Observations of *Macromia splendens* in the Guadiaro river basin, Andalusia, Spain

David Chelmick, FRES

Macromia Scientific. Contact: dgc@davidchelmick.com

ABSTRACT

In 2003, the author discovered *Macromia splendens* (Pictet, 1843) breeding in the River Hozgarganta, which is one of the three principal rivers in the drainage basin of the Guadiaro River (the Guadiaro Cuenca) in Southern Spain. Since that discovery up to the present day the author has made a total of 119 visits to the area, the main purpose of which has been to try to understand how this species, with its need for permanent water, adapts to survive in a region of enormous climatic variation. Throughout the study, periods of extreme weather were encountered which appeared to have little or no impact on the overall populations. Secondly changes made by local people to the rivers to temporarily raise water levels and reduce flow rates greatly increased survival rates for *Macromia* and opened up new areas for colonisation. Far from being restricted to small areas, *M. splendens* survives by ranging over all suitable habitats in the Guadiaro Cuenca.

RESUMEN

En 2003, el autor descubrió una población reproductora de *Macromia splendens* (Pictet, 1843) en el Hozgarganta, uno de los tres principales ríos de la cuenca hidrográfica del río Guadiaro, localizada en el Sur de la península ibérica. Desde ese decubrimiento, el autor ha realizado un total de 119 visitas en el área con el próposito de intentar comprender cómo esa especie, con requerimientos de aguas permanentes para su desarrollo larvario, se adapta en una región de grandes variaciones climáticas. Durante el periodo de estudio,

occurieron varios episodios meteorológicos extremos, sin que estos impactasen de de forma significativa sobre la población. En segundo lugar, las modificaciones hidrológicas realizadas por la población local sobre los ríos para elevar temporalmente los niveles de agua y reducir la velocidad de la corriente han incrementado de forma importante la superviviencia de *Macromia* y permitido la colonización de nuevos hábitats. En la cuenca del Guadiaro, *M. splendens* no está restringuida en pequeñas zonas, muy al contrario, sobrevive occupando todos los hábitats disponibles en esta cuenca hidrográfica.

INTRODUCTION

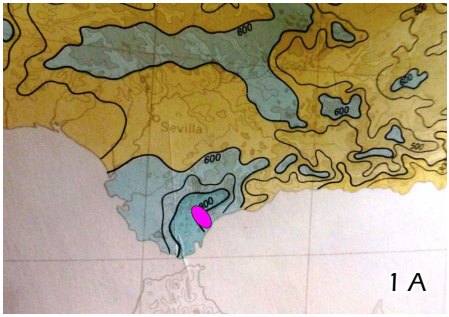
Macromia splendens is one of the largest and, in my opinion, most beautiful of European dragonflies. It is endemic to the Western Palearctic and its distribution has been surprisingly little known until very recently. Its status in Iberia was, until the mid 1990s thought to be restricted to a mere handful of sites. Thanks to greatly increased recording the species is now known to be locally common in western and southern parts of the peninsular where:

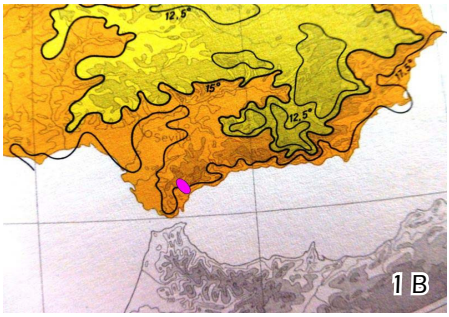
- Permanent water in the form of rivers especially with man-made barrages is available.
- Mean annual temperature exceeds 13 degrees C.
- Annual rainfall exceeds 600 mm.

A summary of the discovery, historical and current distribution is provided in Chelmick (2015a).

CHELMICK, D.G. (2015a) Species review 9: Macromia splendens (Pictet, 1843) (The Splendid Cruiser). *Journal of British Dragonfly Society*, **31(2)**: 89-118.

Figure 1. Climatic characterization of the study area. Fig.1A. Annual rainfall. Fig.1B. Mean annual temperature (Guadiaro Cuenca in pink).





The Guadiaro River Cuenca

Figure 1 shows the Guadiaro drainage basin (henceforth referred to as the Guadiaro Cuenca) located against the backdrop of Annual rainfall (Fig. 1A) and Mean annual temperature (Fig. 1B). Meteorological data is based on Steinhauser (1970). In summary the Guadiaro Cuenca is situated in some of the wettest and warmest parts of Andalusia.

STEINHAUSER, F. (1970) Climatic Atlas of Europe. World Meteorological Organisation, Unesco, Cartographia. 4pp.

I first became aware of the possibility of *M. splendens* breeding in the Guadiaro Cuenca from the discovery in 1983 of the larvae in the Rio Tavizna (Ferreras Romero, 1983), which is only some 30 km as the crow flies from the Guadiaro. In 2000 I visited Ronda on a family holiday. I carried out no specific field work but did look at some of the rivers and thought how suitable they looked for *Macromia*.

FERRERAS ROMERO, M. (1983) Nueva cita de Macromia splendens (Pictet, 1843) (Odon. Corduliidae). *Boletín de la Asociación Española de Enomología*, **6(2)**: 395.

In April 2003 Christina, my wife, and I stayed in Gaucin and spent some time looking for dragonfly larvae on the Genal and Hozgarganta rivers (tributaries of the Guadiaro). On 30-Apr very late in the day and, only on the insistence of Chris, I made a final search on the Rio Hozgarganta (Fig. 2) and was immediately rewarded by finding a final instar larvae of *M. splendens* which

Figure 2. The exact spot on the Hozgarganta where the final instar larva was found on 30-April-2015.

appeared ready to emerge. Since 2003 I have made visits every year, with the exception of 2006, 2013 and 2014, to the three major rivers, which constitute the Guadiaro Cuenca as follows:

- Guadiaro: 26 visits.
- Genal: 66 visits.
- Hozgarganta: 27 visits.

My definition of a visit is a period during one day of between two hours and a full day.

A detailed map summarising my findings is produced as Figure 3. The three rivers are quite different in character and are summarised below.

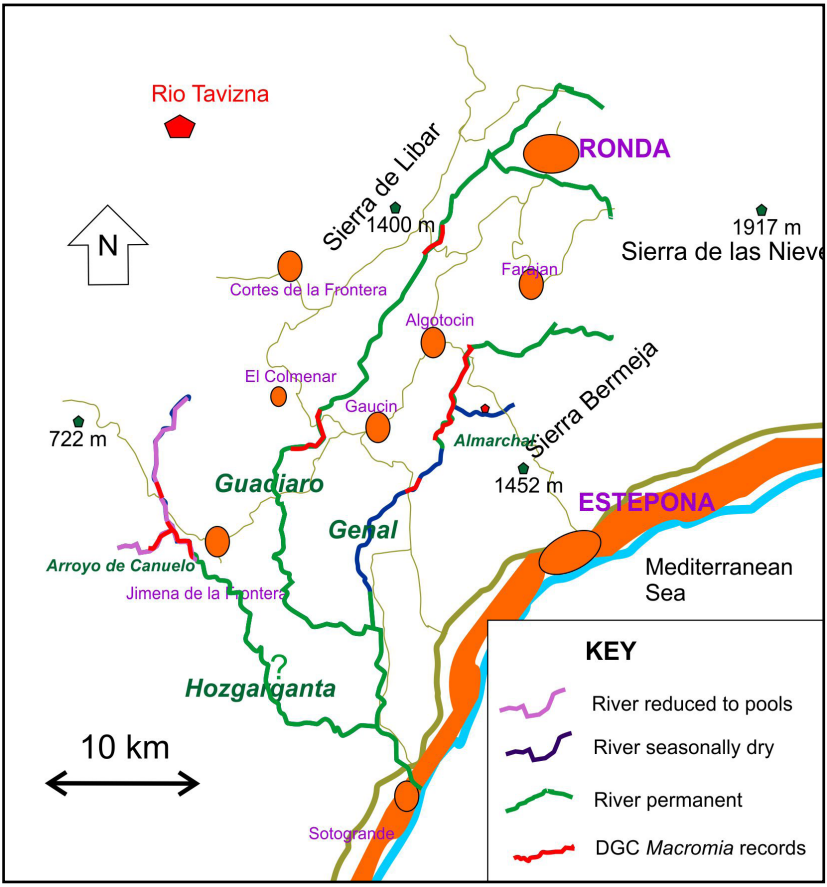


Figure 3. Guadiaro water catchment, showing Macromia findings and seasonal dynamics of the Cuenca. The thick orange strip along the coast shows the extent of the urbanisation

Figure 4. Aspects of the Guadiaro.

Fig. 4A. On the Guadalevin, a small tributary immediately south of Ronda.

Fig. 4B. At Libar where *Macromia* was holding territory upstream of the weir in 2012.

Fig.4C. East of Jimena de la Frontera.

Fig. 4D. The valley near Jimena showing the dominant arable agricultural environment.

The Guadiaro

The largest and principal river of the Cuenca. This is the most man adapted watercourse with a substantial hydro-electric barrage near Comenar and a water abstraction plant north of Cortes, which feeds into the Traviese Guadiaro Majaceite. The river south of Gaucin passes through land which is intensively cultivated. The Guadiaro is a permanent watercourse, which, up until 2010, was badly polluted by effluent probably from pig farms. This was evidenced by the total lack of public bathing areas on this river. However, since 2010, river quality has greatly improved and bathing has returned. Figure 4 shows some of the key features of this the main river of the Guadiaro Cuenca.

Figure 5. Aspects of the Genal.

Fig. 5A. Intensive agriculture downstream of Gaucin Bridge.

Fig. 5B. The Genal near its confluence with the Guadiaro which is usually quite dry in mid summer.

Fig. 5C. "La Roca Blanca", transition mark from pristine woodland habitat to cultivated river (downstream). The river dries up down from this point almost every year.

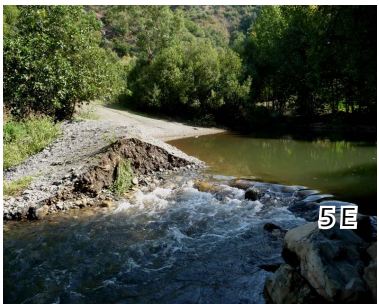
Fig. 5D. The forested uplands of the Genal.

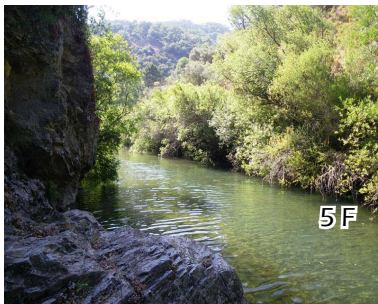
Fig. 5E. One of the many summer dams on the Genal here breached by the winter rains.

Fig. 5F. The Upper Genal, one of the finest *Macromia* stretches.

The Genal

This tributary can be considered as two quite different rivers. From what the locals refer to as "La Roca Blanca" which sits in the middle of the river approximately 1.5 km upstream from Gaucin Bridge [where the road from Gaucin crosses the Genal] to its confluence with the Guadiaro, it is a seasonal stream, dry in most years from the end of June until mid to late August and often much later. Below Gaucin Bridge the river runs through intensively cultivated land whereas upstream of the "Roca Blanca", the river metamorphoses into a pristine woodland stream, which it maintains for the majority of its upland and meandering course. The Genal runs here through dense woodland cultivated for its Cork Oaks (*Quercus suber*) and Sweet chestnuts (*Castanea sativa*) and is rightly considered one of the true jewels of Spanish rivers. Wherever the public can gain access, they take advantage by bathing in its clear unpolluted waters. The authorities encourage this use of the river by creating temporary dams to make large pools and slow the flow. This not only benefits people but also creates more habitat for *Macromia splendens*.





The Hozgarganta

The shortest, most open and wildest of the three rivers. Much of its length is contained within the Alcornocales Natural (*i.e.* Regional) Park. Depending on the winter rainfall, long stretches of the river upstream of Jimena de la Frontera are reduced from mid summer onwards to a series of deep pools although, unlike parts of the Genal, this river never dries up. In contrast to the Guadiaro and the Genal, which rise in the Sierra de las Nieves (the mountains of the snows), the Hozgarganta is sourced at a much lower altitude and, as a consequence, its waters are generally warmer and its adult dragonfly fauna flies earlier. Figure 6 shows examples of this habitat and how it contrasts with the other rivers.

Prevailing weather conditions

The Guadiaro Cuenca is situated in one of the wettest parts of Spain; however, the rainfall can at best be described as intermittent. During the majority of years the river levels are low and as the water table reduces so certain streams dry up completely. The Guadiaro itself is permanent, but

Figure 6. Aspects of the Hozgarganta.

Fig. 6A. The Hozgarganta upstream from Jimena showing the heath and low scrub dominant vegetation. There is little agricultural here other than some grazing for goats.

Fig. 6B. The Hozgarganta at Jimena reduced to pools in summer.

Fig. 6C. Typical landscape of the Hozgarganta near Jimena dominated by heath and scrub. *Macromia* and *Oxygastra* fly here.

Figure 7. Visual impacts of the flood during the winter 2009/2010.

Fig. 7A. The Guadiaro valley becomes a sea.

Fig. 7B. Montejaque dam below Sierra de Libar. This ill-conceived dam flooded for the first time ever in January 2010 leading to fears of a collapse.

Fig. 7C. Normal situation for the Montejaque dam (June 2010).

Fig. 7D. The Rio Almarchal, normally a completely dry Arroyo, in full flood.

both the Genal and Hozgarganta have dry sections or are reduced to deep pools as shown on Figure 3. However, The Guadiaro Cuenca is often transformed by catastrophic storms, an example of which was provided during the winter of 2009/2010 when the rain commenced on Christmas Eve of 2009 and continued almost unceasing until March 2010. I was not present during this period but the scenes shown here were relayed to me by Paul Sutcliffe who lives in a Molino on the banks of the Genal. Figure 7 above shows some examples of the impact. According to Paul Sutcliffe (pers. comm.), the last time things were as bad as this was 1995 when water levels were even higher. Part of the purpose of this paper is to demonstrate how *Macromia splendens* copes with these extreme conditions.

OBSERVATIONS ON LARVAE

Records of Larvae

Larval sampling was not a primary part of the survey work. However, as there was some controversy concerning the larval habitat, I considered that investigation was required. Cordero *et al.* (1999) thought that tree roots were the principal larval habitat whereas Leipelt and Suhling (2005) stated that larval habitat consisted of detritus found on the river bed. I define detritus suitable for *Macromia* as leaf litter, twigs and decaying riparian vegetation combined with stones mud and sand. Using this definition, my findings very much agree with Leipelt and Suhling. All the larvae that I encountered up to 2015, were from the river base. Figure 8 shows a typical situation and detritus habitat.

Table 1 summarises the larval collections. I believe that the larval life history identified by Leipelt and Suhling (2005) to be similar to that on the Guadiaro Cuenca.

- April/ May: final instar F-0 ready to emerge.
- Late May to June: F-2 from eggs laid the previous year.
- Late June to September: F-1 from eggs laid the previous year.
- Late September: F-0 ready for emergence in the following spring.

In summary this species appears to have a two year life cycle on the Guadiaro Cuenca.

Figure 8. Typical larval habitat of detritus from the river bed. The larva can been seen in the centre of the picture.

River	Genal			Guadiaro			Hozgarganta		
Metrics	visits	larvae	water temp.	visits	larvae	water temp.	visits	larvae	water temp.
Totals	66	5	-	26	0	-	27	5	-
30 Apr	-	-	-	-	-	-	2003	F-0	-
21 May	-	-	-	-	-	-	2015	F-0	21.7
28 May	2009	F-2	16.3	-	-	-	-	-	-
04 Jun	2010	0	19.2	-	-	-	2005	2 F-2	-
09 Jun	2008	F-2	19.6	-	-	-	-	-	-
21 Jun	-	-	-	-	-	-	2005	F-1	-
05 Sep	2009	F-1	-	-	-	-	-	-	-
07 Sep	2009	2F-0	-	-	-	-	-	-	-

Table 1. Summary of larval collection on the Guadiaro Cuenca. F-0 = Final Instar; F-1 = instar before final; etc.

Larval behaviour

Some of the larvae that I collected were placed in saucepans overnight in order to observe their behaviour. Leipelt and Suhling (2005) state that the majority of feeding behaviour and, therefore, larval activity takes place at night. I placed one larva in the saucepan (Fig. 9) and observed its behaviour. Throughout the night it made very little movement. When I brushed away some of the sand/mud covering, it recovered itself using its hind leg within approximately 15 minutes.

In another experiment, I noted the total movement of one larva over an entire 12 hours overnight period of just 7cm. My suspicion is that the larvae hardly move in their natural habitat remaining motionless for the majority of their lives simply waiting for prey to appear in front of them. On the

Figure 9. Larval behaviour.

Fig. 9A. Detritus taken directly from the Rio Genal and placed in saucepan.

Fig. 9B. The larvae concealed with little more than eyes and antennae protruding.

Genal and Hozgarganta there is an abundance of fish fry and tadpoles (Fig. 10), which probably represent a large proportion of the larval diet.

NOTES ON EMERGENCE

Terrestrial survival

Leipelt and Suhling (2005) state that a large percentage of larvae can be found in small pockets at the base of rocky river banks. Up until this year I had not found this to be the case; however, in May 2015, I was on one of the tributaries of the Hozgarganta and decided to search for larvae in such small pockets. I was successful at my first attempt. I suspect that the larvae collect in such areas prior to emergence.

LEIPELT, K.G. & SUHLING, F. (2005) Larval biology, life cycle and habitat requirements of *Macromia splendens*, revisited. (Odonata: Macromiidae). *International Journal of Odonatology*, **8**: 33-44.

I decided to breed out the larva which proved to be a lengthy and complex exercise fully detailed in Chelmick (2015b). In summary:

CHELMICK, D.G. (2015b) Travels with Macromia. Agrion, **20**: 60-63.

- The larva first appeared out of the water on 21-May and travelled approximately 4m.
- The larva then returned to the water.
- The larva hardly moved after its return not even attempting to re-cover itself with sand or mud.
- The larva eventually emerged on 28-May. Seven nights after its original attempt.

It would appear that larvae have considerable flexibility in how long they can spend out of the water at the time of emergence.

Figure 10. The river Genal at Algotocin showing the tadpoles which are present in abundance throughout the summer months.

Figure 11. Emergence site on the Genal. Most exuviae were found in overhanging crevices. Normally not more than 0,6m from the water but occasionally up to 2m above the water.

Figure 12A & 12B. The majority of exuviae were found in this overhanging posture sometimes horizontal.

Figure 12C. Colony of harvestmen found where *Macromia* emerges.

Exuviae

A total of 79 exuviae were collected during the study period. Figure 11 shows a typical exuviae collecting situation. Being in the water is essential, had I restricted my collecting from the river bank, numbers would have been greatly reduced. The majority were collected in an overhanging posture (Figs. 12A, 12B). There were, however, many exceptions. Tree trunks and logs adjacent the river were used and other exuviae found close to the water on herbaceous vegetation. One interesting feature was that clumps or colonies of Harvestmen (Arachnida order Opiliones) were often encountered in rocky crevices with *Macromia* exuviae (Fig. 12C).

Table 2. Summary of exuviae collected on the Guadiaro Cuenca

River	Genal		Guadiaro		Hozgarganta		Remarks
Metrics	visits	exuvia	visits	exuvia	visits	exuvia	
Totals	66	48	26	0	27	31	
30 Apr	-	-	-	-	2003	0	
23 May	2009	1	-	-	-	-	
24 May	2009	3	-	-	-	-	
26 May	2009	1	-	-	-	-	
27 May	2009	1	-	-	-	-	
21 May	-	-	-	-	2015	1	
28 May	2009	3	-	-	-	-	
29 May	2009	1	2009	0	2007	0	
31 May	2010	0	-	-	2005	4	
31 May	2007	6	-	-	-	-	2 from Almarchal
1 June	-	-	2009	-	2009	1	
1 June	-	-	-	-	2005	8	
2 June	2010	1	-	-	-	-	
2 June	2009	4	-	-	-	-	
3 June	2009	2	2010	0	2010	0	
4 June	2010	0	-	-	2005	4	
6 June	2008	6	2005	0	-	-	
7 June	2007	1	2012	0	2012	0	
7 June	2008	4	2009	0	2005	5	
8 June	2008	1	2005	0	2005	0	
11 June	2009	4	2009	0	-	-	
12 June	2012	1	-	-	-	-	
12 June	2008	5	-	-	2008	0	
16 June	2009	1	-	-	-	-	found at Gaucin Bridge
4 July	-	-	-	-	2004	3	
5 July	-	-	-	-	2004	4	
6 July	-	-	2004	0	2004	1	
6 Sept.	2009	1	-	-	-	-	
1 Oct.	2008	1	-	-	-	-	

BILEK, A. (1969) Erganzende Beobachtungen zur Lebenzweise von *Macromia splendens* (Pictet 1843) und einigen anderen in der Guyenne vorkommenden Odonata-Arten. *Entomologische Zeitschrift*, **79**: 117-123.

The numbers of exuviae collected were quite low and this appears to be reflected in other studies. Bilek (1967) worked the Rivers Lot and Cele in France over two four week periods in June 1966 and 1967. He found a total of 23 exuviae. Other studies (Chelmick 2015a) indicate higher numbers; but it would appear that based upon exuviae collections, numbers of individuals in populations are never particularly high. Had I, at the time I was collecting *Macromia*, collected exuviae of *Oxygastra* or *Gomphus* spp. then the numbers would have been increased by a factor of at least five. Had I been collecting *Boyeria* then numbers would have been increased by a factor of fifty (Fig. 16A).

The detailed records of exuviae is shown in Table 2. Clearly exuviae persist for long periods after emergence. Those collected in July on the Hozgarganta were clearly old and encrusted with spiders' webs. Those on the Genal in September and October were high up in crevices in cliffs and very much protected from the weather; it is possible that they could have been present from previous years.

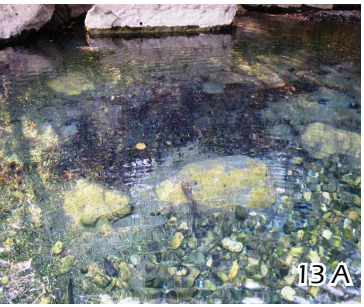
On 31-May-2007, I collected two exuviae from the Rio Almarchal. At the time of collection this stream consisted of only a few pools and dries up subsequentlty

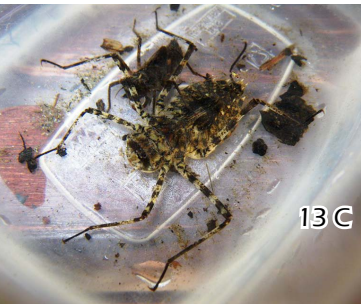
Figure 13. Larvae and habitat of riverine dragonflies.

Fig. 13A. Typical patch of detritus disturbed by the storms of 2010. In previous years, this provided prime habitat for the species shown here.

Fig. 13B & 13C. Macromia final and early instar larvae. Wing case length and overall size are the only apparent differences.

Fig. 13D & 13E. *Oxygastra, Macromia, Gomphus* spp. and *Cordulegaster* larvae, all found in the patches of detritus with *Macromia* in the smallest numbers.





in 2008 and 2009. This river was in full flood in 2010 as shown in Figure 8 but essentially dry once again by the summer of that year leaving only occasional pools. On 16-June-2009 I collected an exuvia from Gaucin Bridge. As stated above, the Genal at this point is dry nearly every year from the end of June until late August and often much later.

As shown in Table 2, all but two of the exuviae that I collected on the Genal were from the years up to and including 2009. The winter storms of 2009/2010 essentially remodelled the course of the river and rendered my favoured exuviae sites unsuitable. My first thought was that the overall population would have been affected by the changes; however, my observations of adults in 2010 and subsequent years indicated that there had been no impact on the populations.

One other feature of the Genal in the summer of 2010 was the absence in the areas that I studied of obvious patches of detritus (Fig. 13A), which are the habitat for *Macromia* and other species (Fig. 13B-E). The river had clearly been scoured by the winter storms.

As evidenced by the adult populations of 2010 and future years, the larvae were clearly present but where?

Figure 14. River bed of the Genal in the summer of 2010.

Fig. 14A. The stony bed of the Rio Genal scoured of detritus in 2010.

Fig. 14B. Riddling in the detritus collected in huge pools in 2010.

Fig 14C. The dam which maintains levels at the key macromia stretch washed away by the winter rains

Figure 15. Example of the permanence of emergence site. Huge fallen tree on the Rio Genal, unmoved by the floods of 2010. *Macromia* exuviae were found under this same tree three years running.

Figure 16. *Macromia* exuviae showing colour variation.

(Following page)

Table 3. Summary of adult observations on the Guadiaro Cuenca. I = single individuals, B = breeding behaviour, 0 = no observation.

For clarification, my visits to the Guadiaro extended well beyond the end of July. For Table 3, I have only shown the periods relevant to the flight season

One example was that one of the two exuviae that I found on the Genal in 2010 was from exactly the same site as in 2008 and 2009. Figure 15 shows the exuvia and the huge fallen tree that was unmoved by the floods. The substrate had been completely transformed but the emergence site was unchanged. The main emergence sites of 2010 were never discovered.

As with many species of dragonfly there is considerable variation in the colour of the exuviae. This is generally thought to indicate cryptic colouration determined by habitat selection. Figure 16 shows the range of colouration from light brown and dark to almost black. This range of colouration in exuviae can be found in close proximity indicating that *Macromia* appears to have considerable flexibility in habitat selection and more research is required to understand the full habitat requirements of the species.

OBSERVATIONS ON ADULT BEHAVIOUR

Flight period

Table 3 shows the days when I was present on the Guadiaro Cuenca during the flight period and the occurrence of *Macromia*. In summary I have been present on the river between 30 of April (2003) and 30 of July (2011) and have observed *Macromia* breeding behaviour as follows:

- Genal, from 29-May until 19-Jun; average water temperature, AWT= 18.6 ºC.
- Guadiaro, from 6-Jun until 13-Jun; AWT= 19.9 ºC.
- Hozgarganta, from 21-May until 7-Jun; AWT= 23.9 ºC.

I have included the average water temperatures as an indication of how the warmer waters of the Hozgarganta demonstrate a much earlier emergence and therefore flight period. Cordero states that, in Galicia, a water temperature of between 22 and 26 ºC is encountered at emergence (Cordero, 2000) and that adults are on the wing until the end of July with the earliest oviposition observed on 23-June (Cordero *et al.*, 1999).

CORDERO RIVERA, A. (2000) Distribution, habitat requirements and conservation of Macromia splendens Pictet (Odonata: Corduliidae), in Galicia (NW Spain). *International Journal of Odonatology*, **3**: 73-83.

CORDERO RIVERA, A., UTZERI, C. & SANTOLAMAZZA CARBONE, S. (1999) Emergence and adult behaviour of Macromia splendens (Pictet) in Galicia, northwestern Spain (Anisoptera: Corduliidae). *Odonatologica*, **28**: 333-342.

River	Genal			Guadiaro			Hozgarganta		
Metrics	visits	adults	water temp.	visits	adults	water temp.	visits	adults	water temp.
Totals	66	-	-	26	-	-	27	-	-
30 Apr	-	-	-	-	-	-	2003	0	-
21 May	-	-	-	-	-	-	2015	B	21.7
22 May	-	-	-	2015	0	18.9	2015	B	21.9
23 May	2009	0	18.1	-	-	-	2015	B	-
24 May	2009	0	17.7	-	-	-	-	-	-
25 May	2009	I	-	-	-	-	-	-	-
26 May	2009	0	-	-	-	-	-	-	-
27 May	2009	0	-	-	-	-	-	-	-
28 May	2009	0	16.3	-	-	-	-	-	-
28 May	2007	0	-	2007	0	-	-	-	-
29 May	2009	B	-	2009	0	-	2007	0	-
29 May	-	-	-	-	-	-	2005	0	-
30 May	2009	0	18.3	2010	0	21.3	2010	0	-
30 May	-	-	-	2007	0	-	-	-	-
31 May	2010	0	20.2	-	-	-	2005	0	-
31 May	2009	0	16.2	-	-	-	-	-	-
31 May	2007	B	-	-	-	-	-	-	-
1 Jun	-	-	-	-	-	-	2010	B	23.5
1 Jun	-	-	-	2009	0	20.5	2009	B	22.7
1 Jun	-	-	-	-	-	-	2005	B	-
2 Jun	2010	0	19.9	-	-	-	-	-	-
2 Jun	2009	B	17.8	-	-	-	-	-	-
3 Jun	2009	B	-	2010	0	-	2010	B	23.7
3 Jun	2007	0	-	-	-	-	2005	B	-
4 Jun	2010	0	19.2	-	-	-	2005	I	-
4 Jun	2009	B	18.3	2007	0	-	-	-	-
5 Jun	2012	0	-	-	-	-	-	-	-
5 Jun	2010	B	19.4	-	-	-	2007	B	-
5 Jun	2009	B	-	-	-	-	2008	0	-
5 Jun	2005	B	-	-	-	-	-	-	-
6 Jun	2012	0	21.0	2009	0	-	-	-	-
6 Jun	2008	B	19.1	2005	B	-	-	-	-

River	Genal			Guadiaro			Hozgarganta		
6 Jun	2005	B	-	-	-	-	-	-	-
7 Jun	2007	B	-	2012	0	22.6	2012	B	25.5
7 Jun	2008	0	-	2009	0	18.0	2005	0	-
7 Jun	-	-	-	2008	0	17.9	-	-	-
8 Jun	2005	0	-	2012	0	22.2	-	-	-
8 Jun	2008	0	-	2005	B	-	2005	0	-
8 Jun	-	-	-	2008	0	19.0	-	-	-
9 Jun	2009	B	17.1	-	-	-	2005	0	-
9 Jun	2008	0	19.6	-	-	-	-	-	-
10 Jun	2012	B	18.5	-	-	-	-	-	-
10 Jun	2009	B	17.4	-	-	-	-	-	-
10 Jun	2008	B	-	-	-	-	-	-	-
11 Jun	2009	B	17.2	2009	0	19.9	-	-	-
11 Jun	2008	0	-	-	-	-	-	-	-
12 Jun	2012	B	18.3	-	-	-	-	-	-
12 Jun	2009	B	17.7	-	-	-	-	-	-
12 Jun	2008	0	18.9	-	-	-	2008	0	23.7
13 Jun	2009	0	-	2012	B	17.5	-	-	-
14 Jun	-	-	-	-	-	-	-	-	-
15 Jun	2009	B	19.7	-	-	-	-	-	-
16 Jun	2009	B	19.3	-	-	-	-	-	-
17 Jun	-	-	-	-	-	-	-	-	-
18 Jun	2009	B	19.7	-	-	-	2009	0	24.4
19 Jun	2009	B	19.9	2009	0	-	-	-	-
20 Jun	-	-	-	-	-	-	-	-	-
4 Jul	-	-	-	-	-	-	2004	0	-
5 Jul	-	-	-	-	-	-	2004	0	-
6 Jul	-	-	-	2004	0	-	2004	0	-
7 Jul	-	-	-	-	-	-	2004	0	-
8 Jul	-	-	-	2004	0	-	2004	0	-
9 Jul	-	-	-	-	-	-	-	-	-
10 Jul	-	-	-	-	-	-	-	-	-
28 Jul	2011	0	-	2011	0	-	-	-	-
29 Jul	-	-	-	-	-	-	-	-	-
30 Jul	2011	0	-	-	-	-	-	-	-

Male territorial behaviour and use of man-adapted habitats

Cordero *et al* (1999) summarise the diurnal flight behaviour as follows:

- Peak adult activity took place between 9:00 and 12:00.
- Adults mainly absent between 13:00 and 16:00.

Table 4 shows diurnal observations made on the Rio Genal during my visits in 2009. To some extent they agree with Cordero. In 2009, indeed in most years, I was absent from the river between 12:30 and 15:00 and was, therefore, unable to establish whether *Macromia* was on the river during this time.

In 2015 during my visits to the Hozgarganta I stayed on the river until 15:00 for two days in order to see whether the adult activity reduced. My visits were on 21 and 23 May, which is at the beginning of the adult season. I arrived on the river at 12:49 on 21-May and immediately observed a male on territory. Further along there was another male on territory. The males were on territory for the entire period up to 15:00 with occasional breaks. On 23-May the situation was repeated with the added bonus of a female ovipositing around my legs at 13:47 during one of the periods when the males were away from the river.

As regards the time of arrival on the river, on 7-June-2012 I met Paul Hopkins on the Hozgarganta. He was making a video of *Macromia* and had been on site since 8:00 am. Males were on the river when he arrived and he saw females ovipositing at 8:30 am.

In summary the males are on the rivers of the Guadiaro Cuenca from 8:00 right through until 18:00 although there does appear to be a peak in activity, based on my Genal observations, in mid late morning.

Cordero carried out marking capture / recapture experiments on adult males (Cordero *et al*, 1999). He observed that individual males were on territory for around 16 minutes. My observations on the Hozgarganta in 2015 would appear to confirm this. I was present quite

Time	Behaviour (morning)	Time	Behaviour (afternoon)
	arrived	**12:00**	*Anax* reappears
09:14	male on territory: weather brightening	**12:11**	3 territories much more leisurely
09:27	back on territory	**12:25**	left site
09:52	back on territory: weather still dull	**15:00**	males patrolling
	arrived	**15:15**	0.45 m above water
09:39	*Macromia* on territory ; no sun	**15:30**	100 m beat
09:56	*Macromia* on territory ; no sun	**15:45**	male patrolling
10:08	2 *Macromia* nothing else on the river ; Oxygastra appear	**16:00**	male patrolling
10:13	3 Males	**16:15**	disturbed copula
10:23	3 Males diving in river to cool	**16:30**	ovipositing around my feet
10:33	female ovipositing	**16:45**	male patrolling
10:58	next day 4 territories: better weather: 5 males	**17:00**	2 males on territory
11:00	2 territories	**17:15**	0.4 m above water
11:10	*Macromia* on territory with Anax	**17:30**	100 m beat
11:12	female ovipositing	**17:45**	
11:15	2 males clash	**18:00**	
11:16	2 territories		left site
11:19	back to one territory. *Anax* problems		
11:20	2 territories		
11:28	Female ovipositing ; BPP photos male at rest at least 28 minutes		
11:31	3 territories		
11:32	4 males fighting		
11:33	5 males fighting		
11:40	7 males fighting		

Table 4. Diurnal behaviour based on the Rio Genal during 2009.

early in the season when the adult population was low. Adult males were present for about 15 minutes and then disappeared for a few minutes. In earlier years most of my observations on the Genal were made later in the season and there was no break in adult activity, presumably males leaving the river being quickly replaced by others.

Males on territory exhibit rather consistent behaviour. When they arrive at the river, often before other species, they fly in long territories (up to 100 m in length) at very high speed and never hovering. They occasionally dive into overhanging vegetation in their search for females. The males are inquisitive and will occasionally fly around an observer especially if the observer is actually in the water. I should point out that no adult insects were collected or even captured during my survey work.

Habitat as selected by the males comprises slow flowing deep stretches of river or stream. To give an idea of the range of such habitat, Figure 17 shows two extremes: Fig. 17A shows a small deep stream whilst Fig. 17B shows the Guadiaro which is much wider. Both are suitable for *Macromia*; size of the river appears to be unimportant, it's the deep sluggish pools and stretches of river that are sought after by the males.

Most of my studies have been on the Genal and I deal with this river in more detail. The most important stretch that I encountered on the Genal is approximately 6 m wide and is illustrated in Figure 18, which showes the long stretch which attracts large numbers (up to seven in the air at any one time) of *Macromia* males. The stretch is approximately

Figure 17. Habitats selected by males.

Fig. 17A. A small stream on the Hozgarganta, one of the best places to see *Macromia* closely.

Fig. 17B. The Guadiaro at Libar where *Macromia* was holding territory in 2012.

Figure 18. River Genal.

Fig. 18A. Key *Macromia* stretch prior to dam rebuilding.

Fig. 18B. Perfect habitat but water levels far too low and more suitable for *Zygonyx torridus*.

Fig. 18C. *Zygonyx torridus*, common on fast flowing shallow parts of the river.

Fig 18D. Excavator hard at work building dams for the tourists on the Genal.

Figure 19. Aspects of the dam.

Fig. 19A. The completed temporary dam on the Genal usually rebuilt by 12/13 June each year.

Fig. 19B. Perfect habitat with water levels raised by at least1m and now attracting *Macromia* in good numbers.

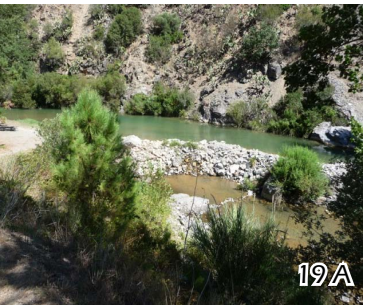
Figures 20 & 21. Interactions with other dragonflies.

Fig. 20A. Open river stretch on the Genal where (20B) *Anax imperator* dominates.

Fig. 21A. The key stretch on the Genal enclosed on one side by rock cliff and on the other by overhanging scrub and trees. *Anax* rarely appears here and (21B) *Macromia* splendens dominates.

150 m long and at peak times it will be divided into four or five territories. However in the conditions shown in Fig. 18A & 18B, the river is quite unsuitable as the water levels are far too low. In this state the river might attract *Zygonyx torridus* but not *Macromia splendens*.

The completed dam is shown in Figure 19A. It not only attracts the tourists but renders the habitat perfect for *Macromia* as can be seen from the dramatically increased water levels shown in Figure 19B. The timing of the dam rebuilding appears to fit in well with the *Macromia* breeding cycle. Paul Winter (pers. comm.) observed the phenomenom this year as I had many occasions previously. He visited the river prior to the dam rebuild and observed little. Three days later, when the dam had been constructed and water levels raised, *Macromia* had returned holding territory as usual. As further evidence of this opportunist behaviour, although this stretch of the Genal is probably the best for observing adults, it very rarely produces exuviae. This would suggest that the adults breed here but that when the winter rains wash away the dam so the larvae wash down river only to settle in more secure deep pools to complete their development.



All three of the Guadiaro rivers have man adapted (dammed) sections, which greatly improve the habitat for *Macromia*. Figure 17B shows the Guadiaro at Libar highlighting the small dam which maintains water levels and provides *Macromia* habitat upstream.

On the Hozgarganta the situation is rather more historical. In the 18th century a dam was constructed to the north of Jimena to provide water power via a canal, which can still be seen, to an armaments factory on the edge of the town known as the Fabrica de Artilleria. This Fabrica provided cannonballs used in the unsuccessful attempt by Spain to capture Gibraltar during the American War of Independence. This was known as the Great Siege of Gibraltar which took place in the early 1780s. Unfortunately, due to the unreliability of the rains, the Fabrica was abandoned after only a few years. The canal is now quite empty and the home of Crag Martins (*Ptyonoprogne rupestris*); however the remnants of the dam are still effective and provide to this day some of the most reliable deep water sections of the Hozgarganta, which are ideal for *M. splendens*.

Inter species competition

One of the problems that *Macromia* suffers is the aggressive territorial presence of the ubiquitous *Anax imperator.* Some years ago, I was present when a *Macromia* of indeterminent unknown sex attacked and killed a male *Anax imperator* on a river in Portugal (Chelmick and Mitchell, 1996). However, this is not the normal situation as, when the two species are present together the best outcome is that they ignore each other but more commonly the two will compete and *Macromia* usually comes off worse.

CHELMICK, D.G. & MITCHELL, P. (1996) *Macromia splendens* (Pictet) in Portugal. *Notulae Odonatologicae*, **4**: 121-122.

Figures 21 & 22 show adjacent stretches of the Genal. On one hand, the river is open on one side and usually dominated by *Anax imperator*; *Macromia* is rarely seen here (Fig. 21A). On the other hand, a key *Macromia* stretch enclosed on both sides which appears to inhibit the presence of *Anax* and allows *Macromia* to dominate (Fig. 22A).

Figure 22. Resting adults on the Genal.

Fig. 22A. A female resting briefly.

Fig. 22B. A male in a tree (22C) spotted by Peter Mitchell and photographed by Bryan Pickess.

Figure 23. Genal, strech of river where a female was ovipositing by th esmal bush when caught by a male

As mentioned above individual males remain on the river for relatively short periods of time and the females come to the river only to find mates and to oviposit. This begs the question – where do the adults go when they are not on the river? The answer is that they range widely across the surrounding vegetation. In all my years of study I have only rarely found settled *Macromia*. The Genal is particularly difficult as the surrounding area is dense woodland excellent for concealing dragonflies. On one occasion I happened upon a female resting briefly in a tree quite near the river (Fig. 22A) and on one other occasion my colleague Peter Mitchell spotted a male settle in a tree just above the water's edge (Fig. 22B).

Such observation opportunities are rare on the Genal primarily because the dense surrounding woodland

which renders close observation very difficult. The Hozgarganta provides better opportunities for observing adult insects hunting and resting; the vegetation is much more open woodland with scrub providing head height opportunities for observation (Fig. 6C). Indeed, this year on the Hozgarganta there were a number of adults flying and settling on the Campo; had I been present slightly later when the adult populations would be at their best, I suspect that observation opportunities would have been greatly improved. Contrarily, the Hozgarganta, being an open river, suffers more than either the Guadiaro or Genal with strong winds, which can continue for long periods sometimes as much as a week and greatly inhibiting adult observation opportunities.

Copulation and Oviposition

In all the years that I have been studying on the Guadiaro I have never seen a copulating pair of *Macromia*. I have witnessed, on a number of occasions, the catching of the female by the male. By way of example, Figure 23 shows a stretch of the Genal where I found a female investigating the base of the dark bush overhanging the water. A male came by and in the blink of an eye caught the female and the pair immediately disappeared high into the surrounding trees. I sought out and investigated what I thought was the chosen tree but to no avail; the pair had vanished, consumed by the vegetation. This high flying behaviour during mating is also found in other Emerald dragonflies. I recall being in the Swiss alps in 2009 when I encountered a male of *Somatochlora alpestris* in the act of catching a female. As with the *Macromia,* the pair flew high into trees but on this occasion I managed to locate them and was able to take some extremely poor but recognisable photographs.

Oviposition is easier to observe but again it is an act performed by the female in very rapid fashion and it has often been completed before you realise what is happening. The females fly in an agitated zig zag manner dipping their abdomens regularly in the chosen locality, the activity can last for just a few seconds but can be

Figure 25. Oviposition sites.

Fig. 25A. Female seen ovipositing here around roots to the left of the picture.

Fig. 25B. Female ovipositing around the submerged sallow branches for about 2 minutes.

Fig. 25C. *Oxygastra* ovipositing here for at least 5 minutes.

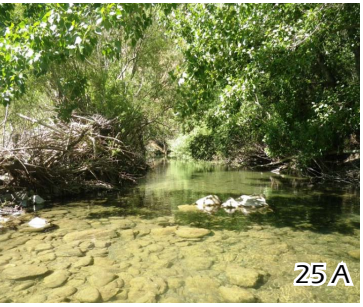
Fig. 25D. Oviposition site for both *Macromia* and *Oxygastra* on the Hozgarganta.

Figure 26. Oviposition at the Genal - Bennarabá.

Fig. 26A. Female ovipositing around this rock for about one minute.

Fig 26B. Substrate where the female was oviposting quite shallow and devoid of detritus.

up to two minutes although the latter is exceptional. As with many dragonflies the females try and avoid contact with the males in order to complete their oviposition. The males, on the other hand are constantly searching out females which are usually to be found laying their eggs; indeed the only reason the females return to the river after mating, is to oviposit. The first point to make is that oviposition can take place at almost any time during daylight hours. The females come to the river to oviposit before the males arrive; alternatively if the sun goes in and the males leave the river, then that is the time for the females. Oviposition sites vary and often do not appear to the human eye to be suitable. Figure 25 shows two sites on the Genal where females have been seen ovipositing. On one hand, a small pool (Fig. 25A). On the left side there is a bush with overhanging roots. I observed a female ovipositing here for a few seconds until discovered by a male when she flew off. On the other hand, a partly submerged willow branch on the key stretch of the Genal (Fig. 25B). I observed a female ovipositing around this branch for two minutes. Males were flying on territory on the other side of the river oblivious of the prize that awaited them just a few yards distant. Oviposition behaviour contrasts with



Oxygastra curtisii which oviposits in a similar rather agitated manner but continues for far longer and, in contrast with *Macromia*, the females will chase off males attempting to mate (Fig. 25C).

It would appear that the females choose a prominent object, fallen tree, submerged branches, large rock or similar for their oviposition site. Figure 26A shows just such a landmark. A female was ovipositing here for a few seconds. Figure 26B shows the substrate over which the female was ovipositing. To the human eye this would appear to be both too shallow and devoid of any detritus that might trap or hide the eggs. However, it is clear that the eggs will not develop here but be carried to suitable habitat. The job of the female is simply to deliver the eggs into the river and to avoid excessive contact with males.

Opportunist Colonisation

The final part of this paper provides examples of dispersal of the adult *Macromia* in the Guadiaro Cuenca.

Example 1 – The Guadiaro and the Desvio at El Colmenar.

In order to cope with the extreme conditions present in the Guadiaro Cuenca, *Macromia* has to make the most of all opportunities for breeding. One such opportunity was presented in 2005 and is illustrated in Figure 27. The road from El Colmenar to Gaucin spans the Guadiaro by means of an ageing iron truss bridge (Fig. 27A). In 2005 this bridge was closed for renovation and a diversion created (The Desvio) downstream approximately three kilometers from the bridge. The Desvio was created by damming the river with culverts to allow passage of water (Fig. 27C). This dam had the effect of ponding up the river and creating *Macromia* habitat (Fig. 27B). As can be seen from the river downsteam of the dam (Fig. 27D), it is shallow and fast flowing and quite unsuitable. I visited the Desvio quite by accident on 6-Jun-2005 with John and Hilary Luck. A male *Macromia* was holding territory on the new pool for the whole time

that we were present (some two hours) and the male was also seen to be investigating the large culverts in his search for females. At least one other male appeared and was chased off. This observation was all the more interesting as it was on a stretch of the Guadiaro that I had always considered polluted with somewhat turbid waters and often offensive odours. Anxious to see whether, the situation remained I revisited the area in 2007. The Desvio had gone, the bridge returned to traffic; the river had reverted to normal flow and was quite unsuitable for *Macromia*. Any oviposition that had taken place would have produced larvae that were now a long way down river.

Example 2 – The Genal at Gaucin Bridge

As mentioned above the Rio Genal at Gaucin Bridge dries up most summers; however in the late Spring (May/June) the river here attracts good numbers of holiday makers taking advantage of the cool waters provided, as with the higher reaches of the river, by a dam creating a fine swimming pool (Fig. 28A). This

Figure 27. Aspects of the river Guadiaro.

Fig. 27A. Distant view of The Colmenar bridge over the Guadiaro.

Fig. 27B. The deep pool formed on the Guadiaro by the creation of the temporary dam for the Desvio.

Fig. 27C. The Desvio providing access to the village of El Colmenar.

Fig. 27D. The Guadiaro downstream of the Desvio.

pool backs up water and creates *Macromia* breeding conditions. In June 2005 in the early evening I observed a male holding territory (Fig. 28B) and, at least, one female ovipositing (Fig. 28C & 28D).

I have found an exuvia at Gaucin Bridge on 16-June 2009. However I suspect that this was not related to the oviposition activity described above which I suspect failed as the river probably dried up the follow summer and there would be no suitable habitat below the bridge.

I visited the area in September 2008 when the region was in the midst of huge storms that had brought premature flooding leading to a raging Genal at Gaucin Bridge (Fig. 29).

Contrast this raging river with the situation in September 2009 just one year later (Fig. 30). The river at Gaucin Bridge is quite dry and the 2005 male territory barren and just a mass of pebbles. Presumably, the exuvia collected in June 2009 was carried to the Bridge in the previous year's storms and emerged before the desiccation of 2009.

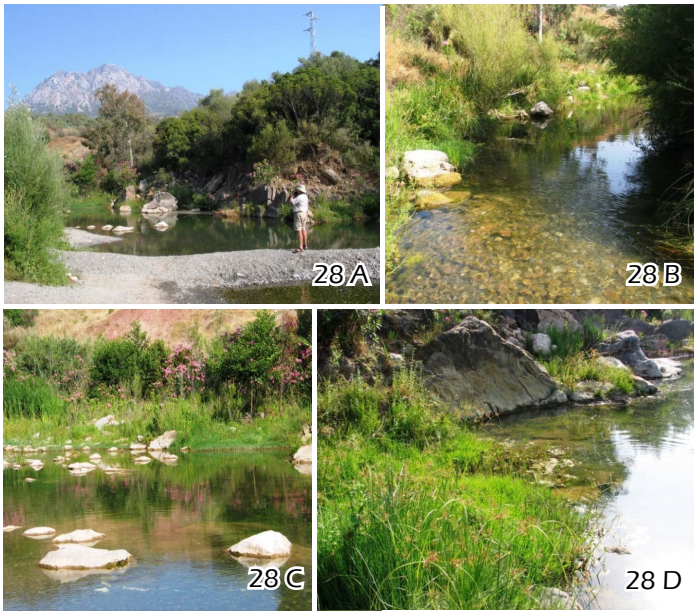


Figure 28. Aspects of the river Genal at the Gaucin bridge.

Fig. 28A. June 2005 with John Luck observing from the swimming pool temporary dam.

Fig. 28B. Male territory.

Fig. 28C. Backed up water which attracted a female *Macromia* to oviposit.

Fig. 28D. The oviposition site.

DISCUSSION

In the Guadiaro Cuenca, *Macromia splendens* has a two year life cycle; it requires permanent water in order to survive. Such habitat is distributed unevenly throughout the area and is highly dependent upon seasonal weather conditions. How does *Macromia* survive, and indeed thrive as it does, in this apparently hostile environment? First point to make is that adult dispersal from breeding habitat is very effective. From the number of males observed on the Genal there would appear to be considerable competition for territories requiring the majority of adults to disperse to new areas. Pools and deep stretches of water, whether formed naturally or by man's adaptations, are quickly colonised by the adult insects. Even in 2005, on the then apparently polluted Guadiaro, males were holding territory on the dammed river created by the Desvio at El Colmenar. The size of the river or stream seems to be unimportant, so long as deep slow stretches or pools are present they will be colonised. This is particularly the case where man adapted or dammed stretches of river are provided. The females often appear to oviposit in unsuitable conditions; however it must be remembered that the eggs rarely remain where they are laid but rely upon movement by seasonal flooding into suitable habitat. The Genal provides a fine example of this; exuviae are rarely found along the most important adult site; females may lay here but their eggs move on. Larval habitat is also very flexible. Most of my records come from detritus on the river bed; however during times of flood

Figure 29. Flood in the Genal.

Fig. 29A. 28 Sep 2008 at Gaucin Bridge. Fig 29B. The male territory in flood.

such habitat is violently removed and yet this appears to have little effect on the adult population. The larvae, as evidenced by their exuviae on emergence, show a wide variety of colours from light brown to almost black. This is probably an adaptation to the background colour of their larval habitat. This can vary from the detritus mentioned above to the interstices of the barren rocky river bed where they lie in wait. It would appear that the larvae in normal weather conditions are very sedentary, barely needing to move in order to feed on the abundant prey found in these rivers. So long as the waters persist, the larvae can survive in almost any habitat.

There is also considerable flexibility on emergence. My 2015 breeding experiment showed that the larvae can remain out of the water for many hours and then return and remain submerged for at least another seven days. This adaptation is vital as the weather conditions at emergence, from Mid May until Mid June, can be extremely variable in the Guadiaro Cuenca with low temperatures, high winds and heavy rain far from uncommon. The larvae often have to wait for many days for the required emergence conditions. Even the emergence habitat varies as the eventual final feeding place of the larvae is not in its control. The preferred emergence is along rocky faces adjacent the river or next to large trees. They particularly prefer locations where there is an overhang which allows the larvae to hang almost horizontally for optimum emergence; however such conditions are not always available and larvae can

Figure 30. The Genal after the flood.

Fig. 30A. The male territory desiccated.

Fig 30B. A closer view of the desiccated habitat.

emerge close to the water and even on herbaceous vegetation.

In summary the following key adaptations:

• A strong dispersal behaviour throughout the valley in order to make the most of breeding opportunities in apparently unsuitable areas.

• An ability of the larvae to develop in almost any habitat which it finds itself in.

• A flexibility of behaviour before and during emergence allow *Macromia* to thrive in the Guadiaro Cuenca, often greatly assisted by man's adaptation to the habitat.

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