xa; Camino, C; Durham, D; Freedom, F; Calistoga, G; Parlier, H; Sonoma (Hoy, Mercetich & Lownsbery, 1984), I; Linden, L; San Luis Obispo, O; Reedley, R and Winters, W.

Table 4

Means, Ranges and Standard Deviations of California, New York and Pennsylvania specimens.

	Reedley	*Freedom*	*Camino*	*Durham*	*Linden*	*Winters*	*Calistoga*	*Parlier*	*Sonoma (1)*	*San Luis Obispo*	X. americanum *NY (2)*	X. rivesi *Pa.*
Body Length mm	1.79	1.81	1.67	1.9	1.68	1.83	1.76	1.76	1.73	2.07	1.75	2.13
range (-)	(2.0-1.5)	(2.0-1.7)	(1.54-1.83)	(1.72-2.09)	(1.56-1.82)	(1.68-1.98)	(1.56-2.06)	(1.65-2.00)	(1.49-1.86)	(1.86-2.25)	(1.64-1.88)	(2.04-2.22)
std. deviation (SD)	0.124	0.119	0.977	0.131	0.083	0.087	0.15	0.09	0.09	0.11	0.02	0.06
Esophagus µm	295	286	250	306	276	300	309	322	248	338	285	316
(-)	(232-374)	(242-323)	(212-213)	(253-343)	(222-323)	(293-323)	(283-374)	(273-414)	(212-333)	(273-393)	(263-323)	(283-384)
SD	40	22	31	27	28	19	18	38	31	42	18	33
Width at Vulva µm	30.3	34.3	34.4	36.7	34.2	33.5	30.3	34.8	35.1	35.7	37.5	42.4
(-)	(26.6-35.1)	(29.1-40.3)	(31.7-39.4)	(32.6-48.0)	(30.0-37.7)	(29.1-36.9)	(26.6-35.1)	(29.1-40.3)	(30.9-38.6)	(32.6-41.1)	(35.1-40.3)	(39.4-49.7)
SD	2.8	3.5	2.2	4.6	2.4	2.0	2.8	3.4	2.2	2.3	1.7	2.7
Odontophore µm	48.8	45.9	46.1	41.8	48.1	49.7	47.3	48.5	47.3	51.4	45.5	52.4
(-)	(46.3-51.3)	(40.3-50.6)	(38.6-53.1)	(44.6-50.6)	(43.7-53.3)	(46.3-60.8)	(42.9-51.4)	(44.6-53.1)	(40.3-51.4)	(46.3-57.4)	(42.9-48.0)	(48.0-58.2)
SD	2.8	2.7	3.4	3.3	7.3	3.9	2.5	2.6	3.6	2.9	1.5	2.9
Odontostyle µm	83.7	79.8	82.5	88.2	79.3	85.2	85.0	76.9	84.0	87.8	69.9	92.5
(-)	(71.1-89.1)	(74.6-84.0)	(71.1-107.1)	(70.3-96.0)	(66.9-86.6)	(77.1-97.7)	(74.6-94.3)	(73.7-82.2)	(78.6-96.7)	(83.1-91.7)	(66.0-80.0)	(86.6-97.7)
SD	6.2	2.7	1.3	6.1	5.3	6.3	6.2	2.4	5.1	3.1	3.7	4.0
Guide Ring µm	69.1	68.1	69.2	76.4	68.4	70.3	74.6	67.6	67.9	78.8	62.3	80.5
(-)	(59.1-78.0)	(63.4-72.0)	(60.8-92.6)	(72.0-79.8)	(56.5-77.1)	(56.2-81.4)	(70.3-82.3)	(64.3-73.7)	(54.0-73.7)	(72.9-84.0)	(56.6-66.0)	(74.6-101)
SD	5.8	2.6	8.4	2.5	6.2	8.2	4.5	3.0	5.4	3.0	2.8	7.3
Tail µm	34.1	36.2	32.3	32.7	34.1	31.4	32.0	34.5	36.3	36.1	34.7	35.1
(-)	(27.4-38.6)	(27.4-46.3)	(24.0-36.0)	(27.4-38.6)	(30.0-38.6)	(25.7-36.0)	(29.1-38.6)	(28.3-29.4)	(32.6-41.1)	(32.6-38.6)	(29.1-37.7)	(31.7-38.6)
SD	3.5	5.5	2.9	3.9	2.5	3.2	2.6	3.8	2.7	2.0	2.4	2.0
Width at Tail µm	19.4	21.4	19.6	21.6	19.9	20.3	21.1	19.8	19.7	22.6	21.6	25.9
(-)	(17.1-21.4)	(19.7-24.9)	(18.0-21.4)	(19.7-24.0)	(18.0-22.3)	(18.9-22.3)	(18.9-22.2)	(18.9-20.6)	(17.1-21.4)	(19.7-25.7)	(18.9-24.0)	(24.9-27.4)
SD	1.2	1.8	1.0	1.4	1.5	1.1	1.3	0.7	1.5	1.8	1.6	0.8
a	59	53	49	52	49	55	52	53	50	58	46	50
(-)	(47-70)	(48-62)	(46-52)	(43-63)	(43-56)	(51-58)	(47-57)	(46-58)	(45-53)	(53-64)	(44-52)	(45-53)
SD	6.1	3.7	2.1	5.7	3.3	1.8	2.8	3.3	2.0	3.2	2.1	2.2
b	6.1	6.4	6.8	6.3	6.1	6.1	5.7	5.5	7.1	6.2	6.2	6.8
(-)	(5.0-7.0)	(5.3-7.4)	(5.0-8.5)	(5.6-7.8)	(5.3-7.9)	(5.2-6.7)	(5.0-6.3)	(4.1-6.5)	(4.5-8.8)	(5.4-7.9)	(5.6-6.8)	(5.6-7.8)
SD	0.7	0.7	0.9	0.6	0.7	0.5	0.5	0.6	1.0	0.7	0.3	0.7
c	52.8	51.3	52.2	58.4	49.6	59.1	55.2	51.5	48.0	57.6	50.5	61.0
(-)	(47.9-60.0)	(39.8-70.1)	(45.5-64.4)	(52.7-68.9)	(44.5-59.3)	(50.2-74.6)	(47.7-63.3)	(42.7-65.0)	(39.5-53.7)	(53.0-62.5)	(46.0-58.9)	(53.2-65.6)
SD	4.3	8.9	5.0	5.3	4.7	8.4	4.6	6.5	4.4	3.1	3.4	4.0
c'	1.8	1.7	1.7	1.5	1.7	1.6	1.5	1.8	1.9	1.6	1.6	1.4
(-)	(1.4-2.0)	(1.4-2.0)	(1.3-1.8)	(1.5-1.9)	(1.3-1.8)	(1.3-1.8)	(1.4-1.8)	(1.4-2.0)	(1.7-2.1)	(1.5-1.8)	(1.4-2.0)	(1.3-1.5)
SD	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1
V %	49.7	51.1	50.5	51.8	50.4	51.5	53.2	48.8	49.7	50.9	49.0	51.3
(-)	(46.1-53.0)	(49.5-55.3)	(45.6-54.0)	(49.3-54.0)	(48.2-52.3)	(48.8-54.0)	(50.9-55.7)	(46.7-50.8)	(48.3-51.4)	(44.0-53.8)	(45.3-51.7)	(48.0-54.4)
SD	2.2	1.6	2.3	1.7	1.4	1.7	1.3	1.5	1.1	2.6	1.8	1.7

(1) Sonoma population from Hoy, Mercetich & Lownsbery (1984); (2) *(ss) sensu stricto.*

Golden 1984), Tarjan's (1956) neotype of *X. americanum*, Lima's (1965) *X. "griphum"* and Lamberti and Bleve-Zacheo's (1979) *X. californicum.* In his thesis, Lima (1965) published Cobb's notes that included two sets of measurements of material used in the type description : the first set was used in the original species description in 1913 (Falls Church) and another set of five females included in Cobb's original notes (Oxnard) which came from the site of the male presented in the species description.

From Cobb's notes Lima concluded that Cobb considered both the California and Virginia populations to be the same species. Indeed Cobb listed the slopes of the Atlantic and Pacific states as type locale. Lima (1965) noted the relatively thinner and longer California specimens and chose to elevate it to the species level, *X. "griphum"*. Lima, however, did not publish the material in accordance with the International Code of Zoological Nomenclature, Articles 7 & 8 (Anon., 1985) and therefore his proposal was invalid. Also, Lima proposed the invalidation of Tarjan's neotype, as it did not come from the type locality as described in Cobb's notes. This may be true, but the type locality is set in the original publication, not the notes, even if they are more discern-

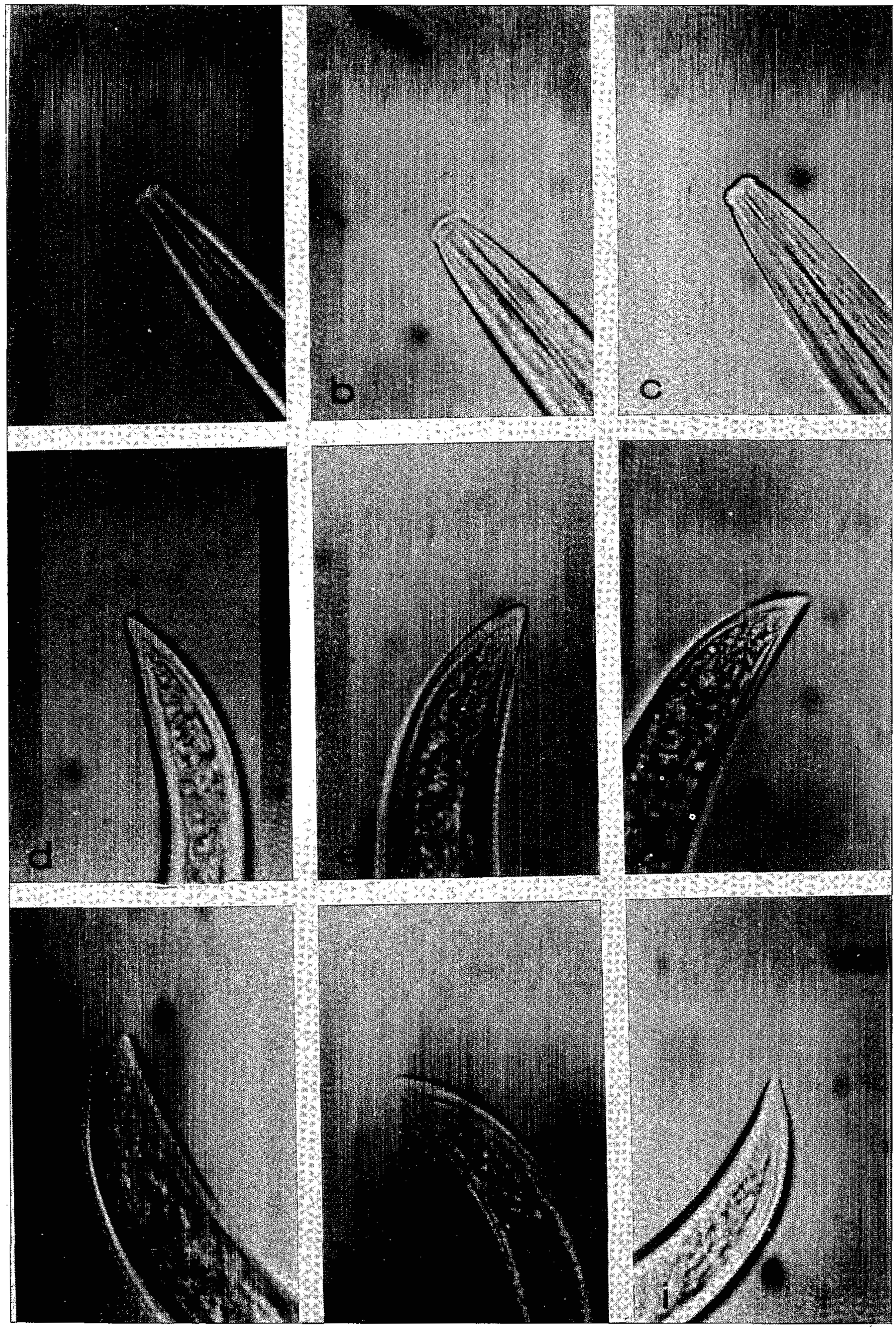

Fig. 5. Top row : lip region of Winters population. a) with incisure and a very slight offset; b) with a raised and rounded lip region; c) with a dramatic and angular offset. Middle row : tails of the Winters population; d) very pointed and narrow; e) robust and bluntly rounded; f) intermediate between d and e. Bottom row : Tails of the Freedom population : g) robust and bluntly rounded; h) narrow and rounded with a thick cuticular layer at the terminus; i) narrow and pointed. Photos a, b, d and i are consistant with *X. americanum* types while c, e, f and g are consistant with *X. californicum* paratypes. Morphometrics and discriminant analysis show these two populations to have small variability in standard measurements, yet vary dramatically in lip and tail morphology.

Table 5

Descriptive statistics of selected type populations.

	X. americanum (1) *Cobb's paratypes Falls Ch., Va.*	X. americanum (2) *Tarjan's neotype Kingston, R.I.*	X. americanum (1) *Lamberti & Golden topotype*	X. griphum (3) *Lima n. sp. Oxnard, Ca.*	X. californicum (4) *Lamberti & Bleve-Zacheo, 1979**
Body length	1.5 (1.4-1.5)	1.6 (1.4-1.9)	1.6 (1.4-1.7)	1.9 (1.8-2.1)	2.0 (1.8-2.2)
Width at vulva	28 (26-30)	— —	32 (29-36)	— —	33 (28-34)
Odontophore	44 (41-46)	47 —	45 (42-47)	48.6 (46-51)	48 (44-53)
Odontostyle	69 (65-73)	72 —	80 (74-83)	91.0 (83-98)	90 (93-98)
Guide ring	53 (51-55)	— —	65 (60-71)	— —	76 (66-83)
Tail	31 (28-35)	— —	35 (33-38)	32.6 (30-36)	31 (27-36)
Width at tail	17 (15-19)	— —	19 (17-21)	— —	19 (17-22)
a	54 (50-57)	42 (33-47)	50 (46-57)	63.8 (55-72)	60 (56-58)
b	5.8 (5.2-6.5)	6.3 (4.7-7.2)	6.8 (5.3-8.2)	6.2 (5.6-6.6)	6.8 (5.5-8.0)
c	49 (45-54)	45 (36-53)	45 (39-52)	59.2 (52-69)	63 (58-76)
c'	1.8 (1.7-2.0)	— —	1.9 (1.7-2.2)	— —	1.6 1.3-1.9)
V	50 (49-52)	51 (46-54)	50 (49-53)	— —	51 (49-55)

(1) Lamberti & Golden, 1984; (2) Tarjan, 1958; (3) Lima, 1965; (4) Lamberti & Bleve-Zacheo, 1979.
* Riverside, CA.

ing, and therefore the neotype withstands this argument. Lamberti and Bleve-Zacheo (1979) also described the thinner California specimens as a new species, *X. californicum.*

In a comparison of odontostyles, the major distinguishing characteristic separating the new species (Lamberti, pers. comm.), the *X. californicum* mean measurement is 91 µm, or about 12 % greater than Lamberti and Golden's *X. americanum* topotype at 80 µm. These authors further reported that Cobb's *X. americanum* topotypes have a mean odontostyle value of 69 µm, or about 14 % less than the population used in their redescription; yet the authors claim that their's and Cobb's specimens reflect variation that is expected in a species and that both should be considered a single species. Both the a and b ratios of the same three populations show equivalent relationships. The authors did not explain why the increased size of the odontostyle led to a new species but that a more pronounced decrease was only a manifestation of phenotypic response.

Lima's (1965) similarity matrix, that is comprised of some 76 *X. americanum s. l.* populations, including 15 California populations shows that all populations which included *X. americanum s. s.* and *X. californicum* (= *X.* " *griphum* "), are identical with respect to their morphometrics at the 82.5 % level. Brown and Topham (1985) studied the morphometric variability between populations of *X. diversicaudatum* (n = 26) and found through a similar analysis procedure that all groups were similar at the 82.5 % level, even though the populations individually showed dramatic morphometric variation. They concluded that the variation is only intraspecific variation, and chose not to propose new species.

The populations in this study match Lima's California paratypes morphometrics and general appearance. With Lima's 76 populations being similar at the 82.5 % level, and by the convention Brown and Topham used with *X. diversicaudatum*, we could claim a lack of sufficient morphological data to justify species status for *X. californicum* without the support of this study.

Griesbach and Maggenti (1989) reported the Winters, Reedley and Parlier populations were able to vector three strains of Tomato ringspot virus under greenhouse conditions. The Winters and Reedley populations also both vectored Tobacco ringspot virus. The Winters population closely matches the morphometrics and paratypes of *X. californicum*. The Parlier group closely matches the morphometrics and paratypes of *X. americanum s. s.* The Reedley population interestingly is intermediate in its characteristics (Table 4). Other study populations similar to either the *X. americanum* or *X. californicum* forms, or intermediate to them failed to vector the viruses in parallel tests. For these California populations, the ability to transmit viruses is not related to morphometrics, and as with *X. diversicaudatum* is highly variable within the species.

It is evident through standard morphometrics that *X. rivesi* constantly stands apart from all other groups studied. Similarly the results of discriminant analysis proved *X. rivesi* to be unique, and that the other groups showed a general clustering with greater or lesser amounts of variation about their respective centroids.

As morphometrics and discriminant analyses studies failed to differentiate the morphogroups, *X. californicum* Lamberti & Bleve-Zacheo, 1979 is considered to be an intraspecific variant or morphotype, and is a junior synonym of *X. americanum* Cobb, 1913.

Additionally, five of the ten California populations studied, Camino, Linden, Parlier, Freedom and Hoy's Sonoma, are nearly identical to Tarjan's neotype and the New York *X. americanum* population. Therefore, it is incorrect to claim that *X. americanum s. s.* is not found in California. It is reasonable to assume that if *X. americanum* were not already endemic, the species would have become established with the great number of hosts plants introduced throughout the state.

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Accepté pour publication le 29 juin 1989.