Preliminary data on the geographical distribution of *Drosophila* species within morphoclimatic domains of Brazil. III. The *cardini* group

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Abstract. A reanalysis, based on museum specimens, of our previously published data on the geographical distribution of the species of *Drosophila* belonging to the *cardini* group in Brazil is presented and discussed. As previously recorded in several papers, including ours, the following four species were recognized: *D. cardini*, *D. cardinoides*, *D. neocardini*, and *D. polymorpha*. However, it was realized that most of the flies we have previously identified as *Drosophila cardinoides* belong in fact to *Drosophila cardini*. To facilitate the proper identification of these four near-sibling species, their holotypes were analyzed and their terminalia were described and illustrated. A key to the four species is also provided.

Keywords. Diptera; Drosophilidae; holotypes; male terminalia; Neotropical Region.

INTRODUCTION

The *Drosophila cardini* species group belonging to the subgenus *Drosophila* was established by Sturtevant (1942). It currently includes 16 species of a large geographical distribution in the Americas (Sturtevant 1942; Wheeler 1949; Heed 1962; Heed & Russell 1971). They are medium-sized flies (2 - 3.5 mm in length) and morphologically extremely similar, but promptly recognized as belonging to their group by their reddish-brown or yellowish, conspicuously shining thorax, and by the presence of several patterns (polymorphic in at least two species) of distal black bands in the tergites, strikingly contrasting with the proximal mostly yellowish areas. The group comprises two subgroups: *dunni* including species from the Antilles and *cardini* with species occurring mainly in the continent in addition to *D. bedicheki* described from Trinidad and *D. acutilabella* found both in the mainland and in some Caribbean islands (Heed & Krishnamurthy 1959; Heed 1962; Heed & Russell 1971). According to Heed (1957), Pipkin (1965) and Pipkin *et al*. (1966), the ecological versatility of these species could be the cause of the wide distribution of the group. The *cardini* species group is phylogenetically related to the *Drosophila calloptera*, the *Drosophila guarani* and the *Drosophila tripunctata* species groups (Frota-Pessoa 1954; Throckmorton 1962; Grimaldi 1990), and the limits among them are not always clear-cut.

Before late '60s (Dobzhansky & Pavan 1943, 1950; Streisinger 1946; Frota-Pessoa 1952; Patterson & Stone 1952; Cunha 1955; Pavan 1959; Futch 1962), only 3 species of the group had been recorded in Brazil: *D. cardinoides* Dobzhansky & Pavan, 1943, *D. neocardini* Streisinger, 1946 and *D. polymorpha* Dobzhansky & Pavan, 1943. Later on, the occurrence of *D.cardini* Sturtevant, 1916 in Brazil was registered in several papers (Mourão *et al*. 1965; Heed & Russell 1971; Napp & Cordeiro 1978; Sene *et al.* 1980; Val *et al*. 1981; Valente & Araújo 1991; Tidon-Sklorz *et al.* 1994; Vilela & Mori 1999).

More than twenty years ago, Sene *et al*. (1980) reported a preliminary data on the geographical distribution of *Drosophila* species in Brazil. Among the 110,914 collected flies, a total of 6,608 specimens were ascribed to four species of *Drosophila* belonging to the *cardini* group. However, reanalyzing the preserved specimens, we have found some mistakes in the identification of imagoes belonging to two of the species in the *cardini* group, namely *D. cardini* and *D. cardinoides*.

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The purpose of the present work, which is the third of a series (SENE *et al.* 1980; VILELA *et al*. 1983), is to clarify those identifications using the external morphology, including especially the setae and the shape of male palpi, as well as the male terminalia which were also redescribed and illustrated, based on the holotypes of the four sampled species.

MATERIAL AND METHODS

The details of the methods and materials were described in

Table I. Numbers of specimens of four species of *Drosophila* belonging to the *cardini* group sampled in fruit-baited traps in several types of Brazilian environments from April 1976 to June 1978. Refer to the first paper of this series (SENE *et al.* 1980) for an annotated list of the sampled localities.

Environment	Locality, State (code according to SENE *et al.* 1980)	Species				
		D.cardini	*D.cardinoides*	*D.neocardini*	*D.polymorpha*	Total
Forests	Boracéia, SP (1)	0	0	0	382	382
	Serra da Bocaina, SP (2)	0	0	0	78	78
	Teresópolis, RJ (5)	0	10	0	68	78
	Santa Tereza, ES (6)	0	1	0	13	14
	Peruíbe, SP (7)	0	4	0	20	24
	Rio Ivaí, PR (8)	14	2	411	2,943	3,370
	Piritiba, BA (9)	55	2	27	49	133
Restingas	Peruíbe, SP (10)	19	0	0	28	47
	Guaratuba, SP (11)	10	0	0	26	36
Pantanal	Miranda, MS (12)	49	12	5	142	208
Disturbed	Irecê, BA (42)	16	0	0	0	16
	Cabreúva, SP (44)	12	0	0	3	15
	Rio Ligeiro, PR (45)	34	40	40	89	203
	Correias, RJ (43)	0	22	0	5	27
Rio Grande do Sul	Guaritas, RS (21)	6	0	0	9	15
	Jaguari, RS (22)	7	0	0	9	16
Coast	Barra do Maxaranguape, RN (13)	2	0	0	0	2
	Arraial do Cabo, RJ (14)	1	0	0	0	1
	Cabo Frio, RJ (15)	1	0	0	0	1
	Guaratuba, SP (16)	2	1	3	14	20
	Peruíbe, SP (17)	91	10	0	23	124
	Barra Velha, SC (18)	5	2	0	9	16
	Ilha de Santa Catarina, SC (19)	0	0	1	0	1
	Tramandaí, RS (20)	51	2	2	297	352
Chaco	Bela Vista, MS (41)	143	35	0	121	299
Cerrados	Barreiras, BA (23)	66	0	0	2	68
	Brasília, DF (24)	5	4	0	3	12
	Lagoa Santa, MG (25)	3	0	0	18	21
	Mogi Guaçu, SP (26)	254	5	0	226	485
	São Carlos, SP (27)	69	0	0	71	140
	Itu, SP (28)	2	0	0	63	65
	Campo Grande, MS (29)	17	25	0	33	75
	Caracol, MS (30)	8	4	0	83	95
Caatingas	Bom Jesus, RN (31)	1	0	0	0	1
	Junco do Seridó, PB (32)	26	0	0	0	26
	São José de Espinharas (41)	41	0	0	0	41
	Milagres, BA (34)	7	0	0	1	8
	Cachoeira dos Monteiros, BA (35)	11	0	0	2	13
	Mira-Serra, BA (36)	5	0	0	2	7
	Ibotirama, BA (37)	24	0	0	4	28
	Barreiras, BA (38)	10	0	0	0	10
	Cafarnaum, BA (39)	20	0	0	2	22
	Xique-Xique, BA (40)	13	0	0	0	13
Total		1,100	181	489	4,838	6,608

SENE *et al*. (1980), who deposited the sampled specimens in the Museu de Zoologia, Universidade de São Paulo (MZSP), São Paulo (SP).

It should be stressed that the data included in the present paper have two main restrictions, as stated in the first one of this series of papers: 1. most of the localities were sampled just once using artificial fruit-baited traps, thus at present we have no information on population fluctuations due to seasonal variations; 2. the results could be influenced by differential preference of the flies attracted to artificial baits.

The postabdomens of the holotypes of *D. cardini, D. cardinoides, D. neocardini* and *D. polymorpha*, and of several non type specimens were removed, dissected by routine methods (WHEELER & KAMBYSELLIS 1966), and are preserved in microvials, filled with glycerin, attached by the stopper to the pin of the respective specimen. Drawings of the terminalia of the holotypes were made using a microscope with an objective 40x and a camera lucida (1x).

The holotypes of *Drosophila cardini* and *Drosophila neocardini* are deposited in the American Museum of Natural History (AMNH), New York, USA, and those of *D. cardinoides* and *D.polymorpha* are housed in the MZSP, São Paulo, Brazil.

RESULTS AND DISCUSSION

The results of the reanalysis of the specimens belonging to the *cardini* group included in the first paper of this series (SENE *et al*. 1980) are presented in Table I. It is now clear that most specimens we have previously identified as *D. cardinoides* are in fact *D. cardini*, especially those from the driest areas. They are so similar morphologically that they have probably been misidentified in the last decades. FREIRE-MAIA & PAVAN (1949) stated that *D. cardinoides* could be a synonym of *D. cardini*, although the latter species, based on its original description, has metaphase plates clearly different (for further notes refer to WHEELER 1949) from those of *D. cardinoides*. We afford the opinion that the absence of *D. cardini* in Brazil in earlier reports (e.g. DOBZHANSKY & PAVAN 1950; PAVAN 1959) should be regarded with caution, although we are unable to investigate this suspicion since most of the specimens collected by earlier collectors were not preserved in museum collections. Moreover, as it happened with *D. cardini* in the Hawaiian islands (HERFORTH *et al.* 1984), there is also a possibility that this species could have been accidentally introduced later in the country after those earlier collections were made.

The majors changes involving the geographical distribution of *D. cardinoides* and *D. cardini* are as follows: *D. cardinoides* is absent in the caatingas (semi-arid areas), rare in the other dried environments, and occurs in low frequency in the wet Atlantic Forest, whereas *D. cardini*, the more abundant member of the group in the caatingas, is as abundant as *D. polymorpha* in the cerrados (type of savannas), the coast and the restingas (strand vegetation), and is absent in the Atlantic Forest, although occurs in inland Forests. Based on its abundance it seems that the latter species is better adapted to drier environments than the former.

The geographical distribution of *D. polymorpha* and *D. neocardini* in Brazil remains the same as presented in SENE *et al*. (1980) because no mistake has been detected for them. However, the data are being republished in Table I for comparison purposes. Two of the subspecies of *D. neocardini*, namely *D. n. itambacuriensis* and *D. n. mourensis* were described by CUNHA (1955) based on the abdomen color pattern and on reproductive isolation. Whether or not just one or both forms are present among the sampled flies is unknown as we were unable to tell them apart based on terminalia analysis only.

Although the terminalia of the four species of *Drosophila* belonging to the *cardini* group known to occur in Brazil have already been described and figured by different authors (STALKER 1953; HEED 1962; HEED & RUSSELL 1971; Val 1982; SUYO *et al.* 1981), they were incompletely illustrated. To facilitate the proper identification of the species we redescribed and illustrated their terminalia below, based on the holotypes.

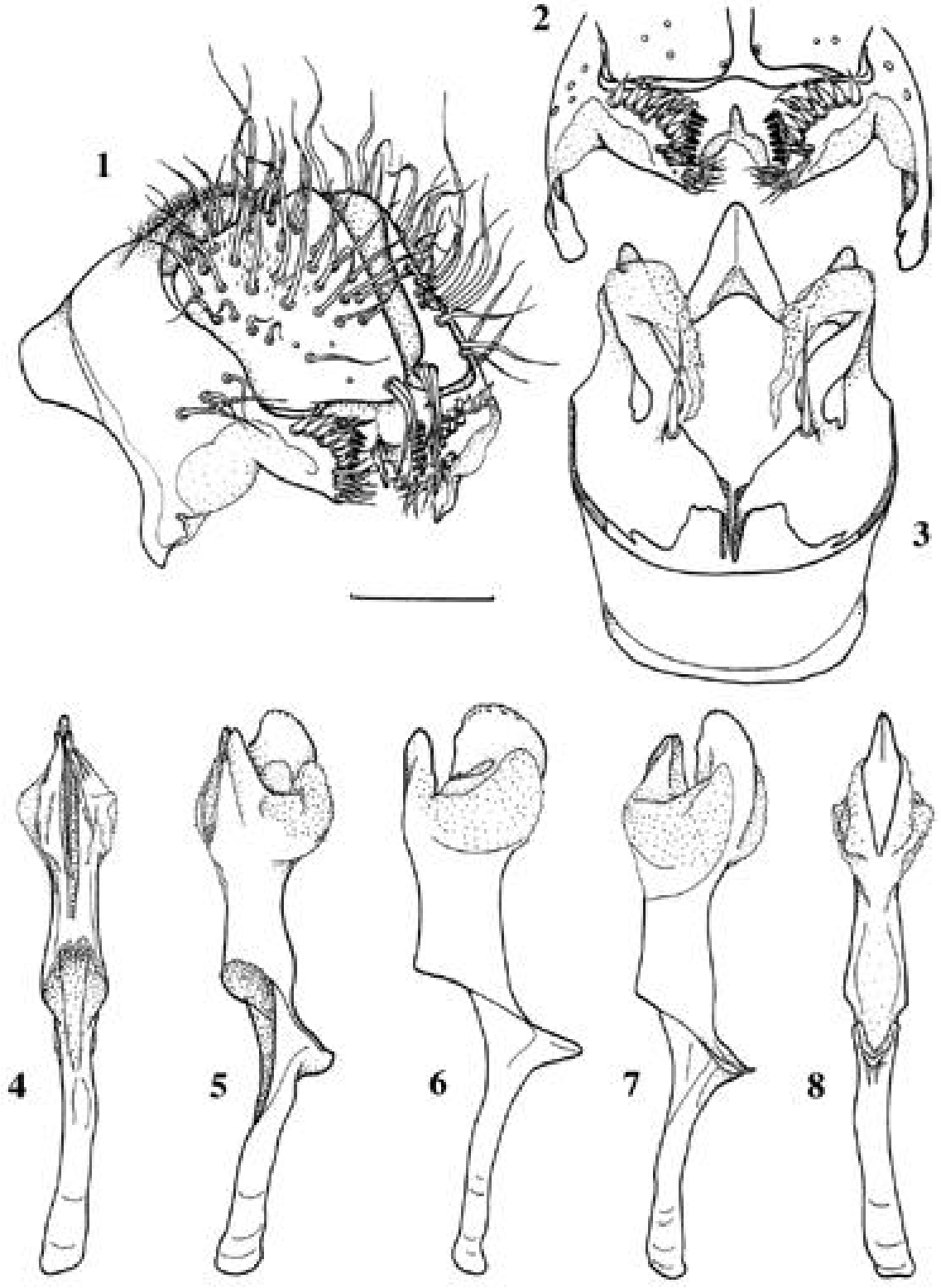
Drosophila cardini Sturtevant, 1916
(Figs. 1-8)

Drosophila cardini Sturtevant, 1916:336.

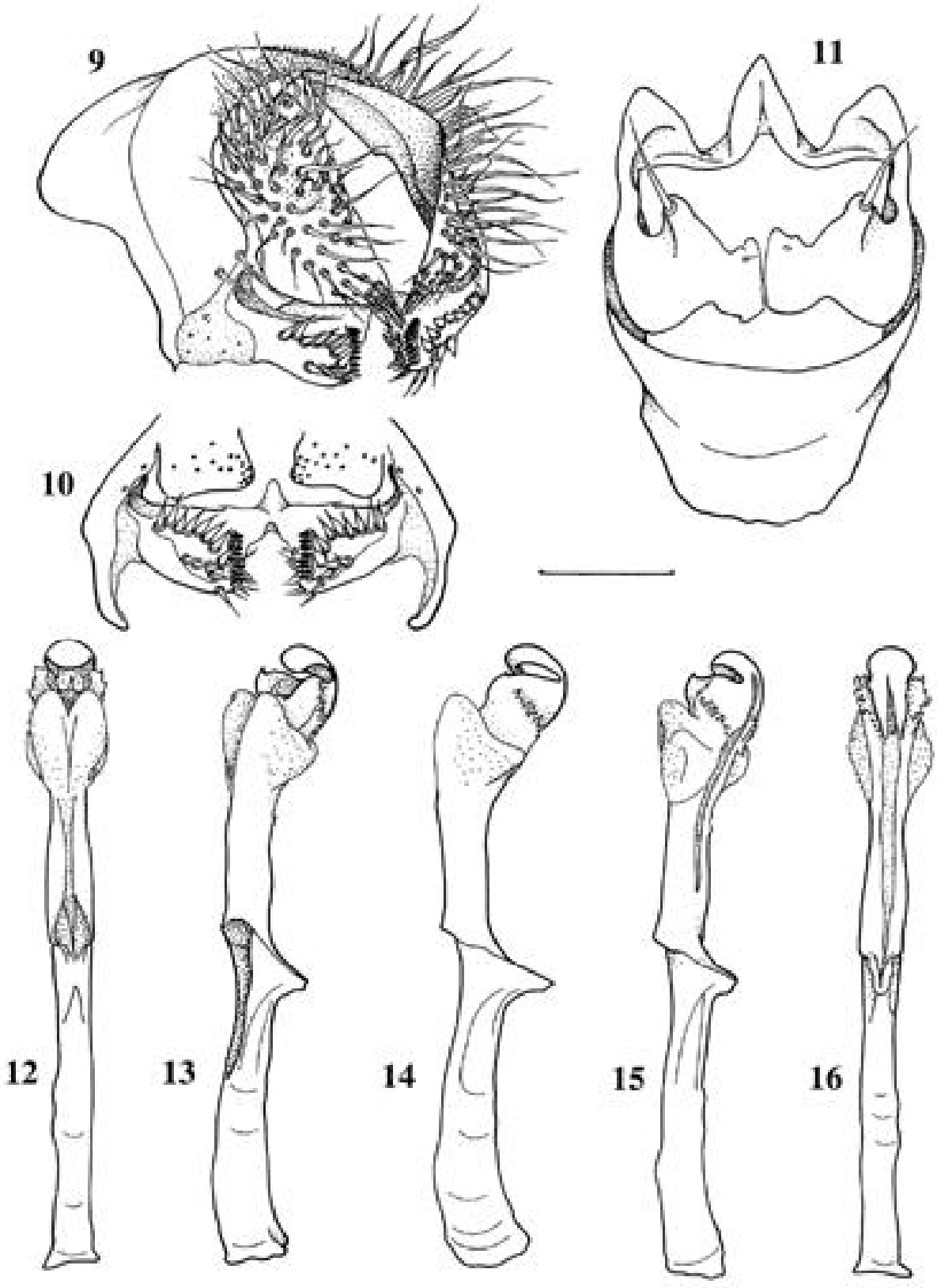
Drosophila (*Drosophila*) *cardini*; Sturtevant, 1942:32; Hsu, 1949:138 (epandrium; see comments by STALKER, 1953: 350); Malogolowkin, 1953:256 (male terminalia); Stalker, 1953:345 (key), 349 (epandrium); Heed, 1962:176 (tip of aedeagus, referred to as apodeme); Suyo *et al*. 1981 (male terminalia).

Specimen dissected. Male holotype, labelled "Havana, Cuba, Jan. Feb. 1915 / Type / Am. Mus. Nat. Hist. Dept. Invert. Zool., No. 24147 / Drosophila cardini Sturtevant", deposited in AMNH (New York).

Male terminalia. Epandrium with about 3 setae just above surstylus, without upper setae, slightly microtrichose at dorsal area; ventral lobe absent. Cerci not fused to epandrium; tip of cercus bearing 3 remarkably long, tightly joined setae. Surstylus dorsally sclerotized, ventrally membranous, not microtrichose, with about 7 short, cone-shaped prensisetae, 11 longer, cone-shaped, sharply pointed outer setae and 13 thin inner setae that come up to outer surface; anterior margin mostly fused to posterior margin of epandrium by membranous tissue. Decasternum as in Figs. 1-2. Hypandrium as long as epandrium; bow present, sclerotized; gonopod fused to paraphysis, bearing one long seta; posterior margin of gonopod (just behind the seta) projected posteriorly, then becoming membranous; paraphysis apparently bare. Aedeagus straight, laterally flattened, bearing two conspicuous finger-shaped, dorsocaudal projections, subapically expanded in dorsal and ventral views, with a membranous sheath, covered with tiny spines; ventrodistal end rounded, laterally flattened, marginally serrated distally and covered with tiny spines; dorsal cleft at very proximal end; aedeagal apodeme as long as aedeagus, rod-shaped; ventral rod widely fused to aedeagal apodeme as in Figs. 4-8.



Figs. 1-8. *Drosophila cardini* Sturtevant, 1916, male terminalia, holotype. **1**, epandrium, cerci, surstyli, and decasternum, oblique posterior view; **2**, surstyli and decasternum, posterior view; **3**, hypandrium and gonopods + paraphyses, posterior view; **4-8**, aedeagus and aedeagal apodeme, several views from dorsal through ventral. All figures were drawn to the same scale. Bar = 0.1 mm.



Figs. 9-16. *Drosophila cardinoides* Dobzhansky & Pavan, 1943, male terminalia, holotype. **9**, epandrium, cerci, surstyli, and decasternum, oblique posterior view; **10**, surstyli and decasternum, posterior view; **11**, hypandrium and gonopods + paraphyses, posterior view; **12-16**, aedeagus and aedeagal apodeme, several views from dorsal through ventral. All figures were drawn to the same scale. Bar = 0.1 mm.

Drosophila cardinoides Dobzhansky & Pavan, 1943
(Figs. 9-16)

Drosophila (*Drosophila*) *cardinoides* Dobzhansky & Pavan, 1943:21; Streisinger, 1946:110 (male terminalia); Hsu, 1949:138 (epandrium); Stalker, 1953:344 (key), 349 (epandrium); Cova-Garcia & Suárez, 1962:324 (egg, puparium, male and female terminalia); Heed, 1962:176 (tip of aedeagus, referred to as apodeme); Heed & Russell, 1971:127 (tip of aedeagus, palpus); Val, 1982:324 (male teminalia, paratype).

Specimen dissected. Male holotype, labelled "Iporanga, São Paulo, VII-1942 / Drosophila cardinoides type/ HOLOTIPO", deposited in MZSP (São Paulo).

Male terminalia. Epandrium with 2 setae just above surstylus, without upper setae, slightly microtrichose at dorsal area; ventral lobe absent. Cerci not fused to epandrium; tip of cercus bearing a tuft of thin setae. Surstylus dorsally strongly sclerotized, not microtrichose, with 8 short, cone-shaped prensisetae, about 12 longer, cone-shaped, sharply pointed outer setae, of which eight are organized in a curved row, and about 12 thin inner setae that come up to outer surface; anterior margin mostly fused to posterior margin of epandrium by membranous tissue. Decasternum as in Fig. 10. Hypandrium slightly longer than epandrium; bow present, sclerotized; gonopod fused to paraphysis, bearing one long seta; paraphysis bearing one setula. Aedeagus straight, rod-shaped, submedially expanded sligthly in dorsal and ventral views, with a membranous, dorsally splitted sheath, covered with tiny spines, which is followed by a serrated collar; subapically deeply incised dorsally and slightly projected ventrally; dorsal cleft at very proximal end; aedeagal apodeme as long as aedeagus, rod-shaped, slightly flattened laterally; ventral rod widely fused to aedeagal apodeme as in Figs. 13-15.

Drosophila neocardini Streisinger, 1946
(Figs. 17-24)

Drosophila (*Drosophila*) *neocardini* Streisinger, 1946:110 (male terminalia); Hsu, 1949:138 (epandrium); Stalker, 1953:344 (key), 347 (proboscis and palpus) 349 (male and female palpi); Heed, 1962:176 (tip of aedeagus, referred to as apodeme); Val, 1982:323 (male terminalia of paralectotype of subspecies *itambacuriensis*), 325 (male terminalia of paralectotype of subspecies *mourensis*).

Specimen dissected. Male holotype, labelled "TYPE / TEFFÉ, AMAZONAS, Th. DOBZHANSKY COLL. / DROSOPHILA NEOCARDINI SP. N., G. STREISINGER", deposited in AMNH (New York).

Male terminalia. Epandrium with one setae just above surstylus, without upper setae, slightly microtrichose at dorsal area; ventral lobe absent. Cerci not fused to epandrium; tip of cercus bearing 3 tightly joined setae, shorter than in *D. polymorpha*. Surstylus strongly sclerotized in dorsal region, not microtrichose, with about 6 short, cone-shaped prensisetae, ca. 7 longer, cone-shaped, sharply pointed outer setae and ca. 7 thin inner setae that come up to outer surface; anterior margin mostly fused to posterior margin of epandrium by membranous tissue. Decasternum as in Figs. 17, 18. Hypandrium as long as epandrium; bow present, sclerotized; gonopod fused to paraphysis, bearing one long seta; posterior margin of gonopod (just behind the seta) membranous and projected posteriorly; paraphysis apparently bare. Aedeagus straight, laterally flattened, subapically expanded slightly in dorsal and ventral views, with a membranous, dorsally splitted sheath, covered with tiny spines, and followed by a serrated collar; ventral end rounded, sharply pointed dorsally; dorsal cleft at very proximal end; aedeagal apodeme as long as aedeagus, rod-shaped; ventral rod widely fused to aedeagal apodeme as in Figs. 21-23.

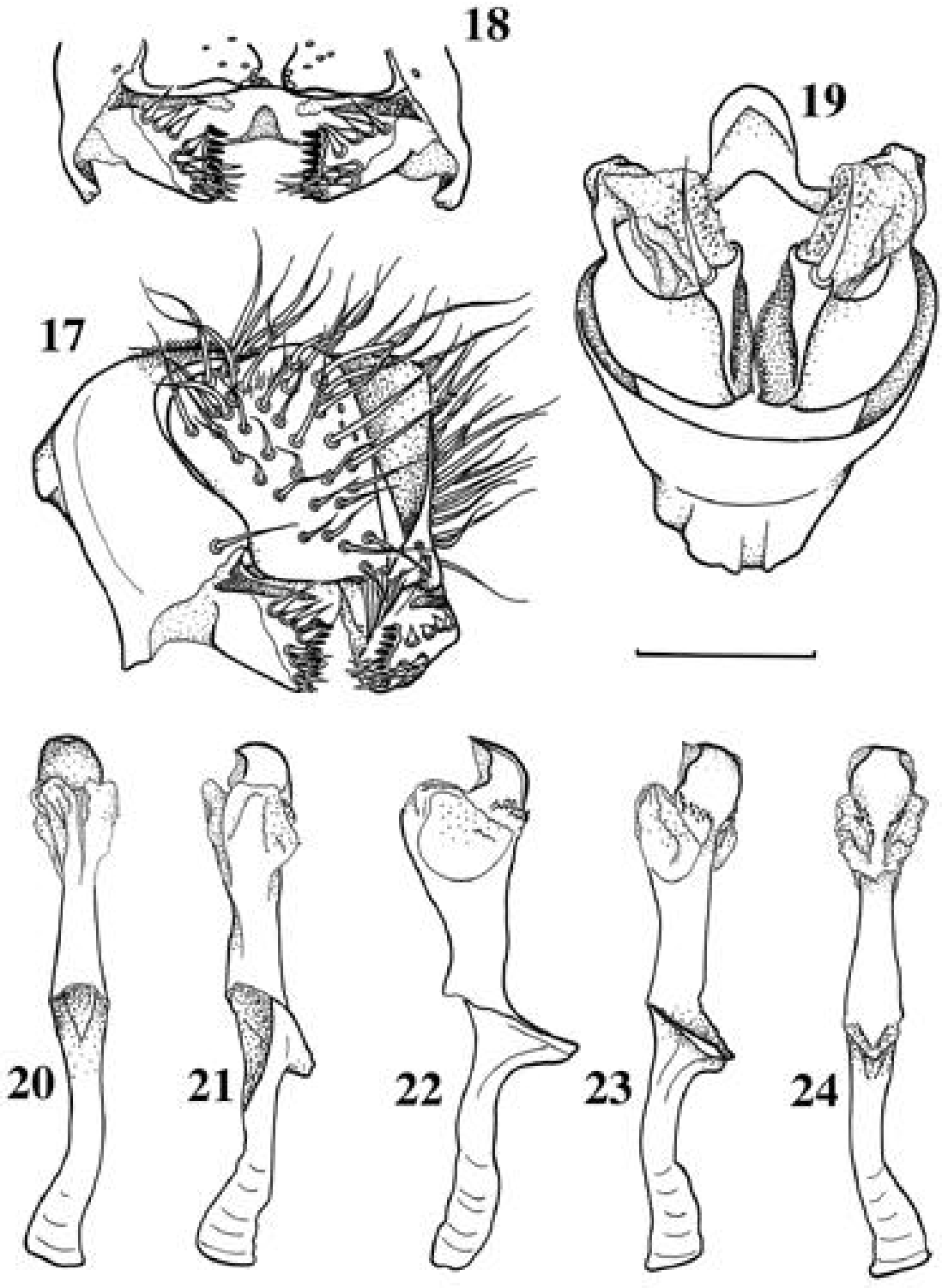
Drosophila polymorpha Dobzhansky & Pavan, 1943
(Figs. 25-32)

Drosophila (*Drosophila*) *polymorpha* Dobzhansky & Pavan, 1943:19; Streisinger, 1946:110 (male terminalia); Cunha, 1949:240 (abdominal patterns); Stalker, 1953:344 (key), 347 (male and female proboscis and palpi, and male fore-femur) 349 (epandrium, male and female palpi); Cova-Gracia & Suárez, 1962:335(egg, puparium, male and female terminalia); Heed, 1962:176 (tip of aedeagus, referred to as apodeme); Suyo *et al.*, 1981 (epandrium, aedeagus); Val, 1982:326 (male terminalia, paratype).

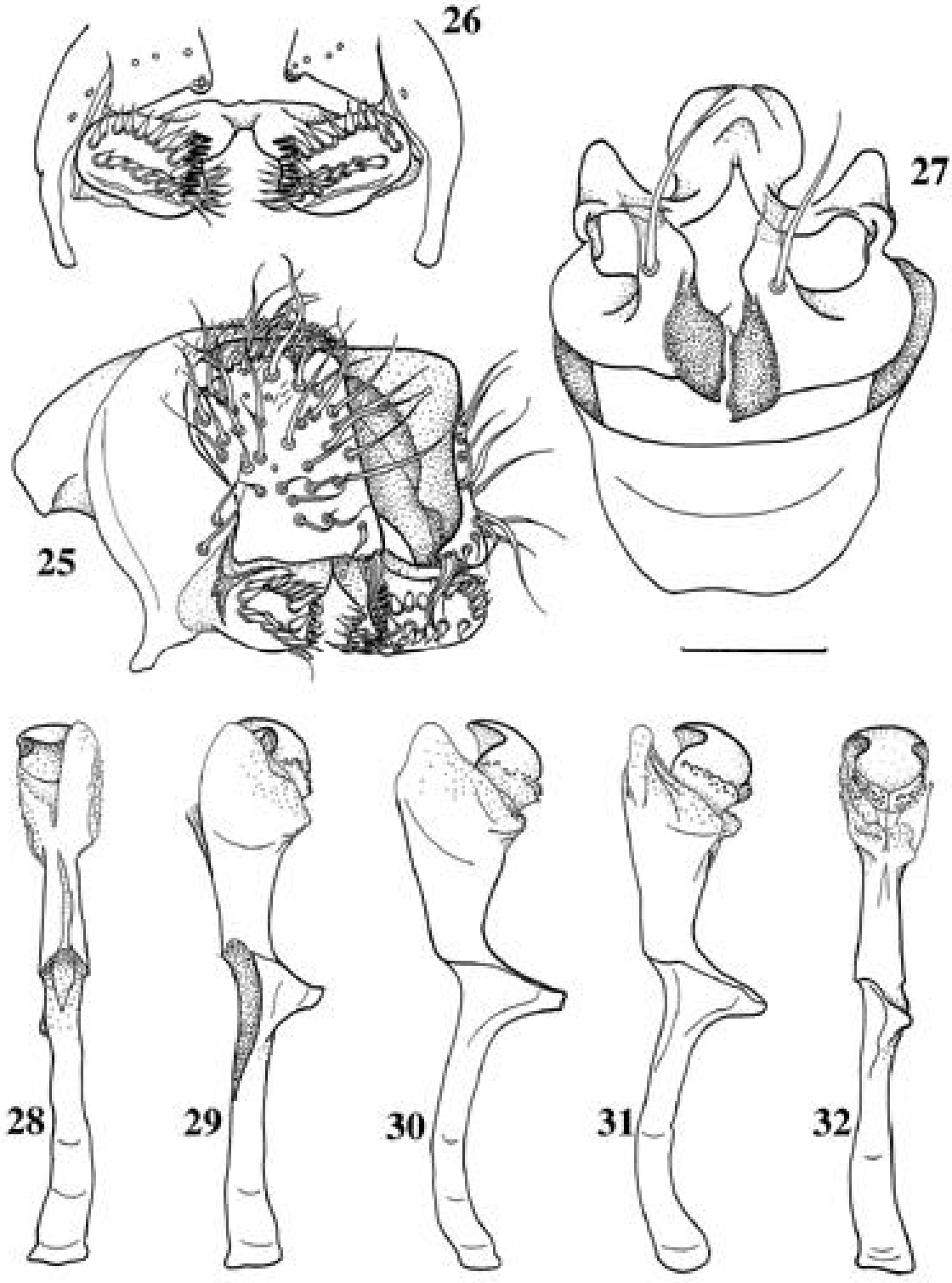
Specimen dissected. Male holotype, labelled "Bertioga, São Paulo, 4-1943 / Drosophila polimorpha (sic) TYPE / HOLOTIPO", deposited in MZSP (São Paulo).

Male terminalia. Epandrium with about 2 setae just above surstylus, without upper setae, slightly microtrichose at dorsal area; ventral lobe absent. Cerci not fused to epandrium; tip of cercus bearing ca. 3 tightly joined setae, thinner and shorter than in *D. cardini*. Surstylus dorsally sclerotized, not microtrichose, with about 8 short, cone-shaped prensisetae, 18 longer, cone-shaped, sharply pointed outer setae conspicuously arranged in an ellipsoidal row (easily recognized in live specimens with an stereomicroscope), and ca.12 thin inner setae that come up to outer surface; anterior margin mostly fused to posterior margin of epandrium by membranous tissue. Decasternum as in Fig. 26. Hypandrium longer than epandrium; bow present, sclerotized; gonopod fused to paraphysis, bearing one long seta; posterior margin of gonopod (just behind the seta) projected posteriorly, then becoming membranous (partially omitted intentionally in Fig. 27); paraphysis bearing one setula. Aedeagus straight, laterally flattened, subapically expanded slightly in dorsal and ventral views, with a membranous dorsally splitted sheath, covered with tiny spines, and followed by a serrated collar; ventral end rounded, dorsally pointed; dorsal cleft at very proximal end; aedeagal apodeme as long as aedeagus, rod-shaped; ventral rod widely fused to aedeagal apodeme as in Figs. 30-31.

Although the analysis of the male terminalia seems to be the safest way to tell the species apart, some other minor external features, such as the shape of the palpi and the size and number of setae on their ventrodistal end, are valuable in sorting them. These features were included in the key presented below, which was designed to distinguish the above-mentioned four species. The geographical distributions cited in the couplets were based on several papers (STREISINGER 1946;



Figs. 17-24. *Drosophila neocardini* Streisinger, 1946, male terminalia, holotype. **17**, epandrium, cerci, surstyli, and decasternum, oblique posterior view; **18**, surstyli and decasternum, posterior view; **19**, hypandrium and gonopods + paraphyses, posterior view; **20-24**, aedeagus and aedeagal apodeme, several views from dorsal through ventral. All figures were drawn to the same scale. Bar = 0.1 mm.



Figs. 25-32. *Drosophila polymorpha* Dobzhansky & Pavan, 1943, male terminalia, holotype. **25**, epandrium, cerci, surstyli, and decasternum, oblique posterior view; **26**, surstyli and decasternum, posterior view; **27**, hypandrium and gonopods (membranous projections intentionally omitted) + paraphyses, posterior view; **28-32**, aedeagus and aedeagal apodeme, several views from dorsal through ventral (right lobe of sheath intentionally omitted). All figures were drawn to the same scale. Bar = 0.1 mm.

STALKER 1953; COVA-GARCIA & SUÁREZ 1962; HEED & RUSSELL 1971; PILARES & VÁSQUEZ 1977; SENE *et al.* 1980; CARSON *et al.* 1983; HERFORTH *et al.* 1984; KANESHIRO 1986; BRNCIC 1987; HOENIGSBERG 1995; GOÑI *et al.* 1998; RAFAEL & VELA 2000). Additionally, the data on the occurrence of the species belonging to the *cardini* group in Argentina were based on the reanalysis of 36 specimens recorded by VILELA *et al.* (1980) and deposited in the MZSP, which were previously identified at the group level only. They are as follows: 18 specimens belonging to *Drosophila cardini* (7 from Resistencia, 6 from Puerto Tirol, 1 from Tapia, 3 from San Miguel de Tucumán and 1 from La Viña), 5 belonging to *D. cardinoides* (3 from Resistencia, and 2 from Puerto Tirol) and 13 belonging to *D. polymorpha* (8 from Resistencia, and 5 from Puerto Tirol).

Key to the Brazilian species of *Drosophila* belonging to the *cardini* group

1. Thorax dark tan 2
   Thorax yellow or light tan 3

2(1). Palpi of both sexes conspicuously distally broad, roughly elephant's foot-shaped in males, bearing some longer setae of about same length, and ventrodistally covered with a dense brush of shorter setae (ca. half length of the longer ones), better recognized in males. Mexico, Central America, Colombia, Venezuela, Trinidad, Ecuador (Galápagos islands), Peru, Chile, Argentina, Brazil (Amazonas, Pará, Mato Grosso do Sul, Distrito Federal, Minas Gerais, Bahia, Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul) ..... *D. cardinoides*

   Palpi roughly club-shaped, bearing differentiated longer setae, as in most species of its genus. Tip of cercus conspicuously bearing ca. 3 long, tightly joined setae. West Indies (Cuba, Grand Cayman, Jamaica, Haiti, Puerto Rico), USA (Hawaii, Florida), Mexico, Central America, Colombia, Venezuela, Guyana, Trinidad, Ecuador, Peru, Chile, Bolivia, Argentina, Brazil (Rio Grande do Norte, Paraíba, Bahia, Rio de Janeiro, Minas Gerais, Distrito Federal, Mato Grosso do Sul, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul) ..... *D. cardini*

3(1). Striking abdominal polymorphism with three types (dark, intermediate and light) of banding patterns. Surstylus with a conspicuous ellipsoidal row of cone-shaped setae (resembling goggles) in the middle area, clearly seen under the stereomicroscope (Figs. 25,26). Central America, Venezuela, Ecuador, Peru, Argentina, Uruguay, Brazil (Rio Grande do Norte, Paraíba, Bahia, Rio de Janeiro, Minas Gerais, Distrito Federal, Mato Grosso do Sul, São Paulo, Paraná, Santa Catarina, Rio Grando do Sul) ..... *D. polymorpha*

   Abdominal banding pattern less variable; dark band of fourth abdominal tergite usually clearly broke into four, and somewhat square-shaped, spots. Surstylus with few cone-shaped setae in the middle area not organized as above (Figs. 17,18). Colombia, Ecuador, Peru, Brazil (Mato Grosso do Sul, Bahia, Minas Gerais, São Paulo, Paraná, Santa Catarina, Rio Grande do Sul) ..... *D. neocardini*

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