

SCIENTIFIC PAPERS

CURRENT SITUATION AND HISTORICAL EVOLUTION OF THE STUDY AND RESEARCH OF BLACK FLIES (DIPTERA: SIMULIIDAE) IN SPAIN. A TALE OF BLEEDING BITES

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Introduction, context and objectives

Spanish entomologists, scientists and researchers are currently facing the seasonal appearance of simuliids, above all during spring, summer and the early autumn months. This is a period when the females of some species of these dipterans cause serious damage to the human population with their bites (Fig. 1), which have been increasing year after year. As a result of complaints from citizens, shortages of antihistamines and hospital overcrowding, blackflies have been a trending topic over the last few years. Indeed, there are frequent news items on national and local television channels, radio stations and newspapers. Nevertheless, what do we know in Spain about these annoying nematocerans?

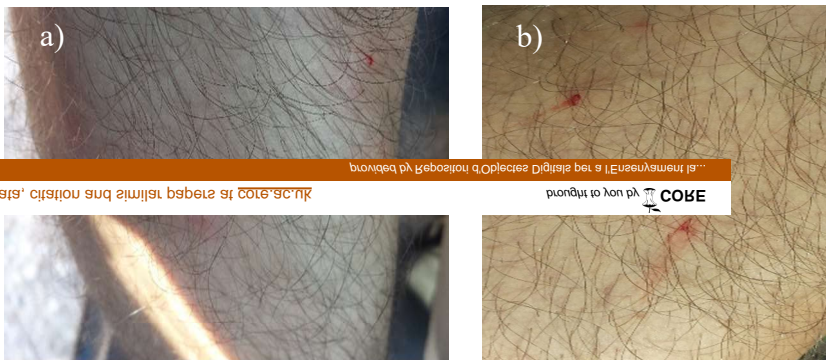


Figure 1. Blackfly bleeding wounds, a) quadriceps and b) calf.

Many academics have noted that in Spain there is a lack of information; is this true? In an attempt to answer this question, an in-depth study has been carried out on all published journal studies and articles regarding the Simuliidae in Spain. We have compiled a comprehensive record of past and present researchers in this field, as well as reporting which themes have been studied historically and which are studied today. Have there been any changes?

The Past and present of the family Simuliidae in Spain

The black flies are nematoceros dipterans belonging to the Simuliidae family. This group of insects has become highly relevant in certain regions of the country since 1995. These insects, considered typical in natural lotic environments of clean fresh water, have colonized water channels of very different dimensions. They are currently present in most of the water courses around the country, as demonstrated in the Valencian Autonomous Region, where they can be found in headwaters, middle stretches and river mouths, as well as in irrigation systems with greater or lesser water permanence, such as irrigation reservoirs, channels and ditches. Since 2017 different regions of the country, such as the Communities of Madrid, Murcia and La Rioja, provinces such as Zaragoza and Córdoba, and some specific areas of Catalonia and the Valencian Autonomous Region, among other places in Spain (Fig. 2), have increasingly suffered the discomforts characteristic of this arthropod.

At present, it is estimated that the number of known living species of black flies in the world is 2,335, although it is a little studied group and it is expected that the actual number is much higher. Indeed, a total number of 103 new species of simuliids has been identified since 2017 (ADLER & CROSSKEY, 2018) and this number is ever increasing. Moreover, in Spain, a total number of 52 species of simuliids have been identified so far (GONZÁLEZ *et al.*, 2002; BELQAT & GARRIDO, 2008; ADLER & CROSSKEY, 2018; LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2017b; LÓPEZ-PEÑA, 2018), which only represents 2.22% of the worldwide simuliid species, and whose provincial distribution can be consulted in LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ (2017b) and in the Doctoral Thesis of LÓPEZ-PEÑA (2018).

What is more, in many regions of the world, these dipterans are one of the groups of clearly harmful arthropods, although not transmitting diseases to man in those places. However, their presence in the tropics and their role in the transmission of some helminthiasis such as human onchocerciasis (*Onchocerca volvulus*) also known as "River blindness" on the African continent and "Robles disease" in certain Latin American countries, as well as the trigger agent of human mansonellosis or Ozzardi's

Mansonella (*Mansonella ozzardi*), is one of the most serious problems carried by this type of vector.



Figure 2. Spanish national territory, its 17 autonomous communities and its 50 provinces (https://d-maps.com/carte.php?num_car=5674&lang=es).

For all these reasons, the knowledge of the simuliids has been addressed mainly in those geographical regions where they have caused health problems such as Central Africa, Central America, South America and some areas of the Arabian Peninsula, particularly Yemen, because of the transmission of nematode pathogenic agents which cause the illnesses mentioned above (Fig. 3).

However, in the particular case of Spain, the first citation referring to simuliids dates from 1888 in a study carried out by ANTIGA, mentioning this family of insects in a catalog of Diptera of Spain. From then on, the work has continued sporadically to this day. In general, there are very few references, these studies being mainly taxonomic (GRENIER & BERTRAND, 1954; CARLSSON, 1969; BEAUCOURNU-SAGUEZ, 1975a, 1975b; CROSSKEY & GRÁCIO, 1985) and faunal among other contributions,

dealing with a wide range of topics. In addition, no comprehensive study of this family had been conducted in Spain and, until 1990, only partial studies were carried out (PUIG *et al.*, 1984; GONZÁLEZ, 1985; GONZÁLEZ *et al.*, 1986, 1987; PUIG *et al.*, 1987). These brief and often indirect references have increased our knowledge of the simuliid species present in the country. It could be summarized that sporadic one-off studies made in the Iberian Peninsula explain the scarcity of information that there is of this family of Diptera.

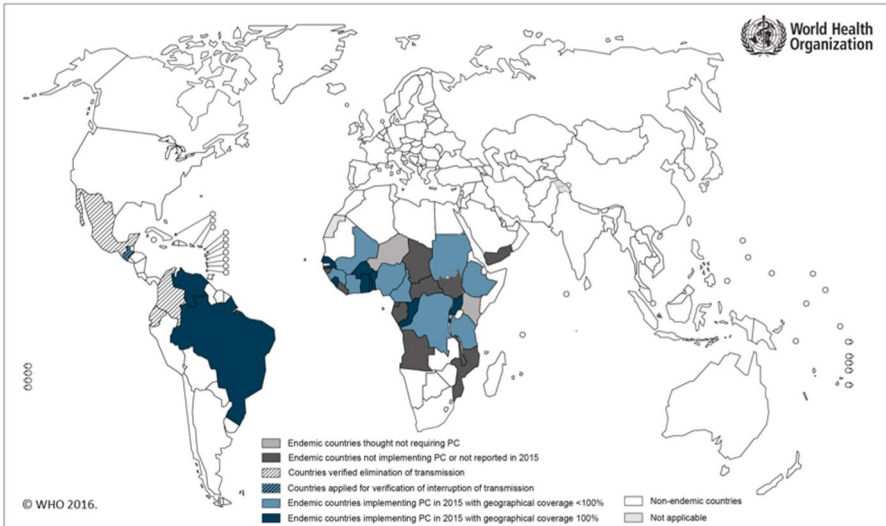


Figure 3. Geographical regions of the world where simuliids have been traditionally studied in-depth (<http://www.who.int/es/news-room/fact-sheets/detail/onchocerciasis>).

Even so, it must be said that the vast majority of the information relating to Spanish Simuliidae awareness has been reflected in journal publications, communications to conferences, congresses and symposiums and university dissertations. To begin with, a total number of 57 scientific articles have been published in journals and research publications. These articles have been produced by authors from other countries such as France, Morocco, Germany or United Kingdom, the reports being written in their mother tongues. Spanish authors have also contributed extensively to this purpose, writing their papers traditionally in Spanish but more recently also in English.

The topics dealt with have been extremely diverse (Fig. 4). The first studies on simuliids in Spain after ANTIGA, were carried out at the

beginning of the 20th century, once again treated in a general way and included in catalogs of Spanish Diptera (STROBL, 1900, 1906; CZERNY & STROBL, 1909; ENCOBET, 1912) at a time when Alfonso XIII began his reign after reaching adulthood. The previous years, in which his mother, Queen María Cristina of Habsburgo ruled the country as regent from 1888 up to 1900, were very difficult times for Spain, where the powerful Spanish empire was suffering its gradual disappearance. Moreover, Catalan and Basque nationalism emerged, causing bewilderment and discomfort in all areas of the country during this period of unrest. And what is more, it must be added that three out of four citizens were illiterate. Therefore, the situation was not propitious to knowledge and science. All these reasons negatively affected the gaining of knowledge of blackflies in the national territory, a situation that explains the absence of papers during these twelve years.

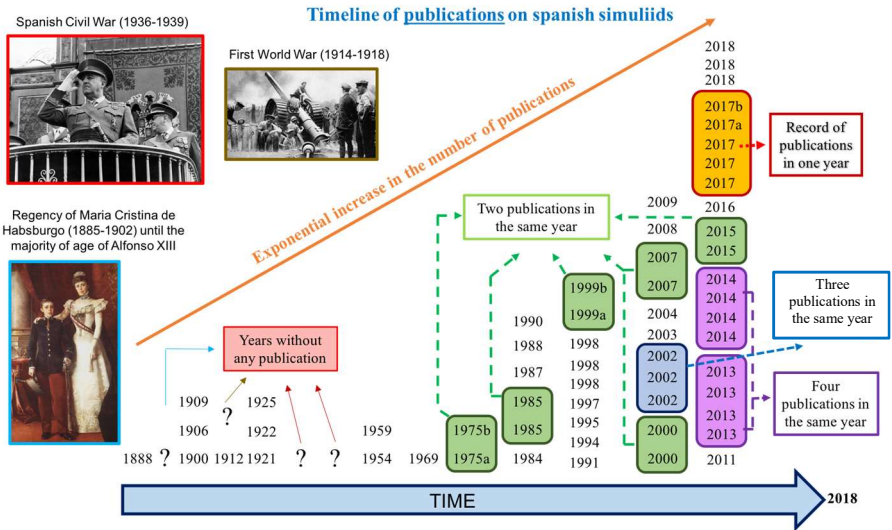


Figure 4. Spanish Simuliidae publications timeline.

Later, the First World War arrived (1914-1918), and again another period of lack of scientific contributions took place particularly two years before the war, the four years that took the war and three years more after this terrible world event. Luckily, some papers were published, dealing one more time as a generic item (SÉGUY, 1921), but also articles about Canary Islands began to appear (ABREU, 1922) as well as information on the Mediterranean simuliids (SÉGUY, 1925) but always describing the species.

There then followed another 29 years without publication, in this case because of a coup d'etat and a dictatorship of Primo de Rivera, from 1923 up to 1930, followed in 1936 by the terrible Spanish Civil War, which lasted up to 1939, a time when the dictatorship of Francisco Franco Bahamonte began, after having defeated the II Spanish Republic, which was to last up to 1975. To both these cases, the negative effect of the seven years of War World II is remarkable (1939-1945), therefore, the three situations were not favorable to continuing research. Nonetheless, during the following decades, sporadic studies dedicated mainly to the **description of new species** were carried out (GRENIER & BERTRAND, 1954; GRENIER & DORIER, 1959; CARLSSON, 1969; BEAUCOURNU-SAGUEZ, 1975a, 1975b; PUIG *et al.*, 1984; CROSSKEY & GRÁCIO, 1985; GONZÁLEZ, 1985; PUIG *et al.*, 1987; CROSSKEY, 1988; CLERGUE-GAZEAU & VINÇON, 1990; CROSSKEY, 1991; CROSSKEY *et al.*, 1998) but rarely dedicated to its biology, ecology and/or biogeography. In the decade of the 90s, diverse work was carried out focused on the **taxonomy** and the **ecology** (MALMQVIST *et al.*, 1995; GONZÁLEZ, 1997; MARTÍNEZ & PORTILLO, 1999a, 1999b; OTERMIN *et al.*, 2002; GARZA-HERNÁNDEZ & RUIZ-ARRONDO, 2018). Recently several studies have been carried out that include studies on **fauna, catalogues and inventories** (NILSSON *et al.*, 1998; CROSSKEY & CROSSKEY, 2000; SANZ *et al.*, 2000; GONZÁLEZ *et al.*, 2002; BELQAT & GARRIDO, 2008; VILLANÚA-INGLADA *et al.*, 2013; LESTÓN *et al.*, 2013, 2014a; CÓRDOBA *et al.*, 2017; LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2017a, 2017b; LÓPEZ-PEÑA, D. & R. JIMÉNEZ-PEYDRÓ, 2018), **distribution** studies and expansion of species (GALLARDO-MAYENCO & TOJA, 2002; RUIZ-ARRONDO *et al.*, 2009; LESTÓN *et al.*, 2014b), **identification keys and guides** (CROSSKEY & BÁEZ, 2004), or also, population control studies (ROVIRA *et al.*, 2007), studies of complaint of simuliids by **pathogenic agents or parasites** (GIRBAL & SANTAMARÍA, 1998), and studies of both **sanitary importance** (GALLEGO *et al.*, 1994; NOGUERA-PALAU, 2003; ANÓNIMO, 2013; RUIZ-ARRONDO *et al.*, 2014; LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2015; RUIZ-ARRONDO *et al.*, 2017; SÁNCHEZ-LÓPEZ *et al.*, 2017) and **veterinary importance** (FIGUERAS *et al.*, 2011). Moreover, recently topics have been covered related to **genetics** (ADLER & SEITZ, 2014; ADLER *et al.*, 2015, 2016; RUIZ-ARRONDO *et al.*, 2018). In addition, it is important to point out that nowadays there are some researchers who are working intensively in order to uncover the bioecology of simuliid species in Spain. As a result of this, many papers are now being published in the same year, it started with two, then three, later four up to even five articles published in the same year. Concerning whether the topics have changed over time or if they are still the same, it is necessary to emphasize that at the beginning they were mainly about Diptera in general as well as descriptive works of species from a particular area of the country, taxonomy and identification keys,

making catalogues and faunal inventories or distribution so as to get a wide range of knowledge about the autoecology of blackfly species present in Spain. Nevertheless, even though some researchers and specialists continue to work on these aspects, works which deal with the health and veterinary importance of some species of simuliids have become the current theme, locating risk areas for both human settlements and farms, and finally also tackling demanding areas such as controlling nuisance blackfly populations.

In addition, 43 oral and poster contributions to congresses, conferences and symposiums on a wide variety of topics have also been made (Fig. 5), such as **faunal studies** (GONZÁLEZ *et al.*, 1986, 1987; JUSTO *et al.*, 2009; BUENO-MARÍ *et al.*, 2013; LÓPEZ-PEÑA *et al.*, 2015b; LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2016a; BELQAT & GALLARDO-MAYENCO, 2016; CID *et al.*, 2017; LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2017b), **distribution** (JUSTO *et al.*, 2008; MARQUÉS, 2012; RUIZ-ARRONDO *et al.*, 2012a; LÓPEZ-PEÑA *et al.*, 2014; LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2014; RUIZ-ARRONDO *et al.*, 2015), **ecology** (BERNOTIENE *et al.*, 2018; JUSTO *et al.*, 2010; LÓPEZ-PEÑA *et al.*, 2015a, 2016a, 2016b; RUIZ-ARRONDO *et al.*, 2016a; LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2017a, 2018a, 2018c), **parasites** (LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2016b; RUIZ-ARRONDO *et al.*, 2017a), **molecular** (RUIZ-ARRONDO *et al.*, 2016b, 2017b), **health importance** (RUIZ-ARRONDO *et al.*, 2012b; LÓPEZ-PEÑA *et al.*, 2018; IGNJATOVIĆ-ĆUPINA *et al.*, 2018; RUIZ-ARRONDO *et al.*, 2018), **veterinary importance** (ORTIZ *et al.*, 2016; LÓPEZ-PEÑA *et al.*, 2018), **control** (VALLE-TRUJILLO & ESCOSA, 2009; RUIZ-ARRONDO *et al.*, 2011; LÓPEZ-PEÑA *et al.*, 2015; OBREGÓN *et al.*, 2016a, 2016b, 2017; MINGUET, 2017; BUENO-MARÍ *et al.*, 2017; MARTÍN-GAVÍN, 2018) and an analysis of the situation and evolution of the knowledge that is available of this dipteran in the national territory from its beginnings to the present day (LÓPEZ-PEÑA & JIMÉNEZ-PEYDRÓ, 2018b).

Scientific oral and poster contributions have traditionally been done mainly by Spanish researchers who have shared their results talking or writing in Spanish national congresses, conferences and symposia. But recently and increasingly, they are attending international ones where their contributions are being displayed in English. Regarding the timeline of these scientific activities, the first one is dated 1986 in the charge of GONZÁLEZ *et al.*, and then since the second contribution in 1987 again by GONZÁLEZ *et al.*, 21 years had to pass until the next work in 2008 by JUSTO *et al.* Since then new, interesting and diverse contributions have been appearing non-stop. It is important to emphasize that during the 1990s few oral or poster communications were made, revealing the minimum importance that blackflies had for both human beings and domestic animals. On the other hand, since the beginning of the 21st century, we can observe how the number of studies on this dipteran has

been growing sharply, owing to the fact that the females of some species of simuliids are annoying humans with their bites, causing bloody bites as well as severe allergic reactions. Such is the case that, in several years two, four, seven, eight and even ten contributions have been made in the same year. Initially the topics were on faunistic analyses, species distribution or ecology, while recently researchers have been focusing on other themes such as blackfly outbreaks and their causes, human and animal health, control of damaging populations or molecular and DNA issues.

Timeline of participations to congresses about Simuliidae of Spain

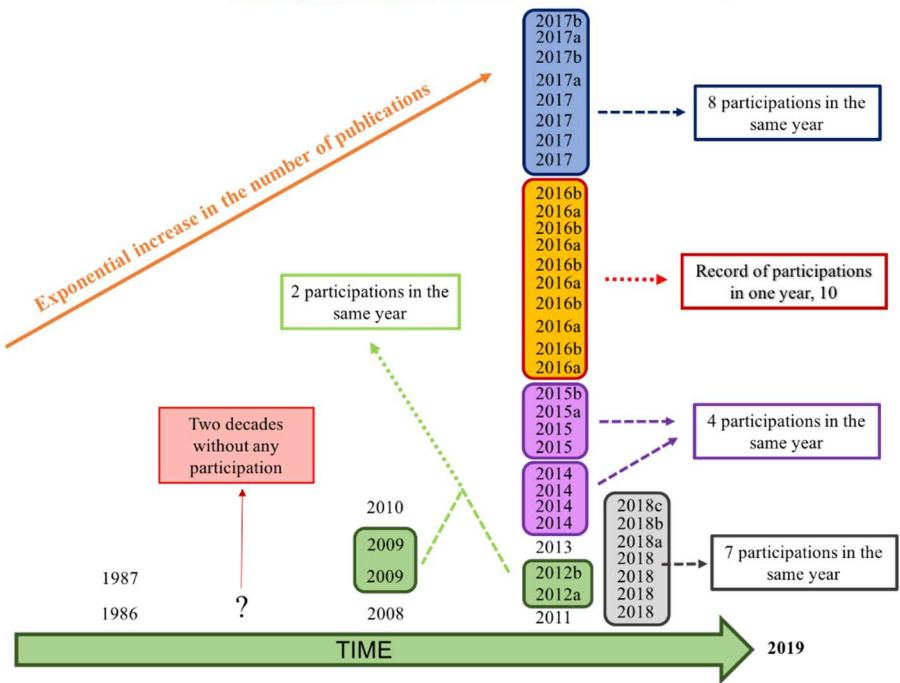


Figure 5. Spanish Simuliidae communications to conferences, congresses and symposiums timeline.

Finally, after the 1990s, academic-scientific research results started to emerge in public universities in the country dealing with a widely varied range of topics such as systematic, faunistic, ecology, distribution themes as well as those of health and veterinary importance. Nine interesting works have been done so far. Firstly, they were few and far between like the GONZÁLEZ **Bachelor’s Thesis** (dissertation) in 1981, and a few years

later this same scientist contributed the first **Doctoral Thesis** (PhD) on simuliids (GONZÁLEZ, 1990), in both cases carried out at the University of Barcelona. Later, two new bachelor's Theses appeared, the first of which was carried out at the University of Salamanca (MARTÍNEZ, 1996) and the second one at the University of Zaragoza (VILLANÚA-INGLADA, 2003). Afterwards, new research works have appeared such as the Doctoral Thesis from the University of Santiago de Compostela (LESTÓN, 2012), as well as **Master's Thesis** (master dissertation) (LÓPEZ-PEÑA, 2014) at the University of Valencia and **Dissertations** (RICOY, 2015) at the University of Jaén. And, finally, the most recent contributions are the new Doctoral Theses in the charge of the University of Zaragoza (RUIZ-ARRONDO, 2018) and the University of Valencia (LÓPEZ-PEÑA, 2018).

Looking at the kind of issues addressed in these academic contributions, we can observe change over time. For instance, while the first researcher opted to study the systems and ecology of the simuliid species of the northeast Spain (GONZÁLEZ, 1981, 1990), others decided to focus on ecology and faunistic analyses of other areas of the country (MARTÍNEZ, 1996; VILLANÚA-INGLADA, 2003; LESTÓN, 2012; RICOY, 2015), whereas nowadays others prefer to do research on the biology, distribution and the epidemiological importance that some species have in particular places of several provinces and autonomous regions, as in the cases of LÓPEZ-PEÑA (2014, 2018) and RUIZ-ARRONDO (2018).

Looking at the timeline of academic works, these have been increasing in importance considerably over time, fundamentally due to demand for more in-depth study of the simuliid species in particular, which cause nuisance. In fact, at the end of the 20th century only three extensive works had been produced, while at the beginning of the 21st century the double has already been published. This considerable difference is due to a range of circumstances. The first one is that the human population in inland villages and towns is decreasing alarmingly, and the extensive cattle industry is being reduced as well. To this fact is added the improvement of the water quality of rivers, streams and torrents due to the laws that restrict the uncontrolled dumping in urban areas, factories and farms as well as the establishment of ecological flows to the exits of reservoirs and swamps. All this is favoring the growth and dispersion of some types of plants, among which the submerged macrophytes stand out and which are an excellent substrate for simuliids. Therefore, due to this increase in the flow velocity of these aquatic environments and the availability of abundant and variable fixation substrates, populations of blackflies are enjoying a considerable increase in population. In addition, due to the optimal conditions of the rivers, this dipteran is colonizing all the stretches of the rivers. And to make matters worse, as a consequence of the reduced availability of hosts (mainly domestic livestock: birds and mammals) in the

inland villages, the females of the autogenous species inflict their bites on the citizens located in human populations near their breeding points.

With respect to the authors of papers, congresses, conferences, symposiums and academic works (Fig. 6), it should be pointed out that currently there are some scientists that are contributing more actively than others. Among them, Strobl, Crosskey, González, Lestón, Justo, Ruiz-Arrondo and López-Peña stand out. However, it is important to remember that every single one of these authors is extremely important because without their work, the knowledge that Spain currently has about its Simuliidae species would not be the same.

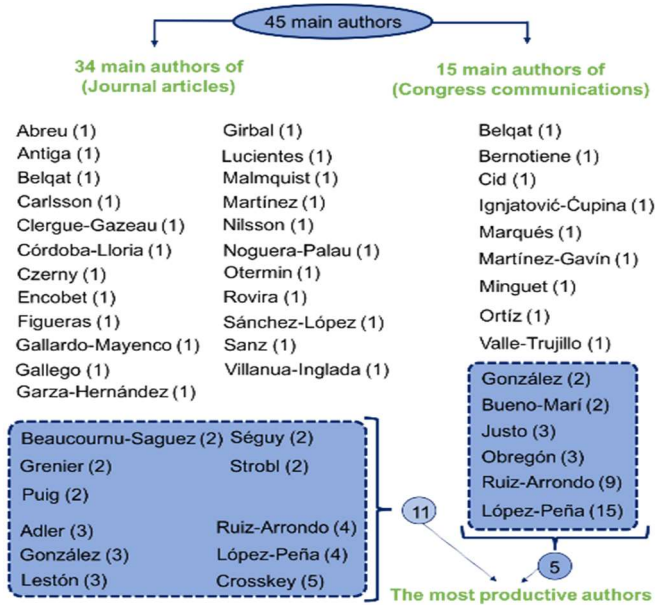


Figure 6. Synopsis of the most outstanding authors and their contributions to the knowledge of the Spanish Simuliidae. The number between parentheses indicates the number of contributions done by each author.

Hopes and desires, a path for the future.

Finally, it should be noted that the lack of information about simuliids in Spain that many people have made reference to in the past, is being remedied as year by year more specialists are appearing and contributing to increase the awareness of these dipterans in our national territory. Without a doubt, there is still a lot of work to do and priorities change over

time, but the most important thing is to know that there are still people excited and motivated to continue studying this arthropod vector of fearsome pathogens and parasites that affect both human and animal well-being.

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