

**PARTHENOGENETIC *ISCHNURA HASTATA* (SAY),
WIDESPREAD IN THE AZORES
(ZYGOPTERA: COENAGRIONIDAE)**

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Literature and personal information on the distribution of *I. hastata* and other odon. spp. in the Azores is reported. *I. hastata* and *I. pumilio* are recorded for the first time from the islands of Corvo and Sao Jorge, respectively. *I. hastata* appears the most common and abundant sp. and its population is formed by only ♀♀ (no ♂♂ were ever recorded). The asexual reproduction of these populations was demonstrated by means of laboratory rearing during several generations. The dispersal ability of this sp. and the possible origin of parthenogenesis after its colonisation of the Azores are briefly discussed. The possible causes of threat are identified and the need for conservation measures is outlined.

INTRODUCTION

To our knowledge, the first publications concerning Neuroptera or Pseudo-Neuroptera material from the Azores are those by DROUËT (1861) and DE GUERNE (1888). However, since DROUËT (1861, p. 90) states: "parmi les névroptères, quelques libellules, vivant soit dans les lieux cultivés autour des habitations, soit près des lacs dans les montagnes, ont frappé mon attention; mais je n'en ai pas capturé et je ne saurais dire à quels genres elles se rapportent", the first larvae of Azorean Odonata, namely "*Aeschna* sp.? Larves; *Agrion* sp.? Id." were probably collected by DE GUERNE (1888, p. 67), from Caldeira, Faial island.

SAMPAIO (1904) listed the fauna of the island of Terceira, and stated that *Libellula*

grandis L. (= *Aeshna grandis*) and *Libellula puella* L. (= *Coenagrion puella*) were common. In his paper, the former species, of which he provided a drawing, is clearly referable to *Anax imperator*, whereas the identity of the latter, a zygopteran, remains unclear. NAVAS (1933) reported *Ischnura pumilio*, *A. imperator* and *Sympetrum fonscolombei*, following an expedition to São Miguel and Terceira. Specimens of these three species, collected by José Maria Álvares Cabral, in 1960, and by António Pacheco (no date) from lake of Sete Cidades (São Miguel), are preserved in the Natural History Collection of the Museu Carlos Machado of Ponta Delgada (São Miguel). VALLE (1940) added *Ischnura hastata* (misidentified as *I. senegalensis*) to the previous list, as the result of an expedition to the islands of São Miguel, São Jorge, Faial, Terceira and Flores. A further expedition to Pico and Faial (GARDNER, 1958) reported all the above species except *I. hastata*, while GARDNER (1960) recorded all the four species in Flores, but only three in Santa Maria. Finally, an expedition to São Miguel, São Jorge and Pico recorded all the four species again (BELLE & VAN TOL, 1990; BELLE, 1992).

Table I presents all literature records of *I. hastata* from the Azores. In total, 95 adult females and 29 female larvae, but no males, were collected. This was considered as a suggestive evidence for parthenogenetic reproduction (BELLE & VAN TOL, 1990). To test this hypothesis, in July 2000, we collected a sample of larvae in Pico island. All of these were females *I. hastata*, they emerged in our laboratory in Spain and the adult colony, reared up to maturation, produced more than 1,900 females during nine generations, but not a single male (CORDERO RIVERA et al., 2001). Given that this is the first case of parthenogenetic

Table I
Literature records of *I. hastata* from the Azores

Reference	Island	Locality	<i>I. hastata</i> specimens	UTM E	UTM N	Altitude (m)
VALLE (1940)	Faial	Caldeira	1 ♀, 4-VII-1938	351000	4272800	570
	São Miguel	Lagoa do Fogo	1 ♀, 2-VIII-1938	634250	4180625	575
	Terceira	Bagacina	7 ♀, 30/31-V-1938; 8 ♀, 17-VII-1938	478000	4286400	838
	Terceira	Furnas (Fumas do Enxofre?)	1 ♀, 12-VI-1938	480000	4287300	660
	São Jorge	Lagoa do Pico Gente	19 ♀, 20-VI-1938	411500	4277600	600
	Flores	Santa Cruz	1 ♀, 16/30-VI-1938	661600	4369300	25
GARDNER (1960)	Flores	Lagoa Branca	25 ♀, 21-VI-1938	653100	4367950	550
	Santa Marfa	Valverde, stream	1 larva ♀, 20-III-1957	666900	4091850	100
	Flores	Lagoa Branca	28 larvae, 14-IV 1957	653100	4367950	550
BELLE & VAN TOL (1990)	Pico	Lagoa do Caiado	13 ♀, 23-VII-1988; 12 ♀, 26-VII-1988	390610	4257500	800
	Pico	Lagoa do Capitao	7 ♀, 24-VII-1988	385170	4260910	700

reproduction in the Odonata (SUOMALAINEN et al., 1987), it was of great relevance to know whether this species was parthenogenetic throughout the Azores or males could be found in some localities. Hereafter we show that parthenogenetic *I. hastata* is widespread in the archipelago and we discuss some ideas on the origin of these populations.

METHODS

The Azores are an archipelago of nine volcanic islands, situated at about 1,500 km from the European coast and 3,900 km from North America. In July 2000 we visited the island of Pico, and in July 2003 we searched for populations of *I. hastata* in all islands except Santa Maria and Graciosa. Collection of adults with hand nets was carried out when meteorological conditions were favourable. By collecting randomly in the shore vegetation, we tried to count at least 30 individuals at each pond. To avoid counting several times the same individuals, we first carried out capture sessions and then proceeded to count the specimens caught. Since occasionally the weather changed very rapidly from clear to rainy, we collected larvae when the adults could not be found.

Putative populations were marked on 1:50.000 maps of the Instituto Geográfico Português. The exact locations of ponds and lakes were obtained with a GPS system, when possible, and distribution maps were produced with ArcView software, on a digital map of the Azores (available at <http://elara.iambiente.pt>). We also revised the odonate specimens preserved in the Museu Carlos Machado of Ponta Delgada (São Miguel, Azores).

For a comparison with the Azorean situation, during July-August, 2003, at Vero Beach (Florida, USA), we recorded sex-ratio and activity patterns of *I. hastata* at three ponds hosting sexual populations, and during June 2004 at Vicam (Sonora, Mexico).

RESULTS

We recorded *Ischnura hastata* in 15 localities in six islands, at elevations between 375 and 800 m (average 640 m) (Fig. 1, Tab. I). There are also 11 records from ten localities of seven islands in the literature (Tab. I). In total we examined more than 330 specimens but did not encounter a single male. The largest populations were recorded in the islands of Pico, São Miguel and Terceira. A larval sample from Caldeirão (Corvo) produced one male *I. pumilio* and 9 females *I. hastata*, this being the first record of *I. hastata* for this island. Another sample of 15 larvae from a pond at Pico das Brenhas (São Jorge) produced only adults of *I. pumilio*, a species not previously recorded from this island. One of us (VV) observed *A. imperator* at Corvo, also not previously recorded from this island. In Florida, among emerging *I. hastata* from artificial ponds, we recorded fewer females than males (Unitarian Universalist Fellowship Pond, 8 ♀, 16♂), but, among mature populations, more females than males (Baptist Church Pond, 38 ♀, 3 ♂; West Airport Pond, 13 ♀, 2 ♂). In Mexico we found almost the same number of males (20) and females (23).

In the Azores, *I. hastata* was common in ponds rich in *Potamogeton* and other macrophytes (Fig. 2). In all cases the species coexisted with some of the other three odonate species known from the Azores. Where both *I. hastata* and *I. pumilio* coexisted, the former was always more abundant than the latter. In general, *I. hastata* was by far the commonest species in every pond.

Females were spotted among the shore vegetation and showed little activity. Immature specimens had orange colouration, which in the laboratory changed to brown-grey in about 5-6 days. In the Azores, three out of 179 females were parasitized by mites (July, 2003), while in

Florida five out of the 54 females and one out of the 21 males. Oviposition was observed into *Potamogeton* and other floating leaves, during the sunny hours of the day. At Lagoa do Cabeço da Rocha (Pico) a few females oviposited under water. On two occasions, July 2000, mature females were spotted while in tandem with males of *I. pumilio* (Fig. 3), but we have not seen any interspecific mating.

According to the map of the protected areas in the Azores region (SECRETARIA REGIONAL DO AMBIENTE, 2001), only four localities in which we recorded *I. hastata* are protected: Caldeira (Faial) as a Nature Reserve (proposed as part of the Natura 2000 network), Lagoa do Caiado (Pico) and Lagoa do Negro (Terceira) included in Forest Reserves and the group of Lagoas das Empadadas, Carvão, Canário a Caldeirão (São Miguel) apparently included in the Protected Landscape of Sete Cidades.

DISCUSSION

Our results indicate that *I. hastata* is a common and widespread species in the Azores. We recorded it in all of the visited islands except São Jorge, where bad meteorological conditions made accurate samplings impossible. However, in this island, a sample of *I. hastata* was collected at "Lagoa do Pico gente" in June 1938 (VALLE, 1940). We were not able to localise this pond, but at a pond at Pico das Brenhas we collected larvae of *I. pumilio*, a species

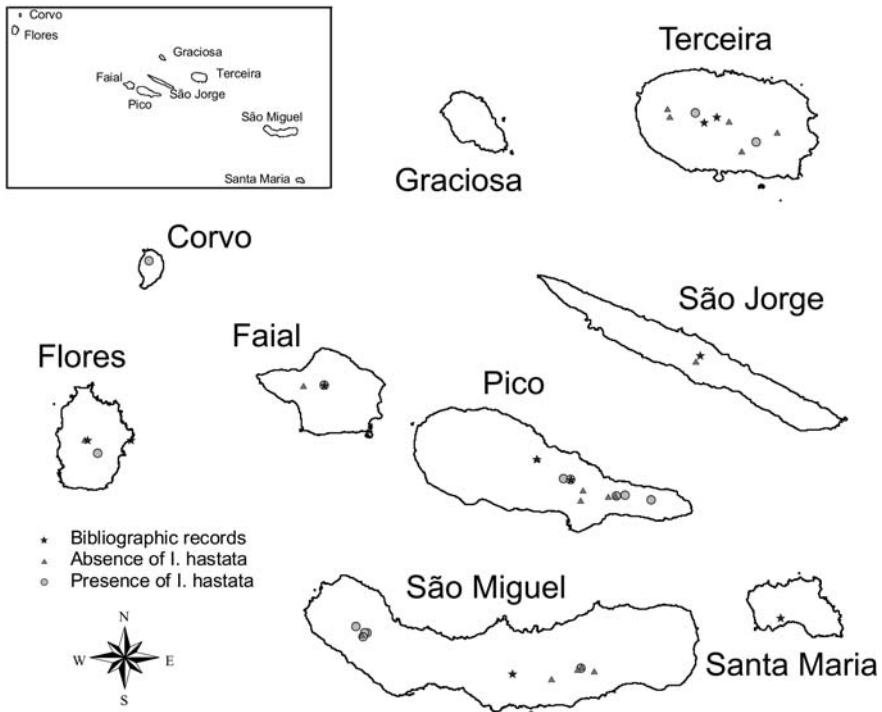


Fig. 1. Distribution of *I. hastata* in the Azores, based on our and on literature records.

previously unknown from this island. There are few dragonfly records from Santa Maria and Graciosa, but it is likely that all four species occur in all of the nine islands. The odonate fauna of the Azores might be even richer, since we have occasionally spotted some large aeshnids, apparently different from *A. imperator*.

Most *I. hastata* populations are concentrated in the islands of Pico, São Miguel, Terceira, Flores and Corvo, which possess at least 88 ponds and lakes (SECRETARIA REGIONAL DO AMBIENTE, 2001). There is also a fairly large population at Caldeira (Faial). Further field work is necessary to confirm the presence of *I. hastata* at São Jorge, Santa Maria (where it is known from a single larva collected in a river in 1957) (GARDNER, 1960) and Graciosa,

the only island from which this species was not reported so far.

Most populations were recorded at a relatively high altitude, but this probably reflects the greater abundance of ponds located at higher elevations rather than the species' ecological preferences. In fact, there is a record of a female from Santa Cruz, Flores, at 25 m a.s.l. (VALLE, 1940). On the other hand, there is a clear preference for ponds densely covered with *Potamogeton* and *Eleocharis*, but further research would be needed to fully understand the ecological requirements of the parthenogenetic *I. hastata*.

These parthenogenetic populations are an exceptional occurrence within the Odonata, and possess a high intrinsic value for conservation. There is some evidence, although anecdotic, of recent extinction in some ponds. For example, in 1988 *I. hastata* was common at Lagoa do Capitão (Pico) (BELLE & VAN TOL, 1990), and we recorded some specimens there in July 2000; nevertheless, in July 2003, this pond had no longer emergent shore vegetation, which had been probably destroyed by stepping cattle, and we could not find any specimen. Also, there are no recent records from São Jorge and Santa Maria, from which the species was reported by VALLE (1940) and GARDNER (1960), respectively.



Fig. 2. Two examples of a typical *I. hastata* habitat at the Azores: (a) Caldeira (Faial), which is included in the Natura 2000 network; - (b) Lagoa do Ginjal (Terceira). Note the presence of abundant vegetation.

Table II

Localities checked for *I. hastata* in July 2003. The "N" column indicates the number of females collected (+observed) or simply the species' presence/absence (yes/no). The degree of protection agrees to the map of the "Plano regional da agua" (SECRETARIA REGIONAL DO AMBIENTE, 2001)

Islands	Sampling locality	N	UTM E	UTM N	Altitude a.s.l. (m)	Pro- tec- tion
Faial	Caldeira	25 (+30)	351000	4272800	570	yes
	unnamed pond	no	347550	4272640	525	no
Pico	Lagoa do Cabeço da Ribeira da Laje	24 (+31)	403700	4254280	443	no
	Lagoa do Capitão	no (yes in 2000)	385170	4260910	700	no
	Lagoa do Cabeço da Rocha	49	389570	4257630	790	no
	Lagoa do Caiado	yes	390610	4257500	800	yes
	Lagoa da Rosada	no	396680	4254770	750	no
	Lagoa do Peixinho	no	397810	4254840	875	no
	Lagoa do Peixinho (2)	yes	398030	4254910	875	no
	unnamed pond	yes	399460	4255010	753	no
	unnamed pond	no	392590	4255820	800	no
	Lagoa do Paul	no	392250	4254100	790	no
São Jorge	Lagoa do Pico das Brenhas	no	410800	4276580	653	no
São Miguel	Lagoa do Congro	no	640450	4179700	500	no
	Lagoa das Fumas	no	647300	4181000	300	no
	Pond at Castelo Branco (1)	1	645250	4181500	600	no
	Pond at Castelo Branco (2)	no	645300	4181600	600	no
	Pond at Castelo Branco (3)	no	644660	4181200	572	no
	Lagoa do Carvão	17 (+27)	610800	4187260	584	yes?
	Lagoas das Empadadas	yes	610490	4187250	740	yes?
	Lagoa do Caldeirão grande	yes	610215	4186650	720	yes?
	Lagoa do Caldeirão pequeno sur	no	609975	4186900	771	yes?
	Lagoa do Canário	yes	609100	4188300	750	yes?
Flores	Lagoa da Lomba	11	656300	4365200	650	no
	Lagoa Seca	no	654000	4367550	550	no
Corvo	Caldeirão	9	662400	4397480	420	no
Terceira	Lagoa da Serra da Ribeirinha	no	483960	4281700	325	no
	Lagoa do Junco	no	489590	4284720	340	no
	Lagoa do Ginjal	32 (+38)	486320	4283240	375	no
	Lagoa do Negro	30 (+6)	476500	4287900	530	yes
	Algar do Carvão	no	481950	4286550	630	no
	Peat-bog at Serra de Santa Barbara	no	472390	4287320	970	no
	Lagoa Negra	no	472000	4288560	830	no
<i>Total number of individuals examined</i>		330				

Furthermore, countrymen at São Miguel informed us that many small ponds got annihilated during the last years to control cattle diseases. Indeed in this island, several ponds and small lakes, to which reference is made in historical records (CONSTANCIA et al., 2001), do not longer exist. Another threat to the conservation of these populations is the

introduction of exotic fish and other predators, which repeatedly took place in the history of these islands (CONSTANCIA et al., 2001) and could contribute to a local decline (although paradoxically *I. hastata* itself might have been introduced!). These facts and considerations suggest that a management plan for *I. hastata* in the Azores should be implemented.

The origin of *I. hastata* populations in the Azores is still unknown. In North America it is a very common species, mainly distributed in the eastern coast of the United States (WESTFALL & MAY, 2000), and also present in Central and South America, the Caribbean and in the Galápagos islands (which proves its ability to colonize islands relatively far from the mainland) (DUNKLE, 1990). Its ability to disperse is also demonstrated by capture in nets mounted on airplanes, at 300 m of altitude (DUNKLE, 1990). There are records of *I. senegalensis* from Madeira (GARDNER, 1962), which perhaps are to be referred to *I. hastata* and are worth checking, while so far no records are known of *I. hastata* from the Canary islands (BAEZ, 1985). This suggests that

this species is a good disperser and might have colonized the Azores spontaneously. It is very likely that the zygopteran larvae collected by DE GUERNE (1888) from Caldeira (Faial) represent the first record of *I. hastata* from the Azores, since in 2003 this locality supported a large population of this species. It is also possible that the "*Libellula puella*" to which SAMPAIO (1904) made reference, were also *I. hastata*, indicating its presence in Terceira for at least a century. Last but not least, *I. hastata* could have been introduced accidentally together with exotic animals and/or plants, or even by being transported in water tanks by ancient sailors.

Since there is no evidence of parthenogenetic populations in the New World, the Azorean populations probably developed parthenogenesis after colonization. In this perspective, our American sampling is intriguing. In fact, in Florida, even though the sex ratio at emergence appeared male-biased (although so on the basis of a single counting), in the reproductive period it apparently turned to female-biased. This is an unusual occurrence among dragonflies (CORBET, 1999), which might be due to the lower male survival or the higher dispersal. In Mexico we found the usual paritary sex-ratio.

Several types of parthenogenesis have been described in insects (SUOMALAINEN et al., 1987), and recent investigations concluded that endosymbiotic bacteria of the *Wolbachia* genus are able to modify the reproductive system of their hosts to produce



Fig. 3. Tandem between *I. pumilio* (♂) and *I. hastata* (♀), observed in Pico, July 2000. Interactions between the two species were common, but apparently *I. hastata* females did not accept copulation.

parthenogenetic females in haplodiploid insects (O'NEILL et al., 1997; HUIGENS et al., 2000; KOIVISTO & BRAIG, 2003). It is possible that also *I. hastata* females got infected with a parthenogenesis-inducing bacterium, but preliminary investigations with PCR technology have ruled out the presence of *Wolbachia* (unpublished results). On the other hand, since *I. hastata* is a diplo-diploid insect, its mechanism of parthenogenesis should be different.

In conclusion, parthenogenetic populations of *I. hastata* are found only in the Azores, where this species is the dominant odonate. We hope that this report will stimulate further research on these populations and will contribute to soliciting more initiatives for the conservation of this exceptional species.

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