Macroinvertebrates assemblages in the Canary Islands and Madeira

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Abstract

This study describes the freshwater macroinvertebrates assemblages in 17 streams of four of the Canary Islands (Tenerife, Gran Canaria, La Palma and La Gomera) and 10 streams of Madeira Island, at least in two seasons of the year. Without the Diptera, since this group has not been identified, a total of 71 taxa have been found in the Canary Islands belonging to 34 families. In Madeira, a total of 63 taxa belonging to 33 families have been found. The biogeographical origin of the species is mostly Paleartic region and endemic.

Endemisms have a significant presence in both archipelagos, being around one third in both cases. The endemicity in Tricoptera and Coleoptera is remarkable. There seems to be a tendency towards greater biodiversity and endemicity in those currents in better conserved areas, that are found within the Natural Parks in the Canary Islands and in the high areas of Madeira.

The status of freshwater macroinvertebrates is quite uncertain as recent data on these communities are scarce. The overexploitation of aquifers and the diversion of natural water flows for irrigation have caused the drying up of many of the natural flows, which inevitably endangers the fauna that inhabits them.

The protection of a stream with a high conservation value is proposed to contribute to the conservation of the Macaronesian native freshwater macroinvertebrate fauna.

Key words: Freshwater streams; Macroinvertebrates; Canary Islands, Madeira, Macaronesia.

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1. Introduction

1.1. Freshwater macroinvertebrates

1.1.1. Characteristics

Macroinvertebrates are a diverse array of animals without backbones, operationally defined as those that are retained by a mesh with a pore size of 0.2 to 0.5 mm. It includes taxa of worms, mollusks, crustaceans, mites and insects (Hussain & Pandit, 2012). Freshwater invertebrates that live linked to running water include representatives of almost every taxonomical group that exist in freshwater. This is because rivers may change and evolve but rarely disappear, but lakes, given their relative shorts periods of existence, usually act as evolutionary traps (Hynes, 1970). On oceanic islands the freshwater fauna is largely represented by insects with taxa that occupy a wide number of niches due to the relative absence of competitors for local resources (Hughes, 2003).

Many physical, biological and chemical factors regulate the composition and distribution of invertebrates in freshwater ecosystems (Hussain & Pandit, 2012). The most important ones are the stream speed, temperature, substratum, vegetation, dissolved substances and zoogeography (Hynes, 1970).

Most invertebrates are important components of stream ecosystems. They are a link in the transfer of material and energy from producers to top level consumers (Hussain & Pandit, 2012): They graze periphyton, assist in the breakdown of organic matter and cycling of nutrients, and may become food to predators (Hynes, 1970).

Macroinvertebrates are the organisms most commonly used for biological monitoring of freshwater ecosystems. The premise of biological monitoring is that in relatively complex biotic associations, certain species respond to an environmental disturbance by some measurable effect on community properties such as their abundance. In addition, the level of disturbance is relative to the level of change in populations (Hughes, 2010). The composition and distribution of stream macroinvertebrates is a reflection of the stream health and thus can be used as robust bioindicators (Hussain and Pandit, 2012). This can happen because they have the following features: They are found in most habitats, generally have limited mobility, easy to collect and have well-established sampling techniques and have a great diversity of forms with a wide range of sensitivities to changes.

Value	Definition	Function	Example
Utilitarian	Practical and material exploitation	Physical sustenance/security	Fish biodiversity as a source of food
Naturalistic	Direct experience and exploration	Curiosity, discovery, recreation	Sport fishing, scuba diving or other nature experiences
Ecologist-Scientific	Systematic study of structure, function, and relationship	Knowledge, understanding, observational skills	Understanding the spatial and temporal patterns of aquatic biodiversity distribution. Education.
Aesthetic	Physical appeal and beauty of nature	Inspiration, harmony, security	Appreciation of breaching whale, or salmon spawning runs
Symbolic	Use of nature for language and thought	Communication, mental development	Symbolic value of fish in haida art of native Americans
Humanistic	Strong emotional attachment and "love" for aspects of nature	Bonding, sharing, cooperation, companionship	Appreciation of aquarium pets, koi carp
Moralistic	Spiritual reverence and ethical concern for nature	Order, meaning, kinship, altruism	The spiritual importance of salmon runs and fish conservation for native Americans
Dominionistic	Mastery, physical control, dominance of nature	Mechanical skills, physical prowess, ability to subdue	River flood control, hydropower generation, water storage for irrigation
Negativistic	Fear, aversion, alienation for nature	Security, protection, safety, awe	Fear of waterborne disease

Table 1. Typology of nine basic values of aquatic biodiversity for mankind (Kellert (1997), modified by Geist (2011)).

1.1.2. Value of freshwater biodiversity for mankind.

The importance and value of freshwater biodiversity is easy to understand since it provides crucial services for human societies, some of them irreplaceable (Ninan, 2009). Nine types of aquatic biodiversity values for humanity -or ways in which humanity can perceive these ecosystems- can be found (Table 1). Some of these values provide sustenance for more than one billion people living in extreme poverty (Turner et al., 2007).

Although measuring the level of biodiversity in monetary terms could be inadequate, from an economic point of view it has different values: direct use values, as fauna stock; indirect use values, as a recreational space; option values which corresponds to the activities that will be exploited in the future; and existence values or what people will pay to avoid destruction of these habitats.

1.1.3. Threats to freshwater biodiversity

Freshwater ecosystems are hotspots of human use and alteration (Monroe et al., 2009). Studies conducted in North America on the extinction rate of freshwater organisms estimate an average of 0.5% per decade and, according to projections, it could reach 4% per decade, five times more than any other terrestrial fauna (Postel and Ritchter, 2003). Into freshwater organisms, invertebrates reveals the highest extinction rates, especially mussels where it reach between 2-7% per century (Strayer et al., 2004).

Threats to freshwater macroinvertebrates (and biodiversity in general) include five main interacting groups: overexploitation, water pollution, invasion of exotic species, flow modification and habitat degradation (Naiman and Turner, 2000; Malmqvist and Rundle, 2002; Dudgeon et al., 2006).

- Overexploitation: Mainly affects fish but any species with any or some of the following characteristics are also sensitive: high economic value, low fecundity, late reproduction, large body size or being grouped at certain times (Geist, 2011). Examples of exploitation includes sturgeon caviar or eels.
  This type of overexploitation does not usually affect freshwater invertebrates as they do not have a high economic value. The main problem related to overexploitation is the extraction of water from aquifers. The loss of running water inevitably leads to extinction to lotic taxa (Malmqvist el at., 1995).

- Water pollution: This threat has decreased significantly in recent decades in most industrialized countries (Aarts et al., 2004). Despite this, many of the habitats are not recovering.

- Invasion of exotic species: Introduction events includes accidental, as zebra mussel (*Dreissena polymorpha*) and deliberate for recreational purposes as fishing. Invasive species affect abundance and functional distinctiveness from local species (Strayer et al., 2006). Usually they invade those ecosystems that are already degraded (Koehn, 2004). A classic example of the catastrophic effects that this threat can have is the introduction of the Nile Perch (*Lates niloticus*) into Lake Victoria in Africa.

- Flow modifications: Produced by modifications of the stream flow by constructions as dams. Have severe consequences for the aquatic species which cannot get adapted to the new flow regimen. As some results of habitat fragmentation are reduced genetic interchange, possibilities of recolonization, the modulation of the population density and compensating migrations. Only dam constructions are considerate one of the major threats to river ecosystems (Postel and Ritcher, 2003).

- Habitat degradation: Occurs in different forms, mainly as changes in catchment areas that can produce changing patterns of erosion and sedimentation, and also changes on the function of the interstitial zone (Geist and Auserwald, 2007). The elimination of vegetation in the riparian areas causes a change in the physical conditions of the water, increasing the temperature since the shadow has decreased.

From a global point of view, two types of threats van be added that overlap with these five categories: Environmental changes and climatic shifts (Primack, 2008).

1.1.4. Freshwater macroinvertebrates traits. Life-history strategies.

Species traits are related to differences in the environmental conditions where species live so they provide valuable ecological information as they allow linking patterns and processes (Statzner et al., 2004). In addition, species belonging to different groups got different adaptations for the same ecological conditions because evolution is also set by constraints of their building plan (Felsentein, 1985).

Life-history strategies are sets of co-evolved traits which enable species to deal with a range of ecological problems. Moreover, these strategies may be based not just in their adaptations and traits but also in the ability of an organism to handle with temporal and spatial variations in ecosystems (Verberk et al., 2008).

They are useful to explain the differences in species assemblages, either between locations or in different periods; compare waterbodies very far apart which have different span distribution or pool of species; and simplify complex biodiverse assemblages into meaningful relationships (Verberk et al., 2008).

There are four main domains of traits that are interrelated: reproduction, development, dispersal and synchronization (Siepel, 1994).

- Reproduction: Principally related to egg size, egg number, brood care and how reproductive investment is distributed over clutches. These characteristics, in turn, can be distributed in two axes: *per capita* investment and investment in adult longevity. At one end there are semelparous species, which are species that usually got low longevity and high reproductive effort (Stearns, 1976). At the other end, there are iteroparous species, which performs oviposition several times throughout the seasons. Furthermore, species may have two different types of reproduction: sexual and asexual.

- Development: In freshwater, the principal traits of the macroinvertebrate species are development time, growth rate, body size and adaptive morphology and physiology. There is a trade-off between body size and development (Abrams et al., 1996): As a general rule, the species that devote more resources to development spend less time on it, generating small individuals with early maturation; on the other hand, species that invest more resources to growth require more growth time and give large individuals of late maturation (Verberk et al., 2008).
  In terms of adaptive morphology, species capable of tolerating adverse conditions, such as periods with little available food or unfavorable abiotic conditions (eg high salinity), have relatively high development times (Tessier & Woodruff, 2002). Dispersal capacities may also be related with adverse conditions during juvenile development (Van Schaick Zillesen & Brunsting, 1984).
  Some examples of morphology and physiology adaptations related to feeding are storage organs or long pointed mandibles for piercing the prey. Adaptations related to respiration are also important, such as impermeability of the cuticle or the presence of hemoglobin in the blood of some aquatic larvae (Verberk et al., 2008).

- Dispersal: The mode of dispersal of freshwater invertebrates is mainly conditioned by the body plan. It can be active or passive transport or a combination of both (eg. Species capable of flying can cover larger distance by anemochory). With most insects being capable to flying, in many aquatic insects this capacity has been reduced to varying degrees (Verberk et al., 2008). Dispersion by waterfowl is very important in aquatic organisms (Figuerola & Green, 2002).

- Synchronization: Refers to timing of development, reproduction or dispersal. It is strongly related to other species traits as adult life span, development time and number of generations per year (voltanism).
  There are two mechanisms by which organisms reduce their activity to survive during environmental adverse periods such as drought or lack of food, or non-environmental conditions, as mating with conspecifics or predator satiation. First one is quiescence, a flexible mechanism in which animals show low activity in response to a local adverse situation. The other one is diapause, a more rigid mechanism where periods of low activity correspond to predictable periods of extremely harsh conditions (ice sheets in winter or droughts in summer), which usually occurs in resistant states as eggs or pupas (Sota & Mogi, 1992).
  Synchronization mechanisms are especially important in species with a short adult live because it increases the chances of survival (for example find a mate) (Verberk et al., 2008).

Species traits should be seen as a complex set of characteristics developed for adaptation, or what is the same, as a life-story strategy. For example, iteroparous species tend to have a longer adult live, so they invest more energy in adult body size and flying capacity. Active dispersal allows species to choose more suitable places for oviposition (Verberk et al., 2008).

In the Canary Islands, the colonizing species had to adapt to the currents of the archipelago, characterized by a high seasonality in the flow. That is why freshwater invertebrates usually present a rapid development and some stage resistant to drought (Poff and Ward, 1989).

1.2. Freshwater ecosystems

1.2.1. Characteristics

Freshwater ecosystems are hotspots for biodiversity (Strayer and Dungeon, 2010). It is estimated that they contain about 10% of the fauna species and one third of vertebrates, (Dudgeon et al, 2006) representing only about 0.8% of the Earth surface and just containing around 0.01% the worlds water (Gleick, 1996). These estimates take into account, above all, species at the macro-biological level, meanwhile the richness of species of the freshwater fungi and microorganisms has been underestimated (Gessner and Vann Ryckegem, 2003). Freshwater ecosystem diversity includes surface waters (lotic and lentic), subsurface streams (hyporheic and phreatic), riparian systems and the ecotones between them such as springs (Ward & Tockner, 2002). This paper has mainly focused on some of the surface freshwater streams in the Canary Islands and Madeira.

Natural freshwater ecosystems are marked by complex relationships between surface water, groundwater and riparian systems resulting in extraordinary environmental heterogeneity (Ward, 1989).

Factors which influence biodiversity in freshwater ecosystems are ecological and evolutionary: evolutionary speed, geographic area, interspecific interactions, ambient energy, productivity and disturbance (Currie, 1991). These factors are related in different ways resulting in different levels of biodiversity: more time and faster evolution result in greater biodiversity; large and complex areas have more niches which can cause more biodiversity; bigger ecosystem productivity and ambient energy give a bigger number of species (Geist, 2011) and; moderate disturbance by flood events may be crucial for the functional diversity of bed substratum (Geist and Auerswald, 2007). It is important to keep in mind that high biodiversity is not always desirable in conservation when it is given by non-specialized species (Geist et al., 2006).

Macaronesian lotic systems are characterized by low spatial variation. The currents are short and narrow, most of them do not exceed 10 km, and usually decrease dramatically in height over a relatively short distance. The current is highly seasonal and the substrates comprise a mixture of pebbles, sand and gravel (Hughes, 2010).

Madicolous habitats, those consisting of continuously irrigated vertical stone walls, are common in the Canary Islands and Madeira. The invertebrates associated with these ecosystems present high levels of endemicity (Hughes and Malmqvist, 2005).

Due to the differences between continental and island streams, Lüderitz et al. (2010) have created an assessment system for the Canary Islands to evaluate the quality of their currents. It is based on the presence and distribution of aquatic invertebrates and improved by hydromorphological parameters.

First, it is necessary to know a reference condition. The species that live in these ecosystems, together with their hydromorphological conditions, reflect the state of the currents with little or no human influence.

The specific assessment uses five parameters, each of which is multiplied by a factor between 1 and 3 depending on the importance of the parameter:

- Water quality (SI): It is determined by organic contamination as measured by the saprobiotic index.

- Diversity (Di): It is calculated by the Shannon-Wiener index. Expresses the percentage of species present in a stream in relation to the total number of species found on the island.

- Degree of naturalness (NN): It is the sum of the sensitive species, which are those that can only live in very well preserved habitats.

- Refugee function (ES): Expressed as the number of endemic species.

- Hydromorphology (HM): It is the sum of physical characteristics of a water body. This assessment has been developed by adapting and calibrating the Lawa (2000) mapping method together with the suggestions of Raven et al. (2002) and Kumm (2008). It takes into account four zones (river bottom, bank, surroundings and water) each of which is characterized by seven main parameters. All these parameters are measured with a value from 1 to 7, with 1 being the condition of the reference current and 7 being totally changed.

The use of these parameters serves to calculate the Ecological Integrity (EI) of the currents, a very useful tool to compare the conservation status of different streams.

$$EI = \frac{Dix2 + NNx3 + ESx3 + HMx1 + SIx1}{10}$$

1.2.2. State and threats of freshwater ecosystems

Freshwater is a resource for humans that may be extracted, contaminated, contained and diverted, the extreme vulnerability of these ecosystems is a fact that reflects it (Geist, 2011). Studies conducted in 139 of the largest rivers in North America, Mexico, Europe and the former Soviet Union estimates that a 77% is strongly or moderately affected by fragmentation of the river channels by dams (Dynesius and Nilsson, 1994).

The number of freshwater species in the oceanic islands compared to the mainland or other major islands such as the British Isles, is quite small, as is the number of the currents themselves. However, the islands usually contain a considerable number of endemic species and subspecies, which are highly sensitive to the disappearance of natural water currents (Lüderitz el al., 2010).

Macaronesian freshwater ecosystems are particularly sensitive because of their high conservation value, determined by a large number of endemisms and for the inherent fragility of island ecosystems. In the Canary Islands the decrease in the number of natural perennial streams makes that freshwater macroinvertebrates are among the fauna most threatened by the disappearance of natural ecosystems and the inability of this species to adapt to new semi-natural and artificial habitats (Malmqvist et al., 1995). In the archipelago there are barely left a dozen of permanent stream currents, some of them with seasonal droughts**.** Between 1933 and 1973, the number of perennial streams in Gran Canaria has decreased from 285 to just 20 and this number is continuing to fall. The situation in Tenerife is not much different where there are currently less than 10 documented permanent currents (Lüderitz et al, 2016). Although, the small streams of the islands support a surprisingly rich and diverse fauna (Malmqvist et al., 1993). Only in the island of Tenerife, there are about 170 known freshwater arthropods, 17 of which are endemic to the island (Malmqvist et al., 1995). The Madeira region is much wetter and therefore has a greater number of streams, it comprises approximately 126 catchments and 200 streams (Hughes, 2006).

The main threats to freshwater habitats in the Canary Islands and Madeira can be grouped as follows:

- Decrease in forested areas: Deforestation has resulted in a decline in water capitation due to horizontal rainfall (Bramwell and Bramwell, 1974).

- Water diversion: Caused by the deviation of water from the source for agriculture in both archipelagos and also for hydroelectric production in Madeira. Historically this has been done through the so-called "*levadas*" in Madeira, or "*canales*" in the Canary Islands - narrow channels dug into the rock and designed to capture and carry the water drained by the island-. It seriously affects the integrity of the ecosystems and the instream regime flow (Malmqvist et al, 1995).

- Overexploitation of groundwater reservoirs: The water level has dropped so many wells, springs and galleries have dried up. From 70´s, despite the increase in performed length, the water production began it decrease. New industrial water production techniques such as desalination and purification open up new possibilities for aquifer recharge and recovery of the water table. These techniques are increasingly cheaper and allow dependence on groundwater to be reduced; however, it should not be forgotten that these processes involve energy consumption.

- Extensive habitat destruction: As a result of the development of agriculture and the increase in space required for human activities, freshwater habitats are affected at all levels (Hughes, 2005).

- Climate change: There seems to be a trend towards a decrease in rainfall, which naturally leads to a drop in the water available in the streams (Hughes, 2005).

- Destruction of riparian areas and extraction of substrate: Mainly affects low levels (Hughes, 2003).

The future of species depends on factors such as population size, distribution patterns, rarity and changes in water use (Malmqvist et al., 1995).

Endemic species tend to prefer those habitats where the current is constant and permanent, accordingly the disappearance or decreasing of permanent currents can lead to the extinctions on endemic species (Lüderitz et al, 2016). Some of these species might be able to adapt and survive in the artificial habitats, however, there is a tendency in the Canary Islands to cover the channels, which prevents adaptation from occurring. On the contrary, in Madeira there is a tendency to leave the channels or "*levadas"* open, possibly preventing the extinction of many freshwater invertebrates (Malmqvist, et al, 1995).

1.2.3. Conservation of freshwater ecosystems

The key for developing integrative concepts in aquatic ecology and conservation is an understanding of the factors which govern biodiversity. This requires a knowledge of biotic and abiotic factors and the identification of functional roles and processes in habitats (Geist, 2011). Terrestrial freshwater conservation that only protects isolated high quality areas will probably fail for freshwater ecosystems (Boon, 2000).

A successful restoration requires a holistic management of the environment that takes into account all levels of biodiversity organization. IFECB (Integrative Freshwater Ecology and Biodiversity Conservation) approaches focuses on most important species (umbrella, keystone, indicator or flagship species) and major anthropogenic impacts (usually dam construction) (Geist, 2011). In spite of this, the IFEBC concept not only target the conservation of key species, but also integrates into the conservation plan the different levels of organization, including from molecular biodiversity to the ecosystem biodiversity. In this approach, it attempts to develop holistic ecosystem management plans, which also take into account functional biodiversity in order to devise successful conservation plans. It addresses the processes that govern the dynamics of biodiversity and productivity and the temporal and spatial distribution of species (Geist, 2011).

An example of how habitat conservation must go beyond the site itself is the importance of the Laurisilva forests for the maintenance of freshwater ecosystems. These relict forests from the Tertiary period are fundamental for the hydrological cycle of the Canary Islands and Madeira, and therefore, they are vital for the protection of freshwater habitats and their species (Hughes, 2005). Compared to 500 years ago, the extension of Laurisilva remaining in Madeira is 20%, in Tenerife 10% and in Gran Canaria only 1% (Bramwell, 1990).

Developing holistic conservation plans requires research and understanding of ecosystems. It is essential to know the temporal and spatial variation of species in habitats, the problem is that the only series of long-term data are usually physical-chemists. The incorporation of genetic information is also essential. Understanding spatial and temporal genetic diversity allows us to understand evolutionary processes, pathways of colonization, life strategies, interactions between organisms and the interaction between genes and environmental factors. When setting conservation priorities, genetic information is a great tool for determining priority populations or retaining as much genetic diversity as possible. Again, the problem is that freshwater species are generally poorly studied in the genetic field. Creating sampling methods with this comprehensive approach requires establishing a database of microsatellites and deriving management techniques based on genetic information.

1.3. Legislation for freshwater conservation

Directive 2000/60/CE from 23th October 2000, Water Frame Directive or WFA from this point on, establishes a community framework for action on water policy in the European Union. The main approaches contemplated in this policy are environmental and sustainable management and use of water. To avoid problems related to administrative or political boundaries, it establishes that the basic unit of action is the river basin.

It defines both the ecological objectives of conservation and the methods of assessment of surface freshwater bodies in Europe. To this end, it requires the member states: to identify the types of surface water in their territory, the reference conditions and to establish five categories of ecological quality (bad, low, moderate, good and high). The main objective is that all surface water bodies had to achieve at least "good" status by 2015. The ecological status is determined by studying parameters that measure changes in the structure and function of biological elements in comparison to those found in reference habitats.

Member States and their communities have transposed the WFD through their own legislation. In the Canary Islands, the decree 165/2015 of July 3rd, approves the instruction of hydrological planning for the intracommunity hydrographic demarcations of the autonomous community of the Canary Islands, has the purpose of concluding the process of transposition of the WFD in our autonomous community. In the case of Portugal, Decree-Law 112/2002 of 17 April establishes that the state must draw up a National Water Plan or NWP, documents that define a strategy for the integrated management of water bodies. The community of Madeira has its own plan: Regional Water Plan of Madeira or PRAM.

To cover a territory as large as the European Union and its islands, it was necessary to compartmentalize the land, so 25 ecoregions were established in the WFD (Figure 1). Madeira and the Canary Islands constitute, together with the Azores, the Iberian Peninsula and the Balearic Islands, the ecoregion number 1.

It has been common in Europe to develop similar conservation projects and assessment methods between regions that share ecosystemic characteristics and/or the disturbances they suffer. This has not been the case for the Macaronesian archipelagos, the ultra-peripheral territories that are geologically isolated and economically underdeveloped in relation to other European territories, causing, among other issues, a huge delay in the implementation of the WFD in this areas (Hughes, 2005).

We can find a clear example in the hydrographic plans of the Canary Islands, legal-technical documents that arise both from the DMA requirement and from the Canary Islands Water Law (Decree 319/1996). In the hydrographic plans of the four Canary Islands contemplated in this study (Tenerife, Gran Canaria, La Gomera and La Palma), with regard to the characterization of the surface water bodies, they conclude that:

"The classification criteria set out in the WFD and, in addition, in the HPI, for epicontinental surface waters, are NOT APPLICABLE in this demarcation, since they do not there are river courses that are comparable to permanent, intermittent or strong rivers seasonal, only sporadic surface flows generated under conditions adverse weather events, such as strong storm events, which are very discontinuous in the time and space, which means that for long periods of time the network of drainage is dry."

This implies that although the WFD requires its member states to conserve their freshwater bodies, in the Canaries they are not even considered for study because they do not fall within the criteria defined either in the general criteria or in those of their eco-region. This case is repeated in many of the small streams of Madeira.

These reasons would justify the creation of a differentiated eco-region for the Macaronesian archipelagos (Hughes, 2010). In fact, there are already researchers who have realized this need and have developed specific assessment methods for the islands, such as the Madeiran Biotic Index or MBI (Hughes et al., 2003) or a system for assessing the fauna, chemical quality and hydromorphology of currents in the Canary Islands developed by Lüderitz et al., 2010 and explained above (1.2.1. Freshwater ecosystems, Characteristics).

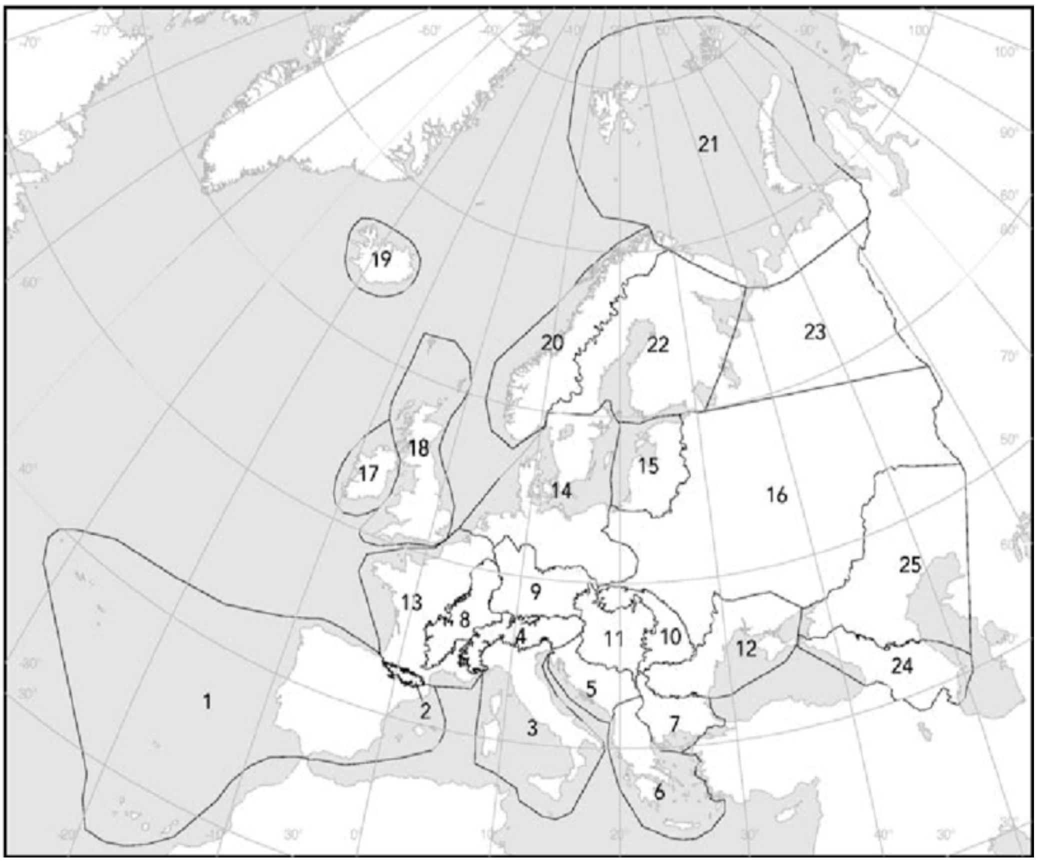

Figure 1. Europe's WFD Ecoregion delineations showing 25 ecoregion delineations (as in the official WFD Map A, Annnex XI). Map adapted from the free access EEA ecoregion map (EEA, Copenhagen, 2004 http://www.eea.europa.eu)

1.4. Objectives

- To make an approximation to the current state of the freshwater macroinvertebrate communities within the freshwater currents of the Canary Islands and Madeira island.
- To find out if there are similarities in the freshwater currents between the archipelagos.

2. Material and methods

2.1. Study area: The Canary Islands and Madeira

The data for this study was sampled in the Canary Islands and Madeira. Both of them are volcanic archipelagos located at North Atlantic Ocean. They are part of Macaronesia, a term coined by P.B. Webb in 1850 that now includes the two archipelagos mentioned, plus the Azores (more questionably), Cape Verde and SW Morocco. There are scattered between parallels 15° and 40° N and the meridians 13° and 32° W that share climatic, floristic, zoological and geological characteristics. It is considered a distinct phyto-geographical region within Holarctic Kingdom. These archipelagos are home to some of the preserved Laurisilva areas in the world, Tertiary relic forests with a rich associated invertebrate's biodiversity, including freshwater macroinvertebrates.

All islands of Macaronesia are truly oceanic -those that have formed by accumulative volcanic eruptions on the ocean floor and have never been connected to continental landmasses-. They range in relief from low-lying to mountainous or high (Howarth and Ramsay, 1991). High islands use to have an important altitude habitat zonation and higher rainfall levels and, as a result, a wide environmental variety and great biodiversity within small areas. (Sadler, 1999). Island age is also a strong influence in water resources on oceanic islands. Fresh lava is highly permeable but over the time this permeability and porosity decreases. As a result, young islands use to contain large reserves of freshwater, but residence time of groundwater in fractured aquifers is relatively short (maybe from decades to centuries) (Whittaker & Fernandez-Palacios, 2007).
The data for this study have been taken in four of the Canary Islands (Tenerife, La Gomera, La Palma and Gran Canaria) and Madeira Island.

2.1.1. The Canary Islands.

Is the largest (7450 km^2) and highest (3718 m a.s.l) of the Macaronesia archipelagos. It is formed by seven major islands and seven islets, located between parallels 27° and 29° N and the meridians 13° and 18° W. Major islands could be divided in three groups: Eastern islands, Lanzarote and Fuerteventura; central islands, Gran Canaria and Tenerife and; western islands: La Gomera, El Hierro and La Palma.

2.1.1.1. Geology.

Canary Islands are the result of various geological episodes. There are a few theories about the origin, but the most accepted is that of the hot spot (Carracedo & Day, 2002).

The beginning of the formation of the Canary Islands differs according to the evidence. K-Ar dating suggest that their origin dates from 36 million years ago (Abdel-Monem et al., 1972) to 39 million years (Coello et al., 1992). Radiometric evidence suggest that they are much older: 70-80 million years ago (Balogh et al., 1999).

As for the age of emergence of the islands, it follows a NE- SW sequential pattern: Fuerteventura 22 My (Carracedo & Day, 2002), Lanzarote 15,5 My (Coello et al., 1992), Gran Canaria 14-15 My (Schmincke et al, 1997), Tenerife 11,9 My (Guillou et al., 2004), La Gomera 11-12 My (Cantagrel et al., 1984), La Palma 1,8 My (Carracedo & Day, 2002), and El Hierro 1,2 My (Carracedo et al., 2002).

Generally, geological history of Canary Islands is characterized by alternation of geological activity, quiescence and erosion processes, gravitational slides and recent eruptions (Carracedo & Day, 2002). This geological events have set up orography of the islands over million years. As a result, a great number of environmental gradients exist (Whittaker and Fernandez-Palacios, 2007).

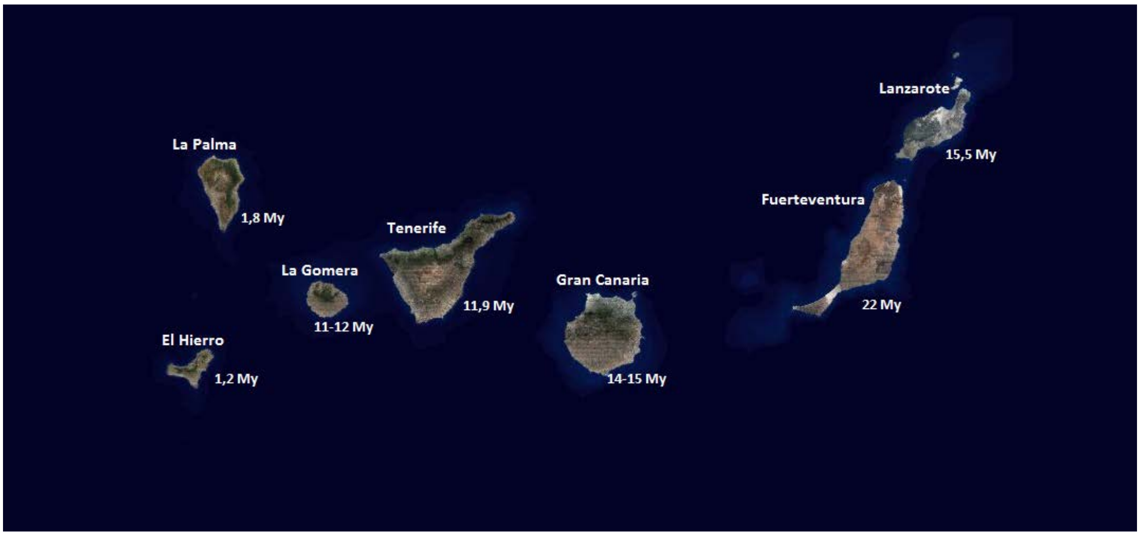

Figure 2. Map of the Canary Islands indicating the geological ages of the islands

2.1.1.2. Climatology

The climate of the Canary Islands is basically a Mediterranean one but is influenced by a series of modifying factors. These are the close proximity of eastern islands to the coast of North Africa and the Sahara Desert, the oceanic position of the western islands on the edge of the North East Trade Wind system and the high altitude of the peaks of western and central islands. The thermotypes that can be found on the island range from inframediterranean to oromediterranean and the ombrotypes from hyperarid to humid.

The coolest month tends to be February, and the hottest period is on summer, with an oscillation between 20°C and 25°C for western islands and up to 35°C on Lanzarote and Fuerteventura, the two semi-deserted eastern islands. Differences between North and South in the larger islands are over 10°C due to the Trade Wind effect. The North East Trade Winds bring in moisture from its flows over the Canary Current, where it is forced to rise by the mountain barriers of the western and central islands; then it is cooled and forms a zone of precipitation at about 800 to 1500 meters. This causes a more or less persistent cloud-layer at this level on the north side of all the western and central islands and provides conditions for the vegetation development. In the south side of these high islands, there is usually a rain shadow so the precipitation is much lower. Generally, the precipitation levels are higher the further western one goes on the archipelago (Bramwell and Bramwell, 1974): La Palma is the wettest island (740 mm/year), and as opposed, Lanzarote and Fuerteventura are extremely dry (< 150 mm/year). The dryness of eastern islands is because they are too low to intercept the Trade Winds and also due to the hot winds coming from the Sahara Desert.

2.1.1.3. Water resources

Water in the Canary Islands is a scarce resource that has conditioned the human development of the archipelago. There are mainly three types of water resources: Freshwater surface streams, groundwater and industrial production water.

Because of the small territory and the lack of rainfall, there are no rivers, just a very few streams that carry water throughout the year, such as El Cedro in La Gomera or Barranco del Infierno in Tenerife. The lack of large rivers makes the surface water an unimportant resource for human supply, forcing it to depend on other sources.

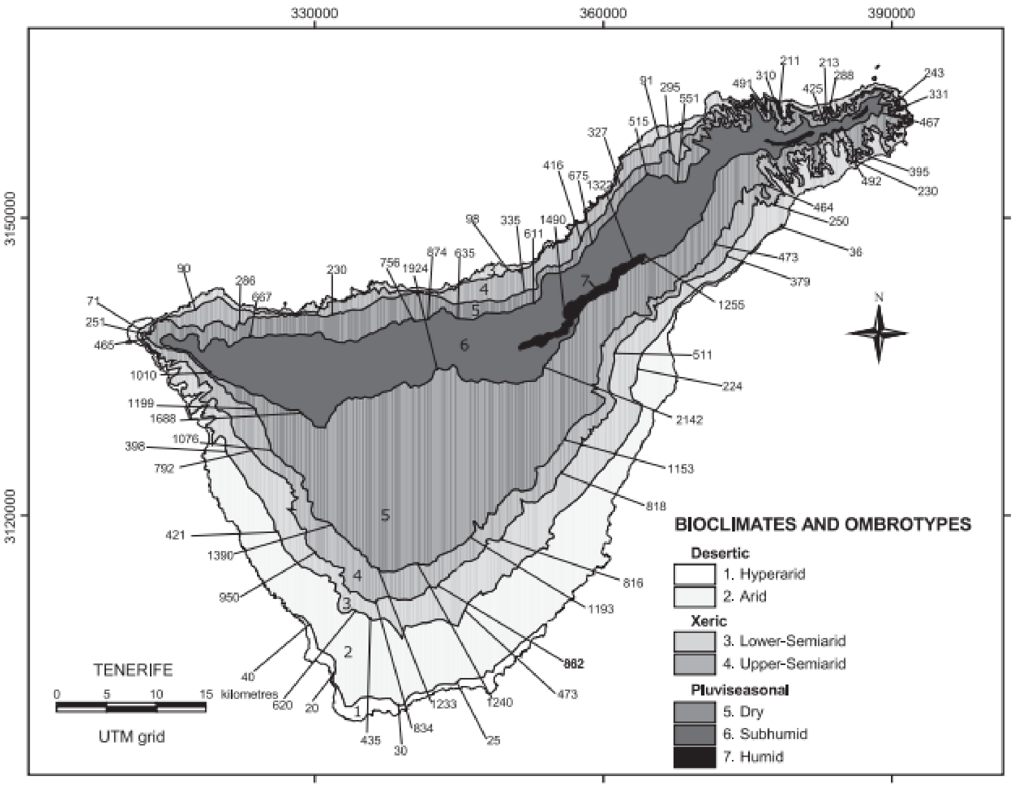

Figure 3. Ombrotype and bioclimate map of Tenerife (extracted from Del-Arco, et al., (2006))

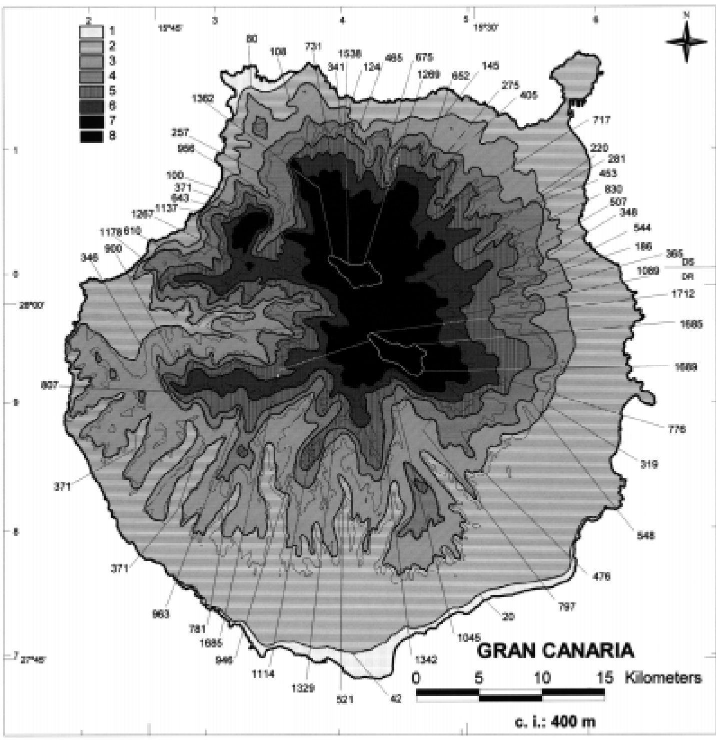

Figure 4. Ombrotype map of Gran Canaria. **Legend: 1:** Hyperarid; **2:** Arid; **3:** Lower-semiard; **4:** Upper-semiard; **5:** Lower-dry; **6:** Upper-dry; **7:** Sub-humid; **8:** Humid (Extracted from Del-Arco et al., (2002)).

As for its hydrography, the center and western islands are deeply excavated by a radial network of ravines that start on the central areas of the summits and head towards the coast. The coastline is irregular, large cliffs are common but wide beaches and soft platforms can also be found in eastern and southern areas (Plan hidrológico de Gran Canaria, 2017).

The Canary Islands have been a pioneer in the implementation of water extraction techniques. The ways to capture or retain water have been very diverse, historically the most important ones have been the springs, wells and galleries, and recently desalination and depuration are also used (Recursos hídricos de Canarias, 2015). The introduction of these techniques has allowed people to no longer depend on the water cycle, leading to greater security and stability but also to the commercialization and privatization of a historically public resource.

Groundwater comes from aquifers. Water can flow out naturally by springs or artificially by galleries and wells. There are approximately 1600 galleries with more than 2000 km drilled. In last decades, the water table has dropped because overexploitation (the water that is extracted exceeds the amount that infiltrates by precipitation). From the 70s, despite the increase in perforated length, the water production began its decrease (Recursos hídricos en Canarias, 2015).

2.1.2. Madeiran archipelago.

Madeira archipelago is located at North Atlantic, between parallels 30° 01´ and 33° 08´ N and meridians 15° 51´ and 17°16´ W. With a total area of 796,77 km^2 is constituted by Madeira (736,75 km^2), the biggest island that gives its name to the archipelago; Porto Santo with an area of 42 km^2; Desertas (Deserta Grande, Bugio e Ilhéu Chão) with 14,23 km^2 of total area and Selvagens (Selvagem Grande e Selvagem Pequena) with an extension of 3,62 km^2. The island of Madeira is located approximately 700 km west of the northwest coast of Africa and 800 km from Portugal.

All data contemplated in this study were taken on Madeira Island.

2.1.2.1. Geology.

The island of Madeira was generated from Post-Miocene times until 6000-7000 years B.C (Geldmacher et al., 2000) because intraplate oceanic magmatism activity. As Canary Islands, is a truly oceanic island and the most consensual origin is a hot spot. The island is about 15 km long and 23 km wide.

It is located on the African plate forming a shield 5.5 km high, of which approximately one third stands out. The relief of the island is much accentuated, about 65% of the island has slopes greater than 25% (Recursos hídricos da Ilha da Madeira, 2003). Marked orographic relief produces considerable climatic diversity (Sjögren , 1974).

From the sea the island looks like a flat shield whose edges have been eroded by the waves (Recursos hidricos da Ilha da Madeira, 2003). On the coast, cliffs several hundred meters high are common, although the dissymmetry between the north and the south is clear as the withdrawal of the cliffs has been greater in the north due to the strong hydraulic pressure (Recursos hidricos da Ilha da Madeira, 2003).

The radial drainage pattern of Madeira is typical of oceanic islands as streams flows away from the island central peaks. This high energy river system are short and step (Hughes, 2003), with coarse unstable substrates comprising bed rock, rolled boulders, cobbles and gravels.

2.1.2.2. Climatology

The predominant climate in Madeira is temperate Mediterranean. Termothypes can be found from temperate hyper-oceanic to Mediterranean xeric oceanic and the ombrotypes range from humid to upper semi-arid. Due to its geographic position and mountainous topography, there is a predominance of mild and pleasant temperatures. It is mainly conditioned by the subtropical anticyclone of the Azores, which transports tropical air masses, especially at the oriental part where the subsidence phenomena is frequent. The Trade winds predominate throughout the year.

An important factor for the climate of the island is the presence of a cloud cover which is responsible of horizontal precipitation, a resource that offers high water potential (Prada and Silva, 2001). Under an individual of *Erica arborea* was collected three and a half times more water than in the average annual rainfall of the area (Plan hídrico da Ilha da Madeira, 2003).

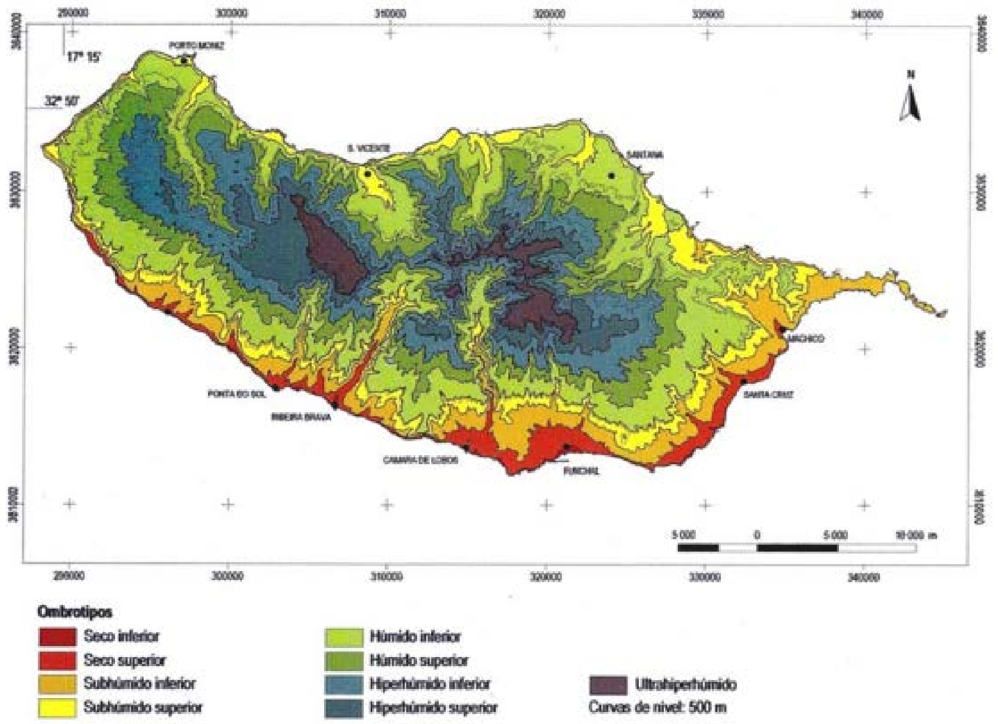

Figure 5. Ombrotype map from Madeira (Extracted from: Capelo et al., 2004)

2.1.2.3. Water resources

The assessment of water resources in Madeira is complicated by several factors: lack of hydrological data, an extensive network of “*levadas*” or man-made canals, underground circulation (Gaspar and Portela, 2002) and landslides that break the stations during the winter and their subsequent abandonment (Recursos hidricos da Ilha da Madeira, 2003).

Groundwater is the main source of supply, during the summer it is the only one while in winter the surface water is also used. The activities for the exploitation of groundwater resemble those of the Canary Islands: galleries, tunnels, wells and springs. Groundwater is vital not only as drinking water and for irrigation, but also for electricity generation. Approximately 20-25% of the island's electrical energy is obtained in this way.

The galleries and tunnels are horizontal catchments, built in the highest parts of the islands to allow water to circulate by gravity. The water from the springs is used through an extensive network of "*levadas*" with an extension of approximately 1000 km (Recursos hídricos da Ilha da Madeira, 2003.

The total volume of extracted water for domestic and industrial use, irrigation and electrical power corresponds to 185 Million per year. Rainfall is not sufficient to maintain the actual balance between recharge and discharge. Taking only this data, the evaluation of groundwater resources is undervalued. This suggests that fog contribution is vital for the maintenance of groundwater resources, but deeper studies are necessary (Recursos hídricos da Ilha da Madeira, 2003).

2.2. Sampling sites.

In the Canary Islands, from November 2006 until November 2018, 34 samples were taken in 17 locations. The ecosystems studied have been natural habitats of running water. All spots were sampled during two periods: autumn and spring. Macroinvertebrates were sampled in 2 places from Gran Canaria, 8 in La Gomera, 5 in Tenerife and 2 in La Palma (Table 1). The characteristics of conservation differ between sampling sites. Four plots from La Gomera are especially well preserved. These permanent streams are located into or near Garajonay National Park, one of the best preserved relicts of Laurisilva worldwide, making possible the presence of undisturbed permanent streams (Lüderitz et al., 2010). These places are of special interest because they can be used as reference ecosystem.

To compare the species found in the 1990s with those data taken by Lüderitz et al. during the 2000s and 2010s, data from Nilsson et al., 1998 and Malmqvist et al., 1995 have been analyzed. In the work carried out by Nilsson et al. in 1998, freshwater invertebrates were collected in 11 streams on the island of Gran Canaria during 1994 and 1995, and some of them only had water for part of the year. The data presented on the basis of the work of Malmqvist et al., 1993, are collect joint information from 15 Tenerife island currents in addition to 42 other freshwater habitat sampling points (madicolous habitats, man-made channels, disconnected pools, ponds, reservoirs and springs).

On the island of Madeira, from October 2017 until February 2018, 36 samples were taken in 18 spots (Table 2). Most of the samples were taken twice, during spring and autumn. The majority of the habitats studied were freshwater streams, although some man-made channels (13_1: Levadas), one pond (11_1: Botanical Garden at Funchal) and one semi-natural pool (12_1: Caldeirão Verde, pool in waterfall) were also sampled. The height difference of the samples is more noticeable in this case. Like in the Canary Islands, the status of conservation varies depending on the site, although areas located more than 500 m a.s.l. are less affected by anthropization (Hughes, 2003).

For both archipelagos, macroinvertebrates were sampled using a hand-net with a mesh size of 0.5 mm, separated into a tray and fixed in 70% ethanol alcohol. It was kept in mind to include all microhabitats: bed substrates, the bottom of stones and rocks, decaying wood, submerged and emergent aquatic plants). The length of the samplings sites were around 100 meters. Once in the laboratory, the invertebrates were identified using a stereoscopic magnifier, according to Balke et al. (1990), Bellman (1993), Freude et al. (1971/1979), Müoller-Libenau (1969), Nybom (1948), Machado (1987), Crosskey (1988) and Waringer and Graf (1997). The material from captures has been obtained by conducting a stratified survey, looking for different habitats within each sampling station.

Code	Island	Location	Major altitude (m)	Date	Site characteristics
GC1	Gran Canaria	Tejeda	1200	Mar 2009 Nov 2010	Near-natural surroundings and hydromorphology, but dry and gutted by fire in October 2017
GC2	Gran Canaria	Barranco de Cernícalos	450	Mar 2009 Nov 2010	Near-natural surroundings and hydromorphology, but dry and gutted by fire in October 2017
G1	La Gomera	La Laja into National Park	590	Nov 2006 Mar 2013	Into Garajonay National Park, pine forest, supplies a reservoir.
G2	La Gomera	La Laja outside National Park	450	Mar 2006 Nov 2013 Nov 2018	Several small dams, extensive agriculture.
G3	La Gomera	Chejelipes	250	Mar 2006 Nov 2013	Several dams and reservoir upstream.
G4	La Gomera	El Cedro into National Park	910	Nov 2006 Mar 2013 Nov 2018	Into Garajonay National Park, laurel forest, with natural morphology for 2.2 km. Serve as reference condition.
G5	La Gomera	El Cedro outside National Park	540	Nov 2006 Mar 2013	Downstream of a waterfall. Influenced by agriculture, water scarcity.
G6	La Gomera	Barranco del Agua	410	Nov 2006 Mar 2013	Influenced by agriculture, water scarcity.
G7	La Gomera	Meriga	970	Nov 2006 Mar 2013	Small stream in Garajonay National Park, laurel forest; downstream of the site pipping of the whole stream.
G8	La Gomera	El Rejo	650	Nov 2006 Mar 2013	Small stream in Garajonay National Park, laurel forest.
TF1	Tenerife	Afur	300	Nov 2006 Mar 2013 Nov 2018	Influenced by agriculture, low flow rates.
TF2	Tenerife	Igueste	400	Nov 2006 Mar 2013	Influenced by extensive agriculture, water scarcity and low flow rates.
TF3	Tenerife	Barranco del Infierno	500	Nov 2006 Mar 2006 Nov 2013	In the nature reserve, natural morphology over a flowing distance of almost 1 km, than a total canalization. Serve as reference condition.
TF4	Tenerife	Masca	450	Nov 2006 Mar 2024	Intensive tourism, water scarcity.
TF5	Tenerife	El Río	1500	Nov 2006 Mar 2013	Natural morphology, serve as reference condition.
TF6	La Palma	Caldera de Taburiente	450	Mar 2008 Nov 2008	Influenced by tourism and agriculture, water scarcity. Frequent flooding.
TF7	La Palma	Corderos	1900	Mar 2008 Nov 2008	Influenced by agriculture, water scarcity.

Table 2. Characteristics of the sampling sites in the Canary Islands

Site	Name/Location	Major altitude (m)	Date	Type of ecosystem
1_1	Ribeira da Janela low	70	Oct 2017 Feb 2018	Stream-flow
1_2	Ribeira da Janela up	1200	Oct 2017 Feb 2018	Stream-flow
2_1	Ribeira da Cova Grande W	1200	Oct 2017 Feb 2018	Stream-flow
2_2	Ribeira da Cova Grande E	1200	Oct 2017 Feb 2018	Stream-flow
3_1	Ribeira de Tabua low	150	Feb 2018 Oct 2018	Stream-flow
3_2	Ribeira da Tabua up	800	Feb 2018 Oct 2018	Stream-flow
4_1	Ribeira da Silveira (Queimadas)	900	Oct 2017 Feb 2018	Stream-flow
5_1	Ribeira da Cidrao, Curral das Freiras	800	Oct 2017 Feb 2018	Stream-flow
5_2	Curral das Freiras	1200	Oct 2017 Feb 2018	Stream-flow
6_1	Ribeira Serra da Aqua	200	Oct 2017 Feb 2018	Stream-flow
7_1	Ribeira Sao Vicente	10	Oct 2017 Feb 2018	Stream-flow
8_1	Ribeira da Faial	30	Oct 2017 Feb 2018	Stream-flow
9_1	Ribeira da Funda low	100	Feb 2018 Oct 2018	Stream-flow
9_2	Ribeira da Funda up	900	Feb 2018 Oct 2018	Stream-flow
10_1	Ribeira da Sao Jorge at Ilha	500	Feb 2018 Oct 2018	Stream-flow
11_1	Botanical Garden at Funchal	300	Feb 2018 Oct 2018	Artificial ecosystem: Pond
12_1	Caldeirão Verde, pool in waterfall	950	Feb 2018 Oct 2018	More or less natural ecosystem: Pool
13_1	Levadas	400 – 900	Feb 2018 Oct 2018	Artificial ecosystem: Data from 5 "*levadas*" or canals

Table 3. Characteristics of the sampling sites in Madeira

Figure 6. Map of the sampling points of Tenerife (IDE Canarias, visor Grafcan).

Figure 7. Map of the sampling points of La Palma (IDE Canarias, Visor Grafcan).

Figure 8. Map of the sampling points of Gran Canaria (IDE Canarias, visor Grafcan).

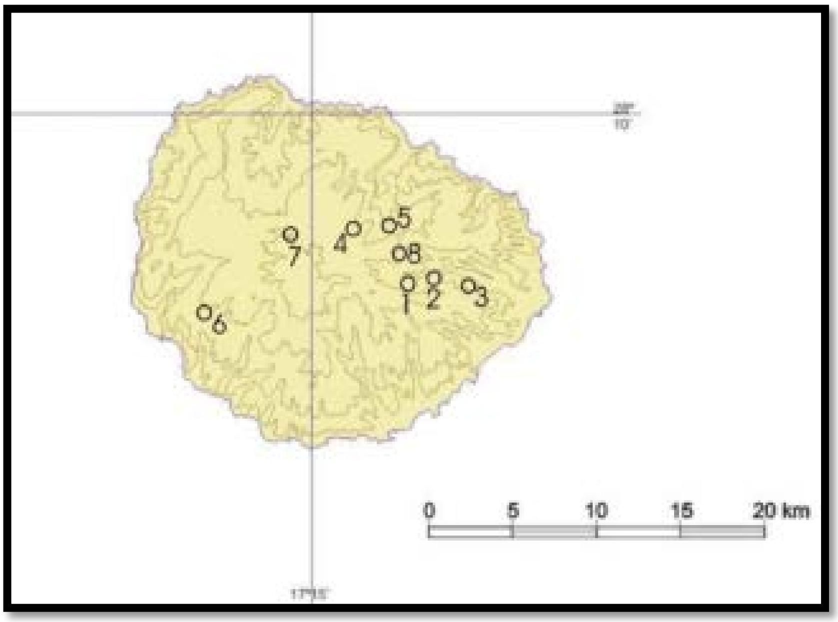

Figure 9. Map of the sampling points of La Gomera (Extracted from: Lüderitz et al., 2010).

Legend: 1: La Laja into National Park; 2: La Laja ouside National Park; 3: Chejelipes; 4: El Cedro (910 m); 5: El Cedro (540 m); 6: Barranco del Agua; 7: Meriga; 8: El Rejo

Figure 10. Map of the sampling points of Madeira (Google Earth).

3. Results

The data obtained for diversity and endemicity in this work are difficult to evaluate as it does not follow a standardized sampling method, the data depend heavily on sampling effort. Moreover, the data series are not large enough to obtain results with statistical power. Despite this, the data on diversity and endemicity by current may be indicative of the state of the ecosystems and suggest possible interesting lines of research, which is why they are collected below.

3.1. The Canary Islands

Without dipterans, since the species of this order have not been identified for not having enough experience with that taxonomic group, a total of 71 species belonging to 12 orders and 34 families have been collected (Annex I). The number of recorded species of each island is 64 for Tenerife, 61 for La Gomera, 29 for La Palma and 34 species for Gran Canaria. The endemic species collected represent 29.2 % of freshwater invertebrate fauna (Table 4).

Coleoptera is the richest group (28 species) followed by Trichoptera (10 species), both with high levels of endemicity. The most diverse family is *Dytiscidae* (Coleoptera) with 14 species, four of which are endemic (Annex I). There are four taxa represented by a single species: *Annelida, Bivalvia, Plathelmyntes* and *Verenoida*. It is remarkable that order *Crustacea* is composed exclusively by endemisms, although only three species where found in the archipelago. Trichoptera also has an impressive level of endemicity (70%) (Table 5).

The most diverse stream is Barranco del Infierno in Tenerife, with 55 species found and 27,3 % endemic, followed by El Cedro in La Gomera, with 52 species of which 36,6 % are endemic. Regarding the level of endemicity, the highest values are found in one stream of La Gomera: Meriga (46.7%); followed by Corderos in La Palma (46.2%) and El Río in Tenerife (45.5%) (Table 6).

	Gran Canaria	La Gomera	Tenerife	La Palma	Canary Islands	Madeira
Number of species	34	61	64	29	71	63
Number of endemisms	10	19	17	8	21	21
% endemisms	29,4	31,1	26,6	27,6	29,6	33,33

Table 4. Diversity and endemicity level by island

Taxonomic group	Madeira		Canary Islands	
	Nº species	**% endemisms**	**Nº species**	**% endemisms**
Annelida	4	0,00	1	0
Crustacea	1	0,00	2	100
Bivalvia	1	0,00	2	0
Coleoptera	18	50,00	28	40
Diptera	3	33,33	-	-
Ephemeroptera	4	50,00	5	40
Gastropoda	7	14,28	5	20
Hemiptera	6	16,67	9	22
Odonata	7	0,00	9	0
Platyhelminthes	1	0,00	1	0
Trichoptera	11	63,64	10	50

Table 5. Level of endemicity for taxonomic groups by archipelago

Of the species sampled, five could be considered to have a very limited distribution as they were only found in one stream: *Coleostoma hispanicum* Küster, 1848; *Gordius aquaticus* Linnaeus, 1758; *Hygrotus musicus* Klug, 1834 *Lepidistoma tenerifensis* Malicky, 1992 and *Orthotrichia angustella* McLachlan, 1865. In addition, five other species were only found in two streams: *Caenis luctuosa* Burmeister, 1839; *Ischnura saharensis* Aguesse, 1968; *Meladema imbricata* Wollaston, 1871 and *Mesovelia vitigera* Horváth, 1895 and *Trithemis arteriosa* Burmeister, 1839 (Anex III).

The biogeographic region of origin of approximately 10% of the species in the Canary Islands has not been identified. For those that have, the main biogeographical region of origin for the species is the Palearctic kingdom (especially Mediterranean). The distribution of almost a third of the species (29.2 %) is limited to the Canary Islands as they are endemic (Figure 8).

Of all the streams sampled, in La Laja and El Cedro, data were taken at two different points, one inside Garajonay National Park and the other outside. In the case of La Laja, the level of endemicity inside Garajonay is approximately 30% while outside, it is almost 10% less. The difference is much more marked in the case of El Rejo, where the section inside the Natural Park has an endemicity of 36.6 %, while outside it is 6.7% (Table 6).

Comparing the data obtained by the sampling of Nilsson et al., 1998 and Malmqvist et al., 1995 with those collected by Lüderitz et al. between the 2000's and the 2010's, there are four species, all of them endemic, that have not been found anymore, and 22 more that were not seen on Tenerife and/or Gran Canaria (Table 8).

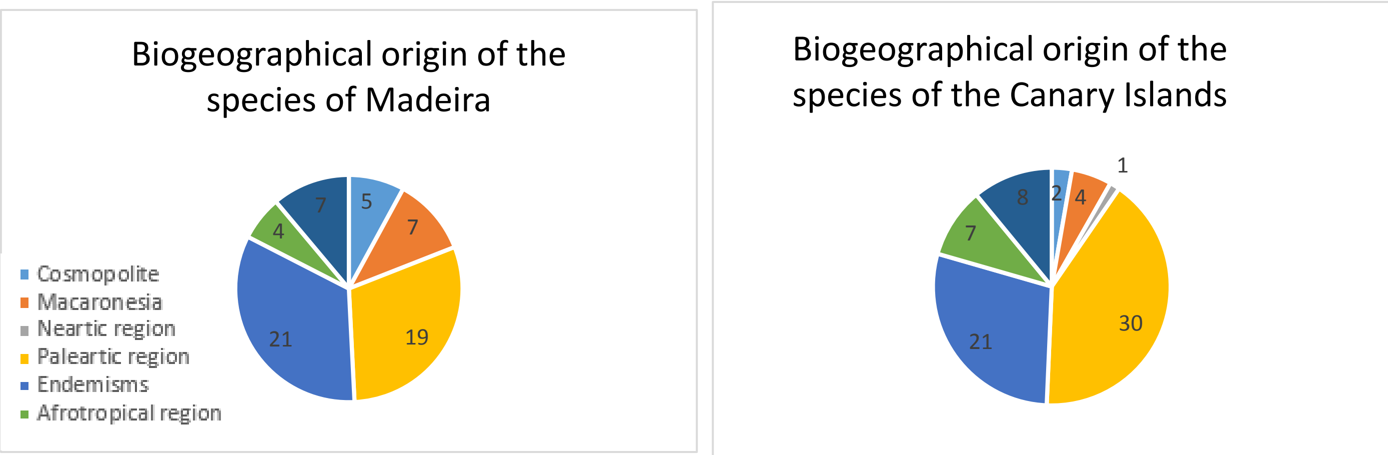

Figure 8. Biogeographical origin of the sampled species.

3.2. Madeira

A total of 63, species, belonging to 16 orders and 33 families have been found. As in the Canary Islands, Coleoptera is the richest group (18) followed by Trichoptera (11) and the most diverse family is *Dytiscidae* (Coleoptera) with 10 species. The most diverse taxa are also those with the highest levels of endemicity, the greatest being Trichoptera (64%) followed by Coleoptera (50%). The percentage of endemisms is significantly high, even more than in the Canary Islands, as it represents one third of the species collected (Table 4).

Bivalvia and Platyhelminthes are groups represented by a single species, in no case was this species endemic. Only three Diptera species were found, despite the fact that they are the group with the highest species representation among freshwater invertebrates (Hughes, 2006) (Table 5). Of all the species, two of those found are categorized as invasive and in both cases are gastropods (Annex II).

Regarding to the biogeographical origin of the species, most of them are endemic and in second place come from the Palaearctic kingdom, which have a greater presence than the Afrotropical, Neartic and Macaronesian species (Figure 8).

Of the species found, 14 were at only one of the sampling points: *Agabus wollastoni* Sharp, 1854; *Anisops debilis canariensis* Noualhier, 1893; *Corixa affinis* Leach, 1817; *Corixa punctata* Illiger, 1807; *Dryops gracilis* Karsch, 1881; *Dryops luridus* Erichson, 1874; *Haliplus lineatocollis suffusus* Wollaston, 1864; *Hydroporus lundbladi* Falkenström, 1938; *Hygrotus confluens* Fabricius, 1787; *Ischnura senegalensis* Rambur, 1942; *Laccobius atricolor* dÓrchymont, 1938; *Microvelia* *gracillima* Reuter, 1883; *Physella acuta* Draparnaud, 1805 and *Zygonyx torridus* Kibry, 1889 (Annex IV).

Six of the currents were in areas with low elevation (<500 m a.s.l.): Ribeira de Funda low, Ribeira da Tabua low, Ribeira da Janela low, Ribeira Serra de Aqua, Ribeira da Faial and Ribeira Sao Vicente. In all cases the level of endemicity is between 10-20%, with the exception of Ribeira da Tabua and Ribeira da Faial which reaches almost a 30%. In any case, in all these streams the endemicity is lower than the average for the island. On the other hand, all those currents located at more than 500 m a.s.l. the endemic species sampled are far more (between 44 and 61%). The streams with the highest levels of endemicity are Ribera da Cova Grande W (53.8%) and Ribera da Cova Grande E (61.1%). Also noteworthy is the percentage of endemisms in Ribeira da Silveira, where half of the species found were endemic (Table 7).

Code	Stream	Major altitude (m a.s.l.)	Date	Number of species	Number of endimisms	% endemisms
GC1	Tejeda	1200	2009-2010	28	8	28,6
GC2	Bco. Cernícalos	450	2009-2010	25	6	24
G1	La Laja into National Park	590	2006-2013-2018	48	13	27,1
G2	La Laja outside National Park	450	2006-2013	36	7	18,4
G3	Chejelipes	250	2006-2013	15	4	26,7
G4	El Cedro into National Park	910	2006-2013	52	19	36,6
G5	El Cedro outside National Park	540	2006-2013	15	1	6,7
G6	Barranco del agua	410	2006-2013	21	6	28,6
G7	Meriga	970	2006-2013	30	14	46,7
G8	El Rejo	650	2006-2013-2018	34	14	41,2
TF 1	Afur	300	2006-2013-2018	42	7	16,7
TF 2	Igueste	400	2006-2013	37	5	13,5
TF 3	Barranco del infierno	500	2006-2013	55	15	27,3
TF 4	Masca	450	2006-2013	44	8	18,2
TF 5	El Río	1500	2006-2013	33	15	45,5
LP1	Caldera de Taburiente	450	2007-2008	28	9	32,1
LP2	Coderos	1900	2007-2008	13	6	46,2

Table 6. Biodiversity and endemicity level by stream in the Canary Islands

Code	Stream	Major altitude (m a.s.l.)	Data	N species	N endemisms	% endemisms
1_1	Ribeira de Janela low	70	Oct 2017 Feb 2018	16	3	18,8%
1_2	Ribeira de Janela up	1200	Oct 2017 Feb 2018	17	8	47,1%
2_1	Ribeira da Cova Grande W	1200	Oct 2017 Feb 2018	13	7	53.8%
2_2	Ribeira da Cova Grande E	1200	Oct 2017 Feb 2018	18	11	61,1%
3_1	Ribeira de Tabua low	150	Feb 2018 Oct 2018	11	3	27,3%
3_2	Ribeira de Tabua up	800	Feb 2018 Oct 2018	17	6	35,4%
4_1	Ribeira da Silveira (Queimadas)	900	Oct 2017 Feb 2018	16	8	50,00%
5_1	Ribeira de Cidrao, Curral das Freiras	800	Oct 2017 Feb 2018	15	5	33,33%
5_2	Over the stream Curral das Freiras	1200	Oct 2017 Feb 2018	13	6	46,2%
6_1	Ribeira Serra de Aqua	200	Oct 2017 Feb 2018	10	2	20,00%
7_1	Ribeira Sao Vicente	10	Oct 2017 Feb 2018	11	2	18,2%
8_1	Ribeira de Faial	30	Oct 2017 Feb 2018	11	3	27,3%
9_1	Ribeira de Funda low	100	Feb 2018	8	1	12,5%
9_2	Ribeira de Funda up	900	Feb 2018	13	6	46,2%
10_1	Ribeira de Sao Jorge at Ilha	500	Feb 2018	20	9	45,00%
11_1	Botanical Garden at Funchal	300	Feb 2018 Oct 2018	22	3	13,6%
12_1	Caldeirão Verde, pool in waterfall	950	Feb 2018	12	5	41,7%
13_1	Levadas	400-900	Feb 2018	19	6	31,6%

Table 7. Biodiversity and endemicity level by stream in Madeira

State	List of species
They have not been seen since the '90s.	- *Hydroporus pilosus* Guignot, 1949 - *Rhipidogammarus rheophilus* Stock & Sánchez, 1990 - *Limnebius canariensis* d´Orchymont, 1938 - *Stictonectes canariensis* Machado, 1987
They have not been seen since the ´90s in Tenerife.	- *Orthotrichia angustella* McLachlan, 1865 - *Coelostoma hispanicum* Küster, 1848 - *Graptodytes delectus* Wollaston, 1864 - *Tinodes canariensis* McLachlan, 1883
They have not been seen since the ´90s in Gran Canaria	- *Baetis canariensis* Müller-Liebenau, 1971 - *Corixa affinis* Leach, 1817 - *Enochrus politus* Küster, 1849 - *Galba truncatula* O. F. Müller, 1774 - *Hydroptila fortunate* Morton, 1893 - *Hygrotus confluens* Fabricius, 1787 - *Mesovelia vittigera* Horváth, 1895 - *Microvelia gracillima* Reuter, 1883 - *Notonecta canariensis* Kirkaldy, 1897 - *Ochthebius lapidicola* Wollaston, 1864 - *Ochthebius quadrifoveolatus* Wollaston, 1854 - *Ochthebius rugulosus* Wollaston, 1857 - *Orthotrichia angustella* McLachlan, 1865 - *Oxyethira spinosella* McLachlan, 1883 - *Sigara lateralis* Leach, 1817 - *Stactobia storai* Nybom, 1948 - *Tinodes canariensis* McLachlan, 1883 - *Velia lindbergi* Tamanini, 1954 - *Zygonyx torridus* Kirby, 1889

Table 8. Comparison of data obtained in de 90´s vs data obtained in the 2000´s and 2010´s

4. Discussion

Quite a few affinities have been found in the species composition of both archipelagos. The predominant orders are in both cases Coleoptera and Trichoptera and the family with the highest diversity *Dytiscidae*, which is meaningful because it is the family with the largest number of species of aquatic beetles described (Los coleópteros acuáticos de las Islas Canarias, 2012). Endemic species represent a very important percentage of the species (around one third) in the two Macaronesian archipelagos. The combination of species found in both archipelagos is typical of island fauna, with the dominance of a few families and the total absence of others (Malmqvist et al, 1995).

It is noteworthy that the number of species found only on the island of Madeira is similar to that found in the Canary Islands, even though in the Canary Islands more territory has been sampled. This is probably due to the fact that the Madeira archipelago is more humid, has a greater number of currents and these are larger and in many cases permanent.

The levels of endemicity vary greatly between groups depending mainly on their ability to disperse. Trichoptera are conservative insects in that their ability to disperse is limited, making it difficult for continental individuals to reach the islands continuously. This isolation logically promotes the formation of endemisms. The opposite example can be found with dragonflies with a zero level of endemicity. Their dispersion capacity is very high being able to travel up to 650 km in active flight (Stauder, 1991). The absence of some stream living habitants as Plecoptera, could be by their low dispersal capacity. The high number of endemisms found are probably neo-endemisms resulting from the last great wave of invasion of the islands (Malmqvist et al., 1995).

The biogeographical origin of the species is also similar for both cases, with the largest number of taxa coming from the Palaearctic kingdom or being endemisms. Most of the species in the Canary Islands come from North Africa (Báez, 1982), and probably also those from Madeira. They surely arrived as a consequence of short jumps and pushed by oriental gales (Hughes and Malmqvist, 2005).

In Madeira, half of the species found at a single sampling point were found in an artificial ecosystem, the pond at Funchal Botanical Park. As this was the only pond-type ecosystem studied, the presence of so many species of limited distribution could be due to the fact that they are macroinvertebrates prefer to live in non-current waters. Of the other half of the species, most were found in Ribeira da Cova Grande (E), a stream located at an altitude of more than 1200 meters with the highest level of endemicity of the currents studied in both archipelagos (61,1%). In the case of the Canary Islands, species with a limited distribution are not concentrated in a few currents. Afur, Barranco del Infierno, El Cedro and El Rio each host two rare species.

In the Canary Islands, the most diverse stream is Barranco del Infierno in Tenerife followed by El Cedro in La Gomera. These currents have in common that both are classified as having "Good ecological status" (Lüderitz et al, 2010). The highest levels of endemicity are found in one current on the island of La Gomera, Mériga (G8), within the Garajonay Natural Park, is one of the best preserved relic of Laurisilva in the world.

In Madeira, it cannot be stated that there are significant differences in the levels of endemicity in the samples taken in the upper-middle (>500 m a.s.l.) and lower-middle (<500 m a.s.l.) areas since the data collected do not have sufficient statistical power. However, from observation of data and other research carried out in this field, it is quite clear that this trend exists. The greater level of endemicity at higher elevations is explained by the difference in conservation status between the lower and upper parts of the island. In the higher areas (above 500 m a.s.l.) human intervention is rather low (Hughes, 2003). Below this level, flows are significantly affected by anthropogenic pressures such as canalization, organic matter discharge, agriculture, flood protection schemes, farming and urbanization (Hughes, 2006). More sampling is needed to obtain larger data sets.

In the Canary Islands, comparing sampling data from the 1990s with those carried out between 2000s-2010s, there is a large number of species that have not been found again. It is difficult to make a sure statement about if these species have suffered extinctions or extirpations since invertebrates are organisms that are not easily seen and deep sampling of freshwater macroinvertebrates has not been carried out in the last decades in the archipelago. In the article published by Malmqvist and colleagues in 1993 on the island of Tenerife, 171 freshwater invertebrate taxa were found, compared to 64 described in the following decades, but it should be borne in mind that only freshwater stream habitats have been sampled in recent years, while six types of freshwater habitat were sampled in the 1993 study (stream sites, madicolous habitats, man-made channels, disconnected freshwater pools, ponds, reservoirs and springs). For Gran Canaria the current state of freshwater invertebrates is even more uncertain. Of the species sampled in the 90s, 19 were not found in the last samplings. Furthermore, the fires in 2017 affected the areas of the currents, so a current evaluation of these is urgent, given that they could have totally affected the composition of species or even caused the disappearance of the flows and substrates. Therefore, without an in-depth study of the current state of freshwater fauna it is not possible to state with certainty the status of many species today.

In the Canarian archipelago, the number of current freshwater flows is alarmingly low as a result of the historical overexploitation of aquifers and the diversion of natural water courses for agriculture. The artificial channels represent the majority of the bodies of running freshwater (Lüderitz et al., 2010) and although some species can adapt to these artificial ecosystems, the tendency to cover them also excludes this possibility. The Macaronesian freshwater ecosystems have a high conservation value and, have been in constant regression. In spite of this, and although in many European territories thanks to the implementation of the WFD many freshwater bodies have been restored, they are absolutely out of focus for both local and international entities. The conservation of freshwater macroinvertebrates and ecosystems depends on the implementation of specific conservation programs for these habitats, given the dubious future of the currents. The creation of a specific eco-region within the WFD for the Macaronesian archipelagos would highlight the current state of these flows and oblige and provide financial support for conservation projects for these habitats.

Restoration projects always involve finding reference ecosystems in order to evaluate the optimal conditions of the hydromorphological, physical-chemical and biological aspects. We can find streams very close to their natural state inside Protected Natural Parks such as Barranco del Infierno in Tenerife, El Cedro in La Gomera or high places with little anthropization in Madeira, such as Ribeira da Cova Grande.

It is also essential to achieve a more or less natural hydromorphology of the flows in order for freshwater ecosystems to recover their ecological functions (Lüderitz et al., 2004). The scale at which hydromorphological degradation has its largest effects is on the benthic macroinvertebrate community (Lüderitz et al., 2010), so they are ideal bioindicators for stream condition. While recovering the morphology of the streams is important, there is a further concern with the drying up of the streams due to the extraction and diversion of water. Measures are needed to prevent, as far as possible, the extraction of water from the source and the natural courses of the streams. As the freshwater streams, madicolous habitats are also vulnerable to desiccation. The development of new industrial water production techniques, such as the use of treated water for irrigation or desalinated water for human consumption, opens up new possibilities for the recovery of this ecosystems.

These programs should concentrate not so much on the most diverse streams but on those with rare species (Malmqvist et al., 1995). A good focus may be those streams in the interior of Laurisilva forests, habitats that are themselves endangered but have high conservation value. Natural streams within these forests were probably very common before the 15th century in the central and western Canary Islands (Kunkel, 1976).

Taking this into account and for various reasons it is proposed to protect the El Cedro stream on the island of La Gomera. This current is still permanent in some of its points and is relatively long, with an unchanged hydromorphology of 2.2 km, the second largest in unaltered length after Taganana of the Canarian currents considered in this study. A section of this stream is located inside the Garajonay National Park, so it is guaranteed that the priority, at least in this area, will be the conservation and not the exploitation of the stream. It already has a high conservation value because it represents a relic of a formerly very common ecosystem, a stream within the Laurisilva forest. It also has one of the highest levels of biodiversity and endemism in the Canary Islands and includes two species that are not found in any other stream (*Gordius aquaticus* (Linnaeus, 1758) and *Orthrotrichia angustella* (McLachlan, 1865) and another rare endemism (*Meladema imbricate* (Wollaston, 1871)). Outside the borders of Garajonay National Park, it would be necessary to eliminate the water catchments resulting from agricultural activity in order to mitigate the main impact on these currents and to restore them to a state closer to nature in their whole extent. It would be expected that with a stronger channel and the recovery of the natural structure of the riverbed, the native fauna would restore spontaneously.

5. Conclusions

1. By observing the communities of freshwater invertebrates living in the streams of the Canary Islands and Madeira, affinities can be found between both archipelagos in terms of species communities, their biogeographical origin and their levels of endemicity.

2. The biodiversity and endemicity of freshwater macroinvertebrates found in the Canary and Madeira currents are surprisingly high given the relatively small amount of water they hold. These species are highly threatened given the poor state of conservation of the currents at present.

3. Legislation for their conservation at both local and international levels is insufficient. It is essential to create a differentiated eco-region of the Macaronesian archipelagos in the Water Framework Directive, given the differentiated characteristics of the river basins and the groups of species that inhabit them. The protection of the Laurisilva forests should be considered within the conservation measures.

4. There has been no updated systematic study of freshwater macroinvertebrate flows in recent years. It is necessary to update the information to know the current status, not only of the flows but of all types of freshwater ecosystems. It is especially urgent to study the currents of Gran Canaria in order to know how the fire had impacts on them. The evaluation of the status of these ecosystems should be defined according to a methodology designed especially for the Macaronesian archipelagos such that developed in 2010 by Lüderitz and colleagues.

5. There is a tendency for the best conserved areas to have higher levels of endemicity and biodiversity. In the Canaries we find this example in the currents within the Natural Parks and in Madeira in the higher areas of the island.

6. It is suggested to protect the El Cedro stream in La Gomera by renaturalizing the hydromorphology of the stream and eliminating water catchments and diversions from it.

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Annex I:

List of species on the Canary Islands

List of species found on the Canary Islands.

Leyend: **NS:** Native for sure; **NP:** Probably native; **ISF:** Invasive species; **IP:** Probably introduced; ***:** Endemic species.

Species	Phylum	Class	Order	Family	Origin category	Biogeographical region of origin
Agabus biguttatus Olivier, 1795	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Paleartic region
Agabus conspersus Marsham, 1802	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Unknow
Agabus nebulosus Forster, 1771	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Paleartic region
**Agapetus adejensis* Enderlein, 1929	Arthropoda	Insecta	Trichoptera	Glossosomatidae	NS	Canary Islands
**Anacaena haemorrhoa* Wollaston, 1864	Arthropoda	Insecta	Coleoptera	Hydrophilidae	NS	Canary Islands
Anax imperator Leach, 1815	Arthropoda	Insecta	Odonata	Aeshnidae	NS	Paleartic region
Anax parthenope Selys, 1839	Arthropoda	Insecta	Odonata	Aeshnidae	NS	Paleartic region
**Ancylus striatus* Quoy & Gaimard, 1834	Mollusca	Gastropoda	Hygrophila	Planorbidae	NS	Macaronesa
Baetis canariensis Müller-Liebenau, 1971	Arthropoda	Insecta	Ephemeroptera	Baetidae	NS	C anary Islands
Baetis nigrescens Navás, 1932	Arthropoda	Insecta	Ephemeroptera	Baetidae	NS	Paleartic region
**Baetis pseudorhodani* Müller-Liebenau, 1971	Arthropoda	Insecta	Ephemeroptera	Baetidae	NS	Canaty Islands
*Bidessus minutissimus*Germar, 1824	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Paleartic region
Caenis luctuosa Burmeister, 1839	Arthropoda	Insecta	Ephemeroptera	Caenidae	NS	Paleartic region
**Chaetogammarus chaetocerus* Beyer & Stock, 1994	Arthropoda	Malacostraca	Amphipoda	Gammaridae	NS	Canary Islands
Cloeon dipterum Linnaeus, 1761	Arthropoda	Insecta	Ephemeroptera	Baetidae	NS	Paleartic region
Coelostoma hispanicum Küster, 1848	Arthropoda	Insecta	Coleoptera	Hydrophilidae	NP	Paleartic region
Corixa affinis Leach, 1817	Arthropoda	Insecta	Hemiptera	Corixidae	NP	Paleartic region
Crocothemis erythraea Brullé, 1832	Arthropoda	Insecta	Odonata	Libellulidae	NS	Paleartic region
Dryops gracilis Karsch, 1881	Arthropoda	Insecta	Coleoptera	Dryopidae	NP	Paleartic region
Dugesia gonocephala Dugès, 1830	Plathyhelminthes	Turbellaria	Tricladia	Dugesiidae		Unknow
Eiseniella tetraedra Savigny, 1826	Annelida	Clitellata	Crassiclitellata	Lumbricidae	ISF	Cosmopolite
Enochrus bicolor Fabricius, 1792	Arthropoda	Insecta	Coleoptera	Hydrophilidae	NP	Paleartic region
Enochrus politus Küster, 1849	Arthropoda	Insecta	Coleoptera	Hydrophilidae	NP	Paleartic region
Euglesa casertanum Poli, 1791	Mollusca	Bivalvia	Verenoida	Sphaeriidae		Cosmopolite
Galba truncatula O. F. Müller, 1774	Mollusca	Gastropoda	Hygrophila	Lymnaeidae	IP	Paleartic región
Gerris thoracicus Schummel, 1832	Arthropoda	Insecta	Hemiptera	Gerridae	NP	Paleartic región
Gordius aquaticus Linnaeus, 1758	Cephalorhyncha	Gordioida	Gordea	Gordiidae		Unknow
**Graptodytes delectus* Wollaston, 1864	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Canary Islands
Gyrinus dejeani Brullé, 1832	Arthropoda	Insecta	Coleoptera	Gyrinidae	NS	Paleartic region

Gyrinus urinator Illiger, 1807	Arthropoda	Insecta	Coleoptera	Gyrinidae	NS	Paleartic region
**Haliplus lineatocollis suffusus* Wollaston, 1864	Arthropoda	Insecta	Coleoptera	Haliplidae	NS	Canary Islands
Hebrus pusillus Fallén, 1807	Arthropoda	Insecta	Hemiptera	Hebridae	NS	Paleartic región
**Hydraena serricollis* Wollaston, 1864	Arthropoda	Insecta	Coleoptera	Hydraenidae	NS	Canary Islands
Hydrometra stagnorum Linnaeus, 1758	Arthropoda	Insecta	Hemiptera	Hydrometridae	NP	Paleartic región
**Hydroporus errans* Sharp, 1882	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Canary Islands
Hydroporus lucasi Reiche, 1866	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Paleartic region
Hydropsyche maroccana Navás, 1935	Arthropoda	Insecta	Trichoptera	Hydropsychidae	NS	Afrotropical región
Hydroptila fortunata Morton, 1893	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Macaronesia
Hygrotus confluens Fabricius, 1787	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	PAleartic region
Hygrotus musicus Klug, 1834	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Unknow
Hyphydrus maculatus Babington, 1841	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Unknow
Ischnura saharensis Aguesse, 1968	Arthropoda	Insecta	Odonata	Coenagriidae	NS	Afrotropical region
Laccobius canariensis d´Orchymont, 1940	Arthropoda	Insecta	Coleoptera	Hydrophilidae	NP	Canay Islands
Laccophilus hyalinus DeGeer, 1774	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Paleartic region
**Lepidostoma tenerifensis* Malicky, 1992	Arthropoda	Insecta	Trichoptera	Lepidostomatidae	NS	Canary Islands
**Limnebius gracilipes* Wollastom, 1864	Arthropoda	Insecta	Coleoptera	Hydraenidae	NS	Canary Islands
Meladema coriacea Laporte, 1834	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Paleartic region
**Meladema imbricata* Wollaston, 1871	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Canary Islands
Mesophylax aspersus Rambur, 1842	Arthropoda	Insecta	Trichoptera	Limnephilidae	NS	Paleartic region
Mesovelia vittigera Horváth, 1895	Arthropoda	Insecta	Hemiptera	Mesoveliidae	NS	Afrotropical region
Microvelia gracillima Reuter, 1883	Arthropoda	Insecta	Hemiptera	Veliidae	NP	Afrotropical region
**Nebrioporus canariensis* Bede, 1881	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Canary Islands
**Notonecta canariensis* Kirkaldy, 1897	Arthropoda	Insecta	Hemiptera	Notonectidae	NS	Canary Islands
**Ochthebius lapidicola* Wollaston, 1864	Arthropoda	Insecta	Coleoptera	Hydraenidae	NS	Canary Islands
Ochthebius quadrifoveolatus Wollaston, 1854	Arthropoda	Insecta	Coleoptera	Hydraenidae	NP	Paleartic region
Ochthebius rugulosus Wollaston, 1857	Arthropoda	Insecta	Coleoptera	Hydraenidae	NP	Paleartic región
Orthetrum chrysostigma Burmeister, 1839	Arthropoda	Insecta	Odonata	Libellulidae	NS	Afrotropical región
Orthotrichia angustella McLachlan, 1865	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Unknow
Oxyethira spinosella McLachlan, 1883	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Madeira
Physella acuta Draparnaud, 1805	Mollusca	Gastropoda	Hygrophila	Physidae	IP	Paleartic región
Planorbis moquini Requien, 1848	Mollusca	Gastropoda	Hygrophila	Planorbidae	IP	Unknow
Pseudosuccinea columella Say, 1817	Mollusca	Gastropoda	Hygrophila	Lymnaeidae	ISP	Neartic region
**Rhipidogammarus gomeranus* Beyer & Stock, 1994	Arthropoda	Malacostraca	Amphipoda	Gammaridae	NS	Canary Islands
Sigara lateralis Leach, 1817	Arthropoda	Insecta	Hemiptera	Corixidae	NP	Paleartic region

Simulium sp.	Arthropoda	Insecta	Diptera	Simuliidae		Unknow
**Stactobia storai* Nybom, 1948	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Canary Islands
Sympetrum fonscolombii	Arthropoda	Insecta	Odonata	Libellulidae	NS	Paleartic region
Sympetrum nigrifemur Sélys, 1884	Arthropoda	Insecta	Odonata	Libellulidae	NS	Unknow
Tinodes canariensis McLachlan, 1883	Arthropoda	Insecta	Trichoptera	Psychomyiidae	NS	Canary Islands
Trithemis arteriosa Burmeister, 1839	Arthropoda	Insecta	Odonata	Libellulidae	NS	Afrotropical región
**Velia lindbergi* Tamanini, 1954	Arthropoda	Insecta	Hemiptera	Veliidae	NP	Canary Islands
**Wormaldia tagananana* Enderlein, 1929	Arthropoda	Insecta	Trichoptera	Philopotamidae	NS	Canary Islands
Zygonyx torridus Kibry, 1889	Arthropoda	Insecta	Odonata	Libellulidae	NS	Afrotropical región

Annex II:

List of species on Madeira

List of species found on Madeira Island.

Leyend: **NS:** Native for sure; **NP:** Probably native; **ISF:** Invasive species; **IP:** Probably introduced; ***:** Endemic species.

Species	Phylum	Class	Order	Family	Origin category	Biogeographical region of origin
**Agabus maderensis* Wollaston, 1854	Arthropoda	Insecta	Coleptera	Dytiscidae	NS	Madeira
Agabus nebulosus Forster, 1771	Arthropoda	Insecta	Coleptera	Dytiscidae	NP	Paleartic region
**Agabus wollastoni* Sharp, 1854	Arthropoda	Insecta	Coleptera	Dytiscidae	NP	Madeira
**Anacaena conglobata* Wollaston, 1854	Arthropoda	Insecta	Coleptera	Hydrophilidae	NS	Madeira
Anax imperator Leach, 1815	Arthropoda	Insecta	Odonata	Aeshnidae	NS	Unknow
**Ancylus aduncus*	Mollusca	Gastropoda	Heterobranchia	Planorbidae	NS	Madeira
Ancylus fluviatilis Müller, 1774	Mollusca	Gastropoda	Heterobranchia	Planorbidae		Paleartic region
Anisops debilis canariensis Noualhier, 1893	Arthropoda	Insecta	Hemiptera	Notonectidae		Macaronesia
Asellus aquaticus Linnaeus, 1758	Arthropoda	Malacostraca	Isopoda	Asellidae	NP	Paleartic region
**Baetis maderensis* Hagen, 1865	Arthropoda	Insecta	Ephemeroptera	Baetidae	NS	Madeira
Baetis pseudorhodani Müller-Liebenau, 1971	Arthropoda	Insecta	Ephemeroptera	Baetidae	NS	Macaronesia
Caenis luctuosa Burmeister, 1839	Arthropoda	Insecta	Ephemeroptera	Caenidae		Unknow
Chironomidae	Arthropoda	Insecta	Diptera		NP	Unknow
**Cloeon peregrinator* Gattolliat & Sartori, 2008	Arthropoda	Insecta	Ephemeroptera	Baetidae	NS	Madeira
Corixa affinis Leach, 1817	Arthropoda	Insecta	Hemiptera	Corixidae	NS	Paleartic region
Corixa punctata Illiger, 1807	Arthropoda	Insecta	Hemiptera	Corixidae	NS	Paleartic region
Crocothemis erythraea Brullé, 1832	Arthropoda	Insecta	Odonata	Libellulidae		Unknow
Dina lineata Müller, 1774	Annelida	Clitellata	Arhynchobdellida	Erpobdellidae	NP	Paleartic region
Dryops gracilis Karsch, 1881	Arthropoda	Insecta	Coleptera	Dryopidae	NP	Paleartic region
Dryops luridus Erichson, 1874	Arthropoda	Insecta	Coleptera	Dryopidae	NP	Paleartic region
Dugesia gonocephala Dugès, 1830	Platyhelminthes	Turbellaria	Tricladida	Dugesiidae	NP	Paleartic region
Eiseniella tetraedra Savigny, 1826	Annelida	Clitellata	Crassicritellata	Lumbricidae	NP	Cosmopolite
Galba truncatula O. F. Müller, 1774	Mollusca	Gastropoda	Hygrophila	Lymnaeidae	IS	Paleartic región
Gyraulus parvus Müller, 1774	Mollusca	Gastropoda	Heterobranchia	Planorbidae	NP	Paleartic región
Gyrinus urinator Illiger, 1807	Arthropoda	Insecta	Coleptera	Gyronidae		Unknow

Haliplus lineatocollis suffusus Wollaston, 1864	Arthropoda	Insecta	Coleptera	Haliplidae	NS	Unknow
**Hydroporus lundbladi* Falkenström, 1938	Arthropoda	Insecta	Coleptera	Dytiscidae	NS	Madeira
Hydroporus obsoletus Aubé, 1838	Arthropoda	Insecta	Coleptera	Dytiscidae	NP	Paleartic region
Hydropsyche maderensis Hagen, 1865	Arthropoda	Insecta	Trichoptera	Hydropsychidae	NS	Macaronesia
Hydroptila fortunata Morton, 1893	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Unknow
Hygrotus confluens Fabricius, 1787	Arthropoda	Insecta	Coleptera	Dytiscidae		Paleartic región
Ischnura senegalensis Rambur, 1942	Arthropoda	Insecta	Odonata	Coenagrionidae	NS	Afrotropical región
**Laccobius atricolor* dÓrchymont, 1938	Arthropoda	Insecta	Coleptera	Hydrophilidae	NS	Madeira
Laccophilus hyalinus DeGeer, 1774	Arthropoda	Insecta	Coleptera	Dytiscidae		Paleartic región
**Limnephilus nybomi* Malicky, 1984	Arthropoda	Insecta	Trichoptera	Limnephilidae	NS	Madeira
Lumbriculus variegatus Müller, 1774	Annelida	Oligochaeta	Lumbriculida	Lumbriculidae		Cosmopolite
**Meladema lanio* Fabricius, 1792	Arthropoda	Insecta	Coleptera	Dytiscidae	NS	Madeira
**Mesophylax oblitus* Hagen, 1865	Arthropoda	Insecta	Trichoptera	Limnephilidae	NS	Madeira
Microvelia gracillima Reuter, 1883	Arthropoda	Insecta	Hemiptera	Veliidae	NS	Afrotropical region
**Nebrioporus dubius* Aubé, 1838	Arthropoda	Insecta	Coleptera	Dytiscidae	NS	Madeira
**Ochthebius algicola* Wollaston, 1871	Arthropoda	Insecta	Coleptera	Hydraenidae	NS	Madeira
Ochthebius heeri Wollaston, 1851	Arthropoda	Insecta	Coleptera	Hydraenidae	NS	Macaronesia
Orthetrum chrysostigma Burmeister, 1839	Arthropoda	Insecta	Odonata	Libellulidae	NS	Afrotropical region
Orthotrichia angustella McLachlan, 1865	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Macaronesia
Oxyethira spinosella McLachlan, 1882	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Macaronesia
Physa fontinalis Linnaeus, 1758	Mollusca	Gastropoda	Heterobranchia	Physidae	NP	Paleartic region
Physella acuta Draparnaud, 1805	Mollusca	Gastropoda	Heterobranchia	Physidae	NP	Paleartic region
Pisidium casertanum Poli, 1791	Mollusca	Bivalvia	Verenoida	Sphaeriidae		Cosmopolite
**Polycentropus flavostictus* Hagen, 1865	Arthropoda	Insecta	Trichoptera	Polycentropodiae	NS	Madeira
**Potamonectes dubius* Aubé, 1838	Arthropoda	Insecta	Coleoptera	Dytiscidae	NS	Madeira
Potamopyrgus antipodarum Alm, 1915	Mollusca	Gastropoda	Littorinimorpha	Tateidae	IS	Cosmopolite
Sigara lateralis Leach, 1817	Arthropoda	Insecta	Hemiptera	Corixidae	NS	Paleartic región
Simulium petricolum Rivosecchi, 1963	Arthropoda	Insecta	Diptera	Simuliidae	NS	Paleartic región
Simulium intermedium Roubaud, 1906	Arthropoda	Insecta	Diptera	Simuliidae	NS	Paleartic region
**Stactobia nybomi* Schmid 1959	Arthropoda	Insecta	Trichoptera	Hydroptilidae	NS	Madeira

Sympetrum fonscolombii Sélys, 1840	Arthropoda	Insecta	Odonata	Libellulidae	NS	Paleartic region
Sympetrum nigrifemur Sélys, 1884	Arthropoda	Insecta	Odonata	Libellulidae	NS	Unknow
**Synagapetus lundbladi* Mosely, 1938	Arthropoda	Insecta	Trichoptera	Glossosomatidae	NS	Madeira
**Synagapetus punctatus* Hagen, 1859	Arthropoda	Insecta	Trichoptera	Glossosomatidae	NS	Madeira
**Tinodes cinerea* Hagen, 1865	Arthropoda	Insecta	Trichoptera	Psychomyiidae	NS	Madeira
**Tipula atlantica* Mannheims, 1962	Arthropoda	Insecta	Diptera	Tipulidae	NS	Madeira
Tubifex tubifex Müller, 1774	Annelida	Oligochaeta	Haplotaxida	Tubificidae	NP	Cosmopolite
**Velia maderensis* Noualhier, 1897	Arthropoda	Insecta	Hemiptera	Veliidae	NS	Madeira
Zygonyx torridus Kibry, 1889	Arthropoda	Insecta	Odonata	Libellulidae	NS	Afrotropical region

Annex III:

List of species by current on the Canary Islands

List of species by current in the Canary Islands

Legend: **GC1**: Tejeda; **GC2**: Barranco de Cernícalos; **G1**: La Laja (590 m); **G2:** La Laja (450 m); **G3**: Chejelipes; **G4**: El Cedro (910 m); **G5**: El Cedro (540 m); **G6**: Barranco del Agua; **G7**: El Rejo; **G8**: Meriga; **TF1:** Afur; **TF2**: Igueste; **TF3**: Barranco del Infierno; **TF4**: Masca; **TF5**: El Rio; **LP1**: Caldera de Taburiente; **LP2**: Codieros; ***_:** Endemism.

Species	**Gran Canaria**		**La Gomera**								**Tenerife**					**La Palma**	
	GC1	GC2	G1	G2	G3	G4	G5	G6	G7	G8	TF1	TF2	TF3	TF4	TF5	LP1	LP2
Agabus biguttatus Olivier, 1795	x	x	x			x			x				x		x	x	
Agabus conspersus Marsham, 1802	x	x	x	x	x	x				x	x			x			
*Agabus nebulosus*Forster, 1771	x		x	x		x					x	x	x		x		
**Agapetus adejensis* Enderlein, 1929	x		x			x			x	x			x		x	x	
**Anacaena haemorrhoa* Wollaston, 1864		x				x			x	x	x		x	x	x		
Anax imperator Leach, 1815		x	x	x	x	x	x	x			x	x	x	x	x	x	
*Anax parthenope*Selys, 1839			x	x							x	x	x	x			
**Ancylus striatus* Quoy & Gaimard, 1834	x	x	x	x		x		x	x	x	x	x	x	x	x	x	
Baetis canariensis Müller-Liebenau, 1971			x			x			x	x			x		x	x	x
*Baetis nigrescens*Navás, 1932	x	x	x			x		x	x		x		x	x		x	
**Baetis pseudorhodani* Müller-Liebenau, 1971	x	x	x			x			x	x	x		x		x	x	x
*Bidessus minutissimus*Germar, 1824	x											x	x	x			
Caenis luctuosa Burmeister, 1839		x	x			x					x						
**Chaetogammarus chaetocerus* Beyer & Stock, 1994						x		x	x								
Cloeon dipterum Linnaeus, 1761	x	x	x	x	x	x	x	x			x	x	x	x		x	
Coelostoma hispanicum Küster, 1848	x																
Corixa affinis Leach, 1817				x							x	x	x	x			
Crocothemis erythraea Brullé, 1832	x		x	x			x	x			x	x	x	x	x		
Dryops gracilis Karsch, 1881		x	x	x		x	x	x	x	x	x	x	x	x	x	x	x
Dugesia gonocephala Dugès, 1830			x	x		x			x	x	x	x	x	x	x		
Eiseniella tetraedra Savigny, 1826	x	x	x	x		x	x		x	x	x	x	x	x	x		x
Enochrus bicolor Fabricius, 1792				x						x		x	x	x			
Enochrus politus Küster, 1849			x							x	x		x		x	x	
Galba truncatula O. F. Müller, 1774			x	x	x		x	x		x	x	x	x	x			
Gerris thoracicus Schummel, 1832			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Gordius aquaticus Linnaeus, 1758						x											
**Graptodytes delectus* Wollaston, 1864	x																
Gyrinus dejeani Brullé, 1832	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Gyrinus urinator Illiger, 1807		x	x	x		x	x	x			x	x	x	x		x	
**Haliplus lineatocollis suffusus* Wollaston, 1864	x	x	x	x	x						x		x	x			
Hebrus pusillus Fallén, 1807			x			x				x	x	x		x	x		x
**Hydraena serricollis* Wollaston, 1864	x			x		x			x	x			x	x	x	x	

Hydrometra stagnorum Linnaeus, 1758			x	x		x	x	x	x	x		x	x	x		x	
**Hydroporus errans* Sharp, 1882	x	x	x	x		x		x	x	x		x	x		x	x	x
Hydroporus lucasi Reiche, 1866			x	x			x			x	x	x	x		x	x	
Hydropsyche maroccana Navás, 1935	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x
Hydroptila fortunata Morton, 1893			x			x			x	x			x	x	x	x	
Hygrotus confluens Fabricius, 1787			x								x	x	x	x			
Hygrotus musicus Klug, 1834	x		x	x		x							x	x			
Hyphydrus maculatus Babington, 1841		x															
Ischnura saharensis Aguesse, 1968											x		x				
Laccobius canariensis d´Orchymont, 1940	x	x	x	x		x				x	x	x	x	x			
Laccophilus hyalinus DeGeer, 1774	x	x	x	x		x			x	x	x	x	x	x	x	x	
**Lepidostoma tenerifensis* Malicky, 1992			x												x		
**Limnebius gracilipes* Wollastom, 1864	x		x			x							x				
Meladema coriacea Laporte, 1834	x	x	x	x		x					x	x	x	x			
**Meladema imbricata* Wollaston, 1871						x									x		
Mesophylax aspersus Rambur, 1842	x	x	x			x		x	x	x		x	x	x	x	x	x
Mesovelia vittigera Horváth, 1895													x	x			
Microvelia gracillima Reuter, 1883			x			x			x		x	x	x	x			
**Nebrioporus canariensis* Bede, 1881	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
**Notonecta canariensis* Kirkaldy, 1897			x	x	x	x		x			x	x	x	x	x	x	x
**Ochthebius lapidicola* Wollaston, 1864			x			x				x			x		x		
Ochthebius quadrifoveolatus Wollaston, 1854			x	x								x	x				
Ochthebius rugulosus Wollaston, 1857			x	x		x		x	x		x	x	x	x			
Orthetrum chrysostigma Burmeister, 1839	x	x	x	x	x						x	x	x	x	x	x	
Orthotrichia angustella McLachlan, 1865						x											
Oxyethira spinosella McLachlan, 1883						x				x				x		x	
Physella acuta Draparnaud, 1805	x	x	x	x		x		x		x	x	x	x	x			
Planorbis moquini Requien, 1848				x	x							x					
Pseudosuccinea columella Say, 1817	x	x									x		x	x			
**Rhipidogammarus gomeranus* Beyer & Stock, 1994						x			x								
Sigara lateralis Leach, 1817			x	x	x	x			x		x	x	x	x			
**Stactobia storai* Nybom, 1948						x			x						x		
Sympetrum fonscolombii			x	x	x	x	x				x	x	x	x	x	x	
Sympetrum nigrifemur Sélys, 1884			x	x							x	x	x		x	x	
Tinodes canariensis McLachlan, 1883						x				x							
Trithemis arteriosa Burmeister, 1839											x			x			
**Velia lindbergi* Tamanini, 1954			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
**Wormaldia tagananana* Enderlein, 1929			x			x			x	x			x		x		

Zygonyx torridus Kibry, 1889				x		x					x		x	x			
Number of species	28	25	48	38	15	52	15	21	30	34	42	37	55	44	33	28	13
Number of endemism	9	6	13	7	4	19	1	6	14	14	7	5	15	8	15	9	6
Percentage of endemisms (%)	32,1	24,0	27,1	18,4	26,7	36,5	6,7	28,6	46,7	41,2	16,7	13,5	27,3	18,2	45,5	32,1	46,2

Annex IV:

List of species by current on Madeira

List of species by current in Madeira Island

Leyend: **1_1:** Ribeira da Janela low (70 m); **1_2:** Ribeira da Janela up (1200m); **2_1:** Ribeira da Cova Grande W; **2_2:** Ribeira da Cova Grande E; **3_1:** Ribeira da Tabua low (150 m); **3_2:** Ribeira da Tabua up (800 m); **4_1:** Ribeira da Silveira (Queimadas); **5_1:** Ribeira da Cidrao, Curral das Freiras; **5_2:** Over Curral das Freiras; **6_1:** Ribeira Serra da Aqua; **7_1:** Ribeira Sao Vicente; **8_1:** Ribeira da Faial; **9_1:** Ribeira da Funda low (100 m); **9_2:** Ribeira da Funda up (900m); **10_1:** Ribeira da Sao Jorge at Ilha; **11_1:** Botanical Garden at Funchal; **12_1:** Caldeirao Verde, pool in the waterfall; **13_1:** Levadas; ***_:** Endemism.

	1_1	**1_2**	**2_1**	**2_2**	**3_1**	**3_2**	**4_1**	**5_1**	**5_2**	**6_1**	**7_1**	**8_1**	**9_1**	**9_2**	**10_1**	**11_1**	**12_1**	**13_1**
**Agabus maderensis* Wollaston, 1854				x		x		x						x	x		x	x
Agabus nebulosus Forster, 1771																x		
**Agabus wollastoni* Sharp, 1854				x														
**Anacaena conglobata* Wollaston, 1854		x	x				x								x		x	
Anax imperator Leach, 1815		x														x		
**Ancyclus aduncus*																		x
Ancylus fluviatilis Müller, 1774	x					x		x	x	x	x							
Anisops debilis canariensis Noualhier, 1893																x		
Asellus aquaticus Linnaeus, 1758	x				x	x				x						x		
**Baetis maderensis* Hagen, 1865	x	x	x	x	x	x		x		x	x	x	x		x			x
Baetis pseudorhodani Müller-Liebenau, 1971	x	x	x	x		x	x	x	x					x	x		x	x
Caenis luctuosa Burmeister, 1839	x											x						x
**Cloeon peregrinator* Gattolliat & Sartori, 2008		x		x	x					x	x	x				x	x	
Corixa affinis Leach, 1817	x																	
Corixa punctata Illiger, 1807																x		
Crocothemis erythraea Brullé, 1832	x							x							x	x		
Dina lineata Müller, 1774											x		x					x
Dryops gracilis Karsch, 1881																	x	
Dryops luridus Erichson, 1874																	x	
Dugesia gonocephala Dugès, 1830	x				x	x	x	x	x	x	x	x	x					x
Eiseniella tetraedra Savigny, 1826			x		x	x	x			x	x		x		x			x
Galba truncatula O. F. Müller, 1774					x					x	x	x						
Gyraulus parvus Müller, 1774												x						
Gyrinus urinator Illiger, 1807	x															x		x

Haliplus lineatocollis suffusus Wollaston, 1864																x		
**Hydroporus lundbladi* Falkenström, 1938		x																
Hydroporus obsoletus Aubé, 1838							x									x		
Hydropsyche maderensis Hagen, 1865		x	x	x		x	x	x	x					x	x		x	x
Hydroptila fortunata Morton, 1893	x		x	x			x		x					x	x			x
Hygrotus confluens Fabricius, 1787																x		
Ischnura senegalensis Rambur, 1942																x		
**Laccobius atricolor* dÓrchymont, 1938																x		
Laccophilus hyalinus DeGeer, 1774	x														x	x		
**Limnephilus nybomi* Malicky, 1984			x	x		x			x									
Lumbriculus variegatus Müller, 1774					x	x				x	x	x	x					
**Meladema lanio* Fabricius, 1792				x												x		
**Mesophylax oblitus* Hagen, 1865		x		x		x	x		x					x	x			x
Microvelia gracillima Reuter, 1883																x		
**Nebrioporus dubius* Aubé, 1838																		
**Ochthebius algicola* Wollaston, 1871																	x	
Ochthebius heeri Wollaston, 1851		x													x			
Orthetrum chrysostigma Burmeister, 1839				x														
Orthotrichia angustella McLachlan, 1865																		
Oxyethira spinosella McLachlan, 1883		x				x												
Physa fontinalis Linnaeus, 1758	x							x		x	x					x		
Physella acuta Draparnaud, 1805																x		
Pisidium casertanum Poli, 1791						x								x				
**Polycentropus flavostictus* Hagen, 1865						x	x	x	x						x			
Potamonectes dubius Aubé, 1838	x			x				x						x			x	x

Potamopyrgus antipodarum Alm, 1915											x	x						
Sigara lateralis Leach, 1817		x			x								x		x	x	x	x
Simulium intermedium Roubaud, 1906	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x
Simulium petricolum Rivosecchi, 1963								x	x									
**Stactobia nybomi* Schmid 1959		x	x	x			x							x	x			
Sympetrum fonscolombii Sélys, 1840		x					x							x	x	x	x	x
Sympetrum nigrifemur Sélys, 1884		x	x	x		x									x	x	x	x
**Synagapetus lundbladi* Mosely, 1938				x			x											
**Synagapetus punctatus* Hagen, 1859	x		x						x						x			
**Tinodes cinerea* Hagen, 1865		x		x		x	x							x				
**Tipula atlantica* Mannheims, 1962	x		x		x		x	x	x			x		x	x			x
Tubifex tubifex Müller, 1774					x							x	x					
**Velia maderensis* Noualhier, 1897		x	x	x			x	x	x					x	x		x	x
Zygonyx torridus Kibry, 1889								x										
Number of species	16	17	13	18	11	17	16	15	13	10	11	11	8	13	20	22	12	19
Number of endemisms	3	8	7	11	3	6	8	5	6	2	2	3	1	6	9	3	5	6
Endemicity (%)	18,8	47,1	53,8	61,1	27,3	35,3	50,0	33,3	46,2	20,0	18,2	27,3	12,5	46,2	45,0	13,6	41,7	31,6