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# Freshwater endemic species and the ecological status of streams in the Canary Islands

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## Abstract

An inventory has been made of endemic aquatic macroinvertebrates in streams of the Canary Islands. The inventory shows that of 31 pristine endemic species, 10 are now extinct. From the remaining 21 species, only 12 occur in streams with undisturbed hydromorphology and natural background conditions, and among these, there are 6 species that only occur in a single body of water on a single island, so they are very near to extinction. The main reason for this development is the dramatic decrease in the number of streams on the Canary Islands due to unsustainable consumption of water for agriculture and tourism and the transformation of most of the remaining streams to canals. However, natural reaches of streams with an endemic macroinvertebrate fauna still exist in specially protected areas of Tenerife, La Gomera, and La Palma. These reaches serve as reference status for the development of a specific assessment method for streams on the islands. This method takes into account common parameters such as water quality and hydromorphology, though to biodiversity and island-specific endemism is given greater emphasis. These last two concepts of stream development could be important tools in both nature conservation and protection of the remaining endemic and sensitive species.

## Introduction

Due to their genesis, the Canary Islands have never had any physical connection to any continental landmass (Carracedo, 2011) and this has greatly influenced the island's flora and fauna. The biota of the Canary Islands are characterized by a "high diversity and distinctiveness" (Juan et al., 2000; Hughes and Malmqvist, 2005; Fernández-Palacios and Whittaker, 2008). Many species can be found here which only live on one or two islands, therefore making endemism a significant factor. The small freshwater streams on the Canary Islands harbour an interesting and surprisingly diverse fauna (Beyer, 1993; Malmqvist et al., 1993, 1995). In this study, the present status of the macroinvertebrate fauna in the flowing water bodies of the Canary Islands is examined with special reference to endemic species and with consideration of current threats and challenges.

For more than 100 years, inland water bodies of the Canary Islands have suffered from anthropogenic disturbance and pollution loading, resulting in a steady drop in the number of perennial streams on both Tenerife and Gran Canaria. Between 1933 and 1973, the number of perennial streams on Gran Canaria decreased from 285 to 20 (Nilsson et al., 1998). In 2009 and 2010, we only found two permanently flowing streams. The same situation has occurred on Tenerife with less than 10 perennial streams being documented there recently (Lüderitz et al., 2010).

Threats to freshwater ecosystems include a decrease in forested areas, consumptive use of groundwater and surface water reservoirs for agricultural irrigation (for irrigation, most streams are channelized to a high degree), and water pollution by both point and non-point sources.

On the other hand, the goals of the EU-Water Framework Directive (WFD) are also valid for the Canary Islands. The main objective is to achieve a 'good ecological status' for all European water bodies by the end of 2015, and, by extension, until 2027. The provisions of this directive offer a good basis for the implementation of integrated strategies to protect water bodies that take into account the complexity of anthropogenic influences and define quantitative environmental quality targets. For the WFD implementation, detailed planning of measures of restoration and re-naturalization are necessary. Consequently, a holistic method of stream assessment is urgently needed to contribute to these requirements (Lüderitz, 2004). For the chemical assessment, European (continental) standards can be used, but biological methods have to be adjusted to the specific situation of island ecosystems. Compared to the situation on the continent and on large land-bridge islands like the British Islands, the number of aquatic species on relatively small islands is limited, as is the number of streams themselves. Thus, assessment systems like AQEM (Assessment System for the Ecological Quality of Streams and Rivers throughout Europe using Benthic Macroinvertebrates), which depend on a relatively high species number (Hering et al., 2003), have only limited suitability.

On oceanic islands, macroinvertebrate assemblages often contain a considerable number of endemic species and subspecies (Juan et al., 2000; Whittaker and Fernández-Palacios, 2007). The disappearance and/or increasing channelization of streams can lead to the extinction of such organisms, so endemic species have to be considered in every assessment approach.

This paper presents an overview of the present status of these endemic species on the Canary Islands. Our hypothesis is that conservation of streams not only maintains the diversity and structure of the community, but also preserves the more endemic and less ubiquitous species. To identify threats to endemic and sensitive organisms and their assemblages, and to develop and implement measures for habitat improvement, a specific assessment system based on the occurrence and distribution of aquatic macroinvertebrates, improved by hydromorphological parameters, has been created. It has been developed by sampling the remaining streams of Gran Canaria, Tenerife, La Gomera and La Palma and by analyzing published data (Beyer, 1993; Malmqvist et al., 1995; Nilsson et al., 1998).

## Methods

With the exception of the brackish Los Molinos stream on Fuerteventura, there are no permanent streams on Fuerteventura or on Lanzarote and El Hierro. Therefore, our investigations focused on the remaining islands Tenerife, La Gomera, Gran Canaria, and La Palma. Altogether, we sampled aquatic macroinvertebrates in 17 stream reaches between spring 2006 and fall 2013. Sampling campaigns on La Gomera and Tenerife were carried out six times in eight and five stream reaches respectively, whereas on La Palma and Gran Canaria, two streams on each island were sampled twice in March and in November (Fig. 1). Four of the reaches on La Gomera are located in, or very near to, the Garajonay National Park, the best Canarian remnant of a laurel forest, a Tertiary relic wiped out in Europe due to the climatic deterioration (Fernández-Palacios et al., 2011), where several undisturbed permanent streams are still present. Two reaches on Tenerife belong to a nature reserve and one reach on La Palma is located in the Caldera de Taburiente National Park. The other reaches are disturbed to a certain degree by anthropogenic influences such as intensive agriculture, channelization and damming (See Supplementary Figs. and Supplementary Tab. 1 for detailed information on the streams).

### *2.1. Biology – sampling and assessment of aquatic macroinvertebrates*

The reaches were sampled in spring and fall. Sampling was conducted over a length of 100 m by means of an extended version of the Multi-Habitat-Sampling technique (Hering et al., 2003; Lüderitz et al., 2004). This method includes all microhabitats (mineral and organic bed substrates submerged and emergent aquatic plants) within the stretches. An area of $10m^2$ at each site was sampled using a hand net with a mesh size of 0.5 mm. The organisms were counted and (except easily identifiable species) fixed in 70% ethyl alcohol and identified with keys provided by Balke et al. (1990), Bellmann (1993), Müller-Liebenau (1971), Nybom (1948), Machado (1987), Crosskey (1988) and Waringer and Graf (1997).

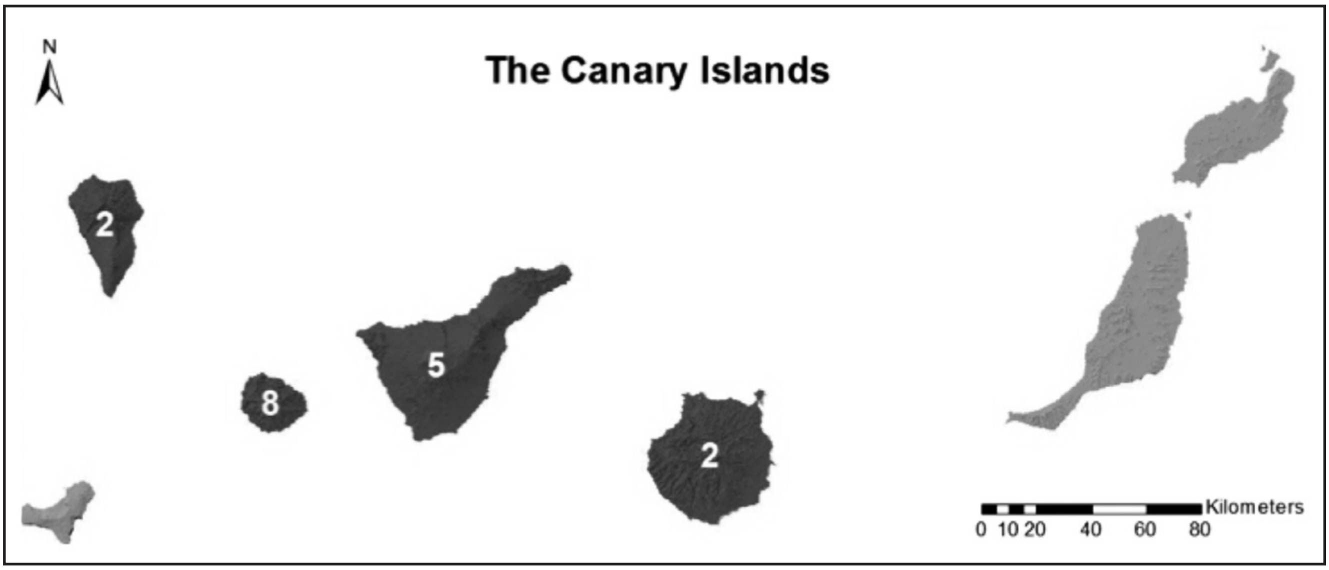


**Fig. 1** Map of the Canary Islands including the number of streams analyzed on each study island.

To conduct an assessment of the collected data with the goal of determining the biological quality of the flowing water body, a reference condition is needed. This reference condition is met, due to their good conservation status, by the ecological communities of *Barranco del Río* and *Barranco del Infierno* (both in Tenerife) and *El Cedro* in La Gomera. Thus, these three streams serve as reference conditions with regard to hydromorphological as well as biological conditions. The species living in these streams reflect a situation without (or with only little) anthropogenic influence and therefore correspond to the reference biocoenosis.

We developed a specific assessment system for the streams of the Canary Islands (Lüderitz et al., 2010) using five metrics: i) *Water quality*, assessed by calculating the *Saprobic Index* which indicates organic pollution; ii) *Diversity,* expressed as the percentage that the collected species at a given stream represent of the total number of species living on that island; iii) *Degree of naturalness,* calculated as the sum of the sensitive species (those occurring only in streams with high water quality and nearly natural hydromorphology) abundances; iv) *Refuge function,* represented by the number of endemic species, and finally v) *Hydromorphology,* calculated as the sum of physical characteristics of a water body is described below. The calibration of biological data for this assessment was conducted with reference to the rare undisturbed stream reaches (sampling sites 4, 9, 13). Finally, the concept of *Ecological Integrity* (Constanza et al., 1992; Karr, 1993) corresponds to the weighted average of the five metrics given above. Regarding conservation, naturalness and endemism play the most significant roles: their weight in the *EI* calculation is highest:

$$EI = \frac{DI\ x\ 2 + NN\ x\ 3 + ES\ x\ 3 + HM\ x1 + SI\ x\ 1}{10}$$

EI: Ecological Integrity; DI: Diversity Index (Shannon-Wiener); NN: Naturalness; ES: Endemic species; HM: Hydromorphology; SI: Saprobic Index

*2.2. Hydromorphology*

The hydromorphological assessment was accomplished by the mapping method given by LAWA (2000) and by considering the suggestions of Raven et al. (2002) and Kumm (2008). After adaptation and calibration to the natural conditions of the Canary Islands, we developed a special survey sheet, where four different zones were considered: river bottom, bank, surroundings, and water (Eller, 2012). These four zones influence substantially the course, form, and situation of a river. There are other influences as well, such as weather (for example, precipitation), but these features were not considered in the course of this hydromorphological assessment. The four zones were then characterized by seven main parameters, which explain the hydromorphological aspects of the specific zone. Closer inspection of the main parameters allowed us to itemize them into functional units. This gives evidence about the hydromorphological status of a flowing water body, so these units, which may differ from stream to stream, have a determining character concerning hydromorphology. To comply with the approach of the WFD, morphological parameters were assessed on a seven-point scale, class 1 corresponding to the condition of the reference stream and class 7 meaning ‘totally changed’. To carry out this classification the reference condition must be well known.

There were some important differences between the Spanish, German and the newly developed survey sheets. During the field survey, the specified characteristics of the flowing water body and its surroundings were recorded with the help of the newly-developed survey sheet by the surveyor. The examined stream was divided into sections that were successively mapped. However, the sizes of the single sections differ among the various survey sheets used. The Spanish survey sheet recommends sections of 300 m. In Germany, the sections' length depends on the river's width, so if the river is narrower than 1 m, the mapped sections should be of 50 m. Similarly, a river width of 1-5 m is related to a length of section of 100 m, 5-10 m corresponds to section length of 200 m, and if the river is wider than 10 m, then the mapped sections should be 500 m.

Using the newly developed survey sheet on Tenerife, a new section started when the surroundings or the stream clearly changed. However, in the evaluation of the collected hydromorphological data, the length of every section was taken into account to weight the sections equally and to compare the results of the different sections and streams.

Another difference between survey sheets was in the reference condition. In Germany, it needs to be assessed for every stream type, whereas in Tenerife it corresponds to *Barranco del Río* and to *Barranco del Infierno* and in La Gomera to *El Cedro*.

### *2.3. Statistical Analyses*

Ordination techniques help to explain community variation (Gauch, 1982) and can be used to evaluate trends through time as well as in space (Franklin et al., 1993; ter Braak and Šmilauer, 1998). Here we used the Detrended Correspondence Analysis (DCA; Hill and Gauch, 1980, using CANOCO; ter Braak and Šmilauer, 1998) to examine how species composition changed over the different sampled areas. Analyses were based on abundance, which we represented graphically on axes DCA I and II. In addition, to compare diversity between sites, we calculated the Simpson Diversity Index for each site, and compared the averages of La Gomera and Tenerife with a two-factor ANOVA (factor 1: sites and factor 2: years sampled; for a $p<0.05$) checked for normality and homoscedasticity with tests of Shapiro-Wilk and Levene (for $p<0.05$). The statistical methods used follow Zar (1984) and were implemented using the SPSS statistical package (SPSS Inc. 1997).

## Results

### *3.1. Diversity, hydromorphology and ecological status*

Altogether, we found 78 macroinvertebrate species in the analyzed streams (Supplementary Tab. 2). The highest species numbers belonged to aquatic beetles (31), followed by caddisflies (10), dragonflies and damselflies (9), bugs (9), mayflies (6), molluscs (6), and freshwater crabs (3).

The species composition analysis (Fig. 2) revealed that, although sharing many species, the streams of Tenerife and La Gomera could be discriminated through DCA axis II. More representative species for Tenerife were *Graptodytes deletus, Coelostoma hispanicum, Meladema imbricata* (Coleoptera) and *Lepidostoma tenerifensis* (Trichoptera); while for La Gomera, they were *Chaetogammarus chaetocerus* (Crustacea), *Pisidium casertanum* (Mollusca)*, Hydrometra stagnorum and Velia lindbergi* (Heteroptera). The samples of La Palma were located in the DCA plane at an intermediate position between Tenerife and La Gomera, while Gran Canaria samples were highly related to those for Tenerife, revealing more similarity to this island than to the others (Fig. 2).

In order to compare the diversity between Tenerife and La Gomera (the only islands providing enough data), we compared the average Simpson Diversity Index of both sites (factor 1) and discriminating the sampling period (2006, 2013; factor 2) with an ANOVA. The results revealed that there were no significant differences in diversity between the sites, despite the species composition differences detected by the DCA.

As far as overall ecological status of the streams of the Canary Islands, it is obvious that only streams in and near the *Garajonay* National Park on La Gomera and in nature reserves on Tenerife show a good or very good ecological status (Eller, 2012). The *El Cedro* stream on La Gomera (4) and *El Río* stream on Tenerife (9) most likely play an outstanding role in the ecology of inland waters and the conservation of endemic and sensitive species on these islands. Furthermore, streams with a good ecological status are *La Laja* (1) and *Meriga* (7) on La Gomera, *Barranco del Infierno* (13) and *Masca* (11) on Tenerife and *Taburiente* (16) on La Palma. These sites are also located in protected areas. All other sites are in a moderate, poor or even bad ecological status (Table 1). Main stressors here are the disturbed hydromorphology (Supplementary Tab. 3) and the lack of water. Outside of protected areas, most streams are channelized and/or piped. Even in National Parks (e. g. at *Meriga*), streams are piped and the water is drained off, although the pipes are clearly broken and out of use. Altogether, there are only 15 km of perennial streams with an undisturbed or nearly undisturbed hydromorphology in the Canary Islands (Supplementary Tab. 1).

*3.2. Situation of endemic species*

In previous studies (Machado 1987; Beyer 1993; Malmqvist et al., 1995; Nilsson et al., 1998), 31 Canarian endemic macroinvertebrate species have

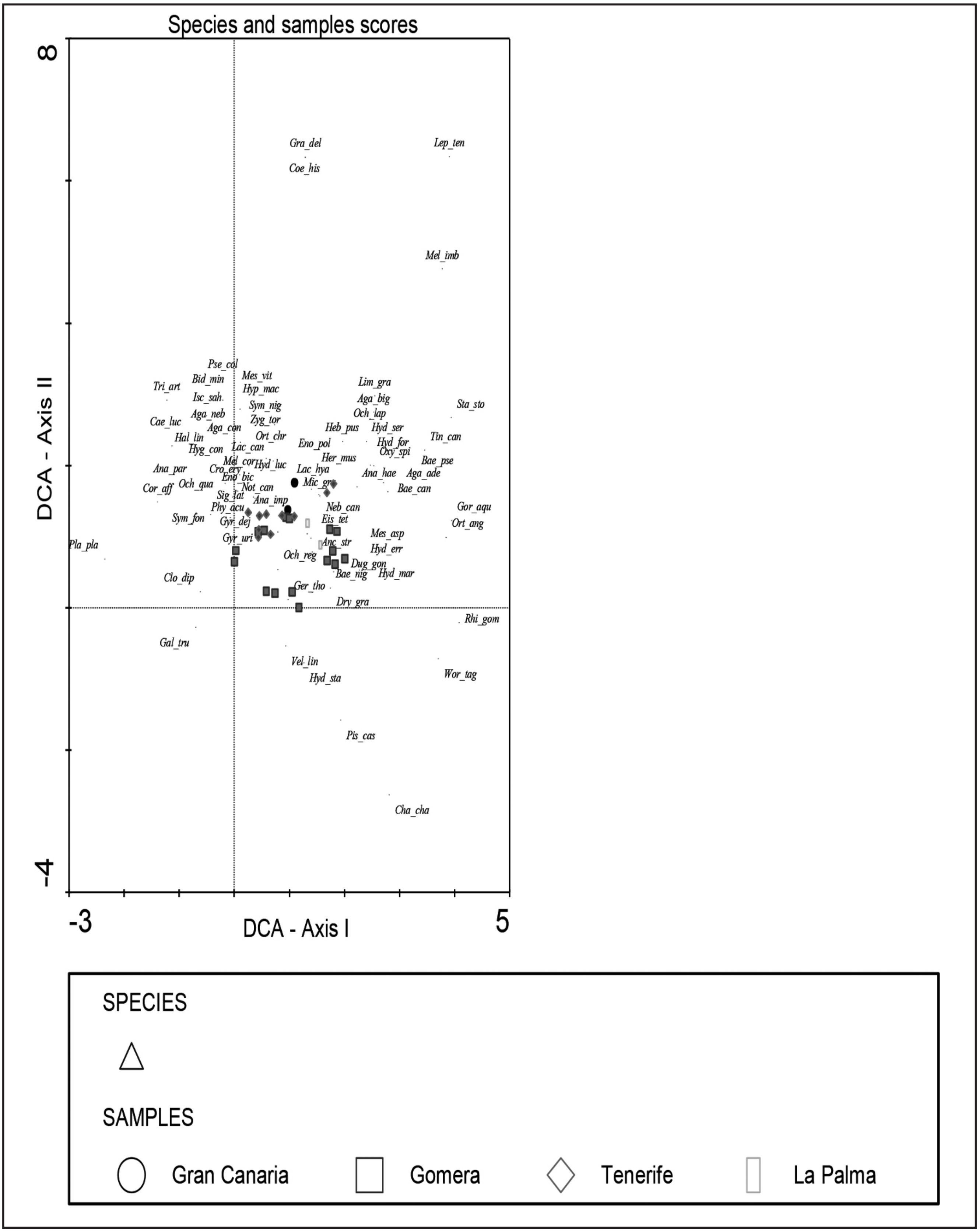


**Fig. 2** Species and site scores (based in species abundances) in the space defined by DCA axes I and II. Eigenvalues were 0.242 and 0.116 respectively, and the cumulative percentage of variance explained by both axes was 28.1%. Species are labelled with the first three generic letters followed by the first three epithet letters.

**Table 1**: Results of the multimetric assessment of 17 Canarian streams (1-8: La Gomera, 9-13: Tenerife, 14-15: Gran Canaria, 16-17: La Palma). First number in the couple: Value of the metric. Second number in the couple: Status value: 5 = very good; 4 = good; 3 = moderate; 2 = poor, 1 = bad.

| Stream | Diversity | Naturalness | Hydro-morphology | Endemic species | Water quality (SI) | Ecological status |
|---|---|---|---|---|---|---|
| 1 | 42 / 5 | 22 / 5 | 1.7 / 4 | 13 / 4 | 1.95 / 4 | 4.8 |
| 2 | 31 / 4 | 15 / 4 | 3.2 / 4 | 8 / 3 | 2.11 / 4 | 3.7 |
| 3 | 14 / 1 | 0 / 1 | 5.2 / 2 | 3 / 1 | 2.16 / 4 | 1.1 |
| 4 | 47 / 5 | 33 / 5 | 1.5 / 4 | 19 / 5 | 1.85 / 4 | 4.8 |
| 5 | 11 / 1 | 0 / 1 | 5.5 / 2 | 1 / 1 | 2.14 / 4 | 1.1 |
| 6 | 21 / 2 | 12 / 3 | 5.5 / 2 | 4 / 2 | 2.00 / 4 | 2.5 |
| 7 | 25 / 3 | 17 / 4 | 2.3 / 4 | 11/ 4 | 1.85 / 4 | 3.8 |
| 8 | 22 / 2 | 15 / 4 | 2.1 / 4 | 9 / 3 | 1.84 / 4 | 3.3 |
| 9 | 32 / 4 | 35 / 5 | 1.0 / 5 | 15 / 5 | 1.85 / 4 | 4.7 |
| 10 | 36 / 4 | 12 / 3 | 3.0 / 4 | 7 / 3 | 2.08 / 4 | 3.4 |
| 11 | 42 / 5 | 15 / 4 | 2.5 / 4 | 9 / 3 | 2.02 / 4 | 3.9 |
| 12 | 35 / 4 | 12 / 3 | 2.8 / 3 | 6 / 3 | 2.08 / 4 | 3.3 |
| 13 | 50 / 5 | 24 / 5 | 2.6 / 4 | 13 / 4 | 1.97 / 4 | 4.5 |
| 14 | 28 / 3 | 1 7/ 4 | 2.8 / 4 | 8 / 3 | 1.96 / 4 | 3.5 |
| 15 | 25 / 3 | 12 / 3 | 3.5 / 3 | 6 / 3 | 2.01 / 4 | 3.1 |
| 16 | 28 / 3 | 19 / 4 | 3.0 / 4 | 12 / 4 | 1.89 / 4 | 3.8 |
| 17 | 13 / 1 | 13 / 3 | 5.4 / 2 | 6 / 3 | 1.89 / 4 | 2.6 |

been documented. Our sampling only recovered 21 endemics (Table 2), meaning that ten species (*Hydroporus compunctus, Hydroptila juba, Hydrotarsus pilosus, Limnebius canariensis, Oecetis canariensis, Polycentropus tenerifiensis, Stictonectes canariensis, Rhipidogammarus rheophilus, Stactobia freyi* and *S. gomeriana*) must be classified as lost or extinct. Among them, six species were historically recorded on only one island. Some of the endemic and sensitive species occur in only a few streams. In 2006, the occurrence of the aquatic beetle *Meladema imbricata* was limited to one stream on La Gomera (*El Cedro*) and one stream on Tenerife (*El Río*). In 2013, we found only the relatively invasive species *M. coriacea* in *El Cedro*, La Gomera with *M. imbricata* restricted now to the short natural stream of *El Río* (9). Also the caddisflies *Lepidostoma tenerifiensis,* and *Stactobia storai* were found only at one and two sites, respectively. *L. tenerifiensis* was not found in 2013, so its future remains unclear.

A further species, *Hydroptila juba*, still present in the nearby archipelago of Madeira, became extincted from the Canary Islands. Furthermore, 11 more species, although still existing, have undergone island(s) extirpations, especially affecting Gran Canaria streams that have lost up to eight species (*Sympetrum nigrifemur, Hydroptila fortunata, Stactobia storai, Tinodes canariensis, Baetis canariensis, Anacaena haemorrhoa, Graptodytes deletus, Meladema imbricata, Ochthebius lapidicola, Notonecta canariensis* and *Velia lindbergi*) (Table 2).

On the other hand, three endemic species (*Sympetrum nigrifemur, Baetis pseudorhodani*, *Notonecta canariensis*) have been detected for the first time in La Palma, all of them present in the Taburiente stream, and one more (*Hydroptila fortunata*) in La Gomera, so we can affirm that 11 endemic species (*Sympetrum nigrifemur, Agapetus adejensis, Baetis canariensis, B. pseudorhodani, Anacaena haemorrhoa, Hydraena serricolis, Hydroporus errans, Nebriporus canariensis, Notonecta canariensis, Velia lindbergi* and *Ancylus striatum*) are still widely distributed on the islands and obviously not at risk. Most of these species are also well adapted to disturbed hydromorphology or can live in ponds.

## Discussion

Stream ecosystems shelter about 10% of global biodiversity, even though they cover less than 1% of the earth's surface (Strayer and Dudgeon, 2010). Although fresh waters provide most essential ecological services for human societies, there is strong pressure on these ecosystems that has led to a high degree of degradation (Geist, 2011; Mueller et al., 2014).

Island environments have relatively low species richness in comparison with similar continental settings

**Table 2**: Status of endemic aquatic macroinvertebrate species on the Canary Islands. †: extinct; 1: highly endangered, only present on one island in one or two water bodies in low abundances; 2: seriously endangered, only present on two islands in low abundances; 3: endangered, present on more than two islands in moderate abundances; 4: frequent. Mad = Madeira; C = Gran Canaria; T = Tenerife; G = La Gomera; P = La Palma; El Hierro (H) and Lanzarote (L) were not sampled.

| Taxonomic group | Species | Original distribution | Present distribution | Present status |
|---|---|---|---|---|
| Odonata | *Sympetrum nigrifemur* | Mad, C, T | Mad, T, P | **4** |
| Trichoptera | *Agapetus adejensis* | C, T, G, P | C, T, G, P | **4** |
| | *Hydroptila fortunata* | Mad, C, T, P | Mad, T, G, P | **3** |
| | *Hydroptila juba* | Mad, T | Mad | **†** |
| | *Lepidostoma tenerifensis* | T | T | **1** |
| | *Oecetis canariensis* | C?, T | _ | **†** |
| | *Polycentropus tenerifensis* | T | _ | **†** |
| | *Stactobia freyi* | C | _ | **†** |
| | *Stactobia gomerina* | G | _ | **†** |
| | *Stactobia storai* | C, T, G, P | T, G | **2** |
| | *Tinodes canariensis* | C, T, G, P | T, G | **1** |
| | *Wormaldia tagananana* | T, G | T, G | **3** |
| Ephemeroptera | *Baetis canariensis* | C, T, G, P | T, G, P | **4** |
| | *Baetis pseudorhodani* | C, T, G | C, T, G, P | **4** |
| Coleoptera | *Anacaena haemorrhoa* | C, T, G, P | C, T, G | **4** |
| | *Graptodytes deletus* | C, T | C | **1** |
| | *Hydraena serricollis* | C, T, G, P | C, T, G, P | **4** |
| | *Hydroporus compunctus* | T, G, P | _ | **†** |
| | *Hydroporus errans* | C, T, G, P | C, T, G, P | **4** |
| | *Hydroporus pilosus* | C, T | _ | **†** |
| | *Limnebius canariensis* | C | _ | **†** |
| | *Meladema imbricata* | T, G, P | T, G | **1** |
| | *Nebrioporus canariensis* | C, T, G, P, H | C, T, G, P | **4** |
| | *Ochthebius lapidicola* | L, C, T, G, P, H | T, G | **3** |
| | *Stictonectes canariensis* | C | _ | **†** |
| Heteroptera | *Notonecta canariensis* | C, T, G | T, G, P | **4** |
| | *Velia lindbergi* | C, T, G, P | T, G, P | **4** |
| Crustacea | *Chaetogammarus chaetocerus* | G | G | **1** |
| | *Rhipidogammarus gomeranus* | G | G | **1** |
| | *Rhipidogammarus rheophilus* | T | _ | **†** |
| Mollusca | *Ancylus striatum* | C, T, G, P | C, T, G, P | **4** |

(Whittaker and Fernández-Palacios, 2007). However, they support important and unique species communities, including many endemic species. They provide important ecosystem services as well. If such ecosystems are affected by degradation, the effects are frequently faster and more devastating than on continents.

On the Canary Islands, inland water bodies have undergone a high degree of domestication, meaning that these ecosystems have been optimized for a few services that provide major economic benefit to humans (Tockner et al., 2011); yet at the same time such alteration may cause unforeseen changes in other ecosystem attributes. With only 15 km of perennial streams having a natural or near-to-natural hydromorphology such domestication seems to be nearly complete.

The rapid decrease in water quality over time at the analyzed sites may be related to intensive use, channelization, and damming downstream of the natural forests. Man-made canals now represent the majority of flowing water bodies on the Canary Islands, while the majority of former stream courses are now dry, except during periods of heavy rain and flooding.

Before humans altered the islands' vegetation, many streams must have existed in the laurel forests. Today only fragments of the laurel forest remain – on La Gomera and mostly in the *Garajonay* National Park. Small streams running through surroundings of this kind show a relatively poor, but balanced composition of species (sites 7, 8). Such small streams join larger ones like *El Cedro* stream (site 4) with relatively high endemic biodiversity. This stream and the upper part of the stream in *Barranco del Río* (site 9) and *Barranco del Infierno* (site 13), both in Tenerife, can serve as reference sites although they may also be disturbed by changes downstream.

Using these reference sites, we developed an assessment method for streams on the Atlantic islands. This method is a special adaptation of the multimetric system developed for assessment of streams in Central Europe (Lüderitz et al., 2004). To assess ecological integrity, it considers the hydromorphological and hydrochemical background, but it mainly emphasizes biological factors such as biodiversity, endemism, and species sensitivity. On relatively small islands with small and isolated populations, such factors must be given much greater emphasis than on continents. This method for assessment of water bodies, in accordance with the requirements of the EU-WFD, is also an instrument to assess conservation value and conservation needs. Our approach is able to distinguish water bodies according to the kind and degree of anthropogenic disturbance and even to detect small differences. This method should also be tested and applied to other water bodies on other archipelagos.

Overall, the number of species found in the reference streams is low. In comparison, in streams of Central Europe, we have found up to three times as many species (e. g. Lüderitz et al., 2004). The reason for this is the absence of the typical lotic elements of continental streams, resulting from the taxonomic disharmony of oceanic islands (Fernández-Palacios and Whittaker, 2008), which means, for instance, groups such as Plecoptera are absent, while limnephilid Trichoptera are only present with one species.

In the past, several studies on freshwater species of the Canary Islands were carried out (Machado, 1987; Beyer, 1993; Malmqvist et al., 1995; Malmqvist et al., 1998), but even the most recent studies are 15-20 years old, so they do not bear any relation to the WFD. Nilsson et al., (1998) documented 56 macroinvertebrate species in streams on Gran Canaria, whereas our sampling only found 46 species. The difference, particularly with regard to the Trichoptera, is striking because there has been a decrease from 8 to 3 species, and a loss of endemics. It has been argued that aquatic insects respond more readily to land use and water quality changes than other macroinvertebrate taxa (Jiang et al., 2014). On Tenerife, the difference between our results (67 sp.) and previous ones (Malmqvist et al., 1995) (70 sp.) is smaller.

From a species composition point of view, Canarian streams show high individuality, and are not interchangeable. None of the studied streams can be delineated as being in greater need of protection than another. On the other hand, the similarity between the stream fauna of Tenerife and La Gomera is striking. The majority of species occur on both islands, but in the case of endemics, they often occur in small and isolated populations. Several species, especially among aquatic beetles and caddisflies, were already classified as endangered by Nilsson et al., (1998). Our results have unfortunately confirmed that 10 of these species have already undergone extinction in a relatively short time. To our knowledge, no other Canarian ecosystem has suffered such a high post-description extinction, and it appears that this trend will continue to increase, unless something is done urgently in the near future.

Our results also show that the numbers of endemic and sensitive species are more affected by degradation, because they are almost absent in the disturbed sites. Endemics are not only species with a limited distribution, but also have a limited adaptability to human-induced changes. In the case of fragmentation and degradation, patchiness becomes an additional adverse factor: maintenance and restoration of original aquatic communities can be hampered by the patchiness of organisms even in the case of best-practice conservation. Benthic invertebrates are not distributed equally, which means that the same microhabitats are not colonized by the same taxa in equal abundances (Sundermann et al., 2008). Accordingly, restoration needs time to manifest itself in aquatic communities, particularly if the re-setting populations are very small (Mueller et al., 2014), and the competition of non-native organisms is high as in the case, e.g., of aquatic beetles on the Canary Islands.

## Conclusions

Tockner et al., (2011) emphasize that conservation efforts will need to be succeeded by, or perhaps even replaced by, increasing levels of management intervention in order to create and maintain the desired ecological values of ecosystems. It follows from their opinion that a key challenge in science and management is to determine the extent to which the negative trade-offs of domestication can be avoided by changing the way ecosystems are managed. It is not so easy to restore healthy ecology to streams and floodplains along regulated water bodies. The more non-natural and interrupted the discharge regime is, and the more hydraulic engineering measures used for restoration, the more important management becomes (Fischer and Cyffka, 2014). To create an effective framework for conservation and restoration work, all kinds of man-made water bodies such as irrigation channels and remaining pools in natural, temporary streams must be included in strategies. There is no doubt that several endemic species are prone to extinction and that only two factors can avoid this fate, namely more water and more natural streams.

The restoration of stream ecosystem health and ecosystem services can be most successful when target-oriented, systematic and integrative approaches are used to determine initial conditions and to measure restoration effects. A stepwise evaluation of the primary factors of disturbance or degradation may also be the most suitable when considering all major drivers of successful restoration.

Target (indicator, flagship, umbrella and keystone)-species based approaches (Pander and Geist, 2013) in combination with an assessment of ecological integrity and hydromorphology can optimally serve for analysis of both status and deficits and as a base for development of restoration measures, and finally, for evaluation of success. Endemic species such as aquatic beetles do seem to be an ideal target species for the public, but they can also play a role in the framework of holistic conservation and restoration strategies.

Currently in the Canary Islands, there is a chance for successful stream restoration because of the abandonment of agriculture in parts of the islands (Fernández-Palacios and Whittaker, 2008). This chance is high in the northern part of La Gomera (*El Cedro*), and especially in *Barranco del Infierno* and in the Anaga massif in Tenerife. For these selected water bodies, the authors will develop restoration concepts during the coming years. Stream restoration will also contribute to re-greening of the *barrancos* (ravines) of the Canary Islands.

While the water demand for agriculture is decreasing, the demand for tourism remains at a high level and may even increase. One strategy for the conservation of water streams is the enhanced use of desalinated seawater with renewable energies. However, the political conditions for conservation of endemics on the Islands have become worse during recent years. The Canarian Parliament has approved a new version of the Canarian catalogue of protected species that has reduced substantially both the number of species included and the protection afforded (Fernandez-Palacios and de Nasciemento, 2011). The delisting and downgrading of numerous endangered species, together with the transfer of the management of Canarian National Parks to each insular administration make it even more challenging to start a real and effective stream restoration programme aimed at generating better conditions for aquatic endemics.

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