

A Review of the Freshwater Fishes of Curaçao, with Comments on those of Aruba and Bonaire

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Abstract.—Based on a field survey and review of published records, I report the occurrence of 13 species of fishes in fresh waters of Curaçao. Seven species are new or previously unpublished freshwater records for the island. New records are also provided for the adjacent islands of Aruba and Bonaire. Although the native freshwater fish fauna is dominated by predatory gobiid and eleotrid fishes, the most frequently encountered species was the endemic molly, *Poecilia vandepolli*. The next most frequent species was the native mountain mullet (*Agonostomus monticola*), followed by the exotic Mozambique tilapia (*Oreochromis mossambicus*) and the native emerald sleeper (*Eretelis smaragdus*). High dams block surface water flows in Curaçao and prevent migration of native amphidromous fish. The introduced tilapia has apparently reduced the abundance of native species.

INTRODUCTION

Important studies have been published about the cyprinodontiform fishes of Curaçao (Hoedeman, 1958; Feltkamp and Kristensen, 1970; Kristensen, 1970; Poeser, 1992) but little is known about the other freshwater fishes of this island. A number of new records have been published since the review by De Beaufort (1940) for the Leeward Antilles (including Curaçao) but extensive surveys have not been undertaken.

To obtain greater insight into the occurrence and status of the freshwater fishes and shrimps of Curaçao, I conducted a 23-site island survey. I report here on the fishes and review all prior records for the island. References including Curaçao within general distributional ranges, but which do not cite actual records for the island, were not included. The freshwater shrimps and sponges collected are reported elsewhere (Debrot and van Soest, 2001; Debrot, in press).

MATERIALS AND METHODS

Curaçao lies in the southern Caribbean, some 70 km N of Venezuela. Total surface area is approximately 444 km² and the highest point is the 375 m Christoffelberg. Annual mean temperature is 27.5 °C, and

annual rainfall, which averages 550 mm, shows a strong lagged relationship with the El Niño-Southern Oscillation (Martis et al., 2002). The vegetation is principally thorny woodlands and scrub. Approximately half of the annual rainfall occurs from October to December. Record levels of rainfall occurred during the 1999 rainy season, particularly in December, when rainfall was about 2.5 times higher than normal. Continued high rainfall during the first quarter of the year meant that streams and reservoirs (dams), which normally would be dry by February, retained water well into June of 2000. The island has no permanent freshwater streams but is traversed by many intermittent streams that carry rainwater to the sea; there are also upwards of 1000 agricultural water catchment dams. At the time of sampling in June 2000, water was still present in the principal dams and streams of the island, but stream flows had become discontinuous and maximum stream depths were below 50 cm.

The main sampling sites (sites 1-17, Fig. 1) were ten of the largest reservoirs, six of the principal streams ("rooi") and a rare permanent livestock watering hole ("pos"). All these sites were intensively sampled during a single daytime visit using a combination of fine mesh (4 mm) cast nets and dipnets (2 man-hours). Additional observa-

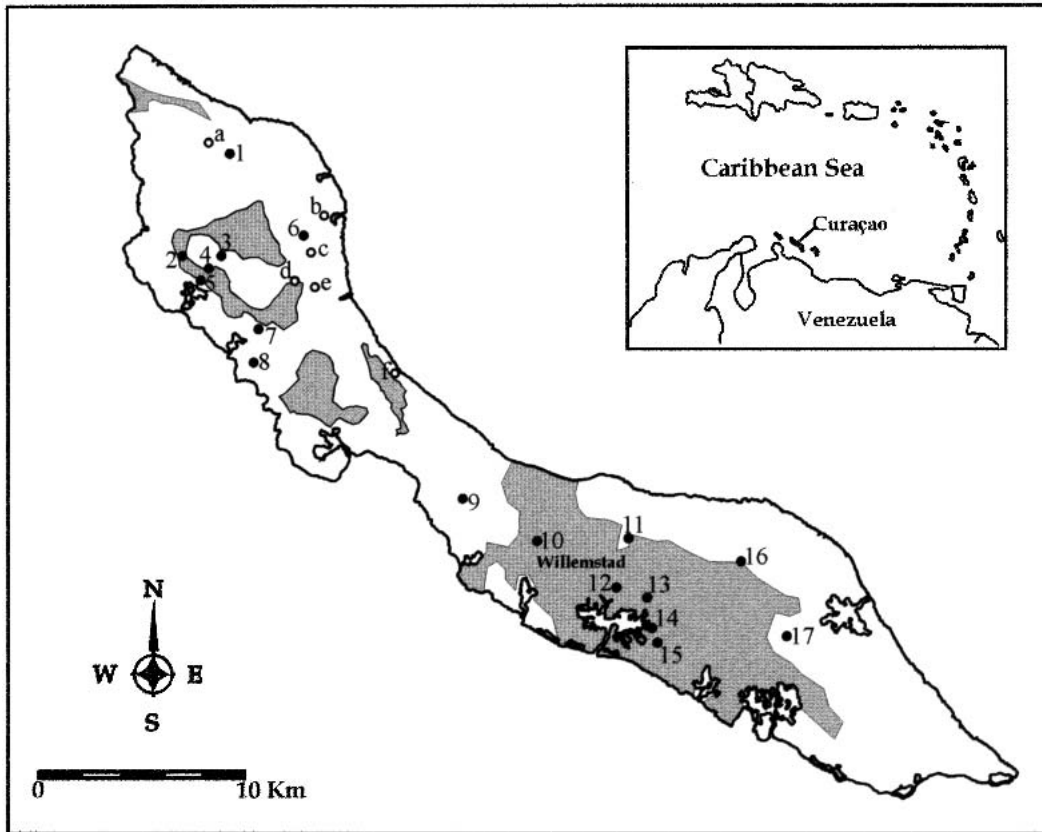


FIG. 1. Main (1-17) and supplemental (a-f) collection sites. Shading indicates populated areas.

tions or specimens were obtained from six supplementary sites which were only briefly sampled (sites a-f, Fig 1.). Ranges for water parameter measurements for the main study sites were pH: 7.15-9.15, conductivity: 1201-8780 μ S; salinity: 0.6-4.8 ppt. Supplementary sampling sites were similar except for site b, which was hypersaline. Only two study sites were higher than 30 m above sea level. Details of habitat parameters for each site, including water depth and altitude above sea level, are found in Debrot (in press). Fish sizes are reported in terms of cm total length (TL). Voucher specimens of all species are deposited in the collections of the Zoological Museum of Amsterdam (ZMA) and their collection numbers are provided. Table 1 provides an overview of the ten species encountered in this survey and their occurrence at each site.

RESULTS

Anguillidae

1. *Anguilla rostrata* (Lesueur, 1817) (ZMA 123.506)

The American eel is one of the few freshwater fishes that has a common name in the Netherlands Antilles. It is locally known as "angieu" (in Papiamentu) and as "aal" or "paling" (in Dutch) (De Boer et al., 1973; Zaneveld, 1983). Aside from the specimens encountered in this survey, Kristensen collected specimens from reservoirs at Dokterstuin, Curaçao (UTM coordinates: ¹⁹492250, ¹³57250), in September 1971, and the road to Lac Bay, Bonaire (UTM ¹⁹582500, ¹³41000), in September 1975 (TL up to 28 cm). I report specimens for three supplementary sampling sites, one of which was

TABLE 1. Freshwater fishes documented at principal (1-17) and supplementary sites (a-f), May-June, 2000, in Curacao. No fishes were found at sites 6, 16, 17, a, c, and f.

Site number/letter	1	2	3	4	5	7	8	9	10	11	12	13	14	15	b	d	e
Site name/location	Rooi Baki, Savonet	Rooi, Sta. Cruz	Dam, Hofi Hooi	Rooi, Hanchi Buriku	Rooi, Kl. Sta. Martha	Dam, Rio Magdalena	Pos di Pia Dr. Maal	Dam di Malpais	Dam De Savaan	Dam di Muizenberg	Rooi, Rio Canario	Dam, Kabouterbos	Roi, Bloempot	Dam Sjera Girouette	Salina, Playa Grandi	Dam, Dokterstuijn	Pos Ariba, Dokterstuijn
<i>Anguilla rostrata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
<i>Oreochromis mossambicus</i>	-	-	+	-	-	+	-	-	+	+	+	-	-	-	-	-	-
<i>Poecilia reticulata</i>	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-
<i>Poecilia vandepolli</i>	-	+	+	+	+	+	+	+	+	+	+	-	+	+	-	-	-
<i>Agonostomus monticola</i>	+	-	+	+	+	-	-	-	+	-	-	-	+	-	-	+	-
<i>Dormitator maculatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
<i>Eretis smaragdus</i>	+	-	-	+	+	-	+	-	-	-	-	-	+	-	+	-	-
<i>Gobionomus dormitor</i>	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Awaous baiana</i>	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	+	-
<i>Evorthodus lyricus</i>	-	-	-	+	+	-	-	-	-	-	-	-	+	-	+	-	-

hypersaline (site b). Specimens measured up to 27.4 cm TL.

This species is reported from as far north as Greenland, throughout most of the West Indies, including the Bahamas and south to Trinidad. Adults, which may reach sizes of 1.5 m, migrate to spawn in the Sargasso Sea.

Cichlidae

2. *Oreochromis mossambicus* (Peters, 1852) (ZMA 123.501, 123.508, 123.510, 123.516)

The Mozambique tilapia was one of the most frequently encountered species in natural or semi-natural freshwater habitats in Curaçao and dominated by far in terms of biomass. Maximum size was 16.9 cm TL. The species was harvested in significant quantities by inhabitants. The only native species found with this exotic were *Agonostomus monticola* and *Poecilia vandepolli*; while the native gobiid and eleotrid components were missing. In Aruba the species was abundant in the water basins built around the natural spring of Fontein (UTM ¹⁹401750, ¹³81625), on 13 March 2000.

This species is native to southern Africa. Eleven specimens from aquaculture ponds in Surinam were introduced to Curaçao by the Caribbean Marine Biological Institute in 1957. The species reproduced well in sea water (Zaneveld, 1959) and was later seeded at various locations in Curaçao and Aruba (Kristensen, 1980). It was also reported by Zaneveld (1983) from unspecified brackish water bays of Curaçao and Aruba. Voous (1979) reported unidentified tilapia for the Bubali pond of Aruba (UTM ¹⁹38675, ¹³93000). Chakalall (1993) lists other species of tilapia imported to the Netherlands Antilles but these were strictly limited to trial culture settings, mainly on Bonaire (G. van Buurt, pers. comm.).

Poeciliidae

3. *Poecilia (Acanthocephalus) reticulata* Peters, 1859 (ZMA 123.504, 123.513)

I found no record or mention of the guppy in the extensive work done on the

wild cyprinodontiforms of the Leeward Islands. Although the species has been present on the island for more than half a century (G. van Buurt, pers. comm.), and was listed for Curaçao by Welcomme (1988), it appears to be a recent exotic in local fresh waters. It has been extensively seeded by the Public Health Service of Curaçao for mosquito control. Apart from seeding, its presence in natural habitats during the rainy season may be due to overflowing wells and agricultural water basins, where it is present year-round.

This species ranges in size from 3.5-5 cm SL. It is native to South America (Venezuela-Brazil) but has been widely introduced elsewhere mainly for mosquito control.

4. *Poecilia (Poecilia) vandepolli* Van Lidth de Jeude, 1887 (ZMA 123.492, 123.493, 123.498, 123.505, 123.509, 123.511, 123.512, 123.514, 123.517)

This species, locally known as "molly" or "machuri", is common and abundant throughout the Leeward Dutch Antilles. It is endemic to these islands but has been apparently introduced into St. Maarten (Poeser, 1992). The species was until recently variously referred to as a subspecies of *P. sphenops* (Kristensen, 1970; Feltkamp and Kristensen, 1970; Kristensen and Hulscher-Emeis, 1972). This fish is found in salinities ranging from fresh to 135 ppt and is common in hypersaline and fresh water. It was the most frequently encountered species during the survey (Table 1) and is commonly seeded to combat mosquitos.

Cyprinodontidae

5. *Cyprinodon dearborni* Meek, 1909

The broad killifish, locally known as "barigonchi", is a common and abundant species in the Leeward Dutch Antilles. It has been amply documented for Curaçao, as well as Aruba and Bonaire, and is no doubt native to the three islands. It is also native to Venezuela and Colombia. This fish is found in salinities ranging from fresh to 130 ppt, but is rarely found in salinities lower than 35 ppt (Kristensen, 1970; Kristensen and Hulscher-Emeis, 1972). Its gen-

eral preference for higher salinities likely explains why it was not encountered in this survey. Records of *Cyprinodon riverendi* and reference to *C. variegatus riverendi* by Metzelaar (1919) actually refer to this species (De Beaufort, 1940). This predaceous fish grows to a maximum size of 4 cm.

Aplocheilidae

6. *Rivulus marmoratus* Poey 1880

The mangrove rivulus has been amply documented for the Leeward Dutch Antilles. Hoedeman (1958) described specimens from these islands as a distinct subspecies (*Rivulus marmoratus bonairensis*). Earlier records of *Rivulus cylindraceus* Poey, 1861, from Bonaire by De Beaufort (1940) represent *Rivulus marmoratus* according to Hoedeman (1958). The species is found in salinities ranging from fresh to 70 ppt, but is rare in salinities below 40 ppt (Kristensen, 1970). In Bonaire it is commonly reported from fresh and brackish water caverns (Hoedeman, 1958; Wagenaar Hummelinck, 1979). It was not encountered in this survey, probably due to its preference for higher salinities and association with karst waters.

The species ranges from Florida and the Bahamas throughout the West Indies to southeast Brazil (Robins and Ray, 1986; Taylor, 2000). Maximum size of this predatory species is 7.5 cm. It is the only vertebrate known to be a self-fertilizing hermaphrodite (Taylor, 2000); males have been rarely encountered in the wild (Taylor, 2000).

Mugilidae

7. *Agonostomus monticola* (Bancroft, 1834) (ZMA 123.506)

Previous records for the mountain mullet are by De Beaufort (1940) for Pos Ariba, Dokterstuin (site e), and by Kristensen (unpubl. data) for Zevenbergen (UTM ¹⁹486100, ¹³62250) for September 1971 (TL up to 25 cm). This is the second most common species in fresh water in Curaçao. The largest specimen from this survey mea-

sured 14.6 cm TL. On 13 March 2000, I observed four specimens in a stream pool in Rooi Buraché at Papilon, Aruba (UTM ¹⁹396625, ¹³81375), thus documenting the species on this island.

This species occurs from North Carolina to Venezuela and throughout most of the West Indies, but is considered rare in fresh waters from the Gulf of Mexico. The species spends its adult life in fresh water (Cruz, 1987) and is catadromous or amphidromous. Elsewhere, it is reported to reach 36 cm TL and is caught for consumption (Thompson, 1978).

Eleotridae

8. *Dormitator maculatus* (Bloch, 1792) (ZMA 123.515)

De Beaufort (1940) listed one record for the fat sleeper from a seawater pool in Curaçao. I found two specimens at one freshwater stream site (site 14). The species ranges from North Carolina, the Bahamas, and Gulf of Mexico throughout most of the West Indies south to Brazil. It is found mostly in fresh water, but also in brackish mangrove areas and is euryhaline (Nordlie and Haney, 1993). It is primarily detritivorous (Winemiller and Ponwith, 1998) and seldom exceeds 25 cm in length (Robins and Ray, 1986).

9. *Eleotris perniger* (Cope, 1871)

Metzelaar (1919) records this species from an unspecified location in Curaçao. In the literature, *E. perniger* has generally been reported as *E. pisonis* (Gmelin, 1789) but the latter is a continental South American species ranging only from southern Brazil to eastern Venezuela (Pezold and Cage, 2002). While all more northerly records refer to *E. amblyopsis* (Cope, 1871) or *E. perniger*, records of *E. pisonis* from the Antilles predominantly refer to the latter (Pezold and Cage, 2002). Kristensen (unpubl. data) recorded numerous specimens measuring up to 10.4 cm TL from Zevenbergen (UTM ¹⁹486100, ¹³62250) in September 1971 (as *E. pisonis*). Records from freshwater caverns in Bonaire (as *E. pisonis*) were provided by De Beaufort (1940) and Kristensen (1970),

the latter of whom reported predation by the species on *Rivulus marmoratus*. According to Zaneveld (1983), in the Netherlands Antilles this species has the local name "angieu", which is more typically used for the American eel. Specimens were not collected during this survey, apparently due to the species' association with oligohaline waters on these arid southern Caribbean islands.

This species ranges from Bermuda and the Bahamas south to Rio de Janeiro; in these areas it occurs in fresh waters and estuaries, including caverns. The species has been documented up to 60 m above sea level (Pezold and Cage, 2002). Its maximum size is 25 cm TL and it feeds mostly on small crustaceans and fish (Pezold and Cage, 2002).

10. *Erotelis smaragdus* (Valenciennes, 1837)
(ZMA 123.496)

The emerald sleeper was collected at six sites in Curaçao (1, 4, 5, 8, 14, b). While no previous records in fresh water could be confirmed for Curaçao, Aruba, or Bonaire, Metzelaar (1919, 1922) provides unspecified records from Bonaire and saltwater records from Curaçao. According to Zaneveld (1983), this species (like *Eleotris perniger*) has the local name "angieu", which is more typically used for the American eel.

The emerald sleeper is found from southeastern Florida, the Bahamas, and Gulf of Mexico, south to Brazil. It occurs mostly in marine coastal waters but also enters brackish and fresh water. Its maximum size is 20 cm (Robins and Ray, 1986).

11. *Gobiomorus dormitor* Lacepède, 1800
(ZMA 123.499)

The bigmouth sleeper had not been reported from fresh waters in Curaçao. It was found at two stream sites in the same drainage system (4 and 5, Table 1). This is the largest eleotrid of the Western Hemisphere and may reach up to 60 cm (Robins and Ray, 1986; Gilmore, 1992). It ranges from South Florida throughout most of the West Indies south to Venezuela. In Puerto Rico the species is considered a game fish. This

eur haline species is typically found in flowing fresh water, where it feeds on fishes and crustaceans (Gilmore, 1992; Winemiller and Ponwith, 1998). Its ecology in an insular setting was studied by Bacheler (2002).

Gobiidae

12. *Awaous (Chonophorus) banana*
(Valenciennes, 1837) (ZMA 123.502,
123.507)

De Beaufort (1940) recorded the river goby at Pos Ariba, Dokterstuin (site e). Records by Kristensen (unpubl. data) for *Awaous tajasica* (Lichtenstein, 1922) from Zevenbergen (UTM ¹⁹486100, ¹³62250), in September 1971, and measuring up to 20 cm TL, probably refer to *Awaous banana*, with which it may easily be confused and which may have led to many uncertain records in the West Indies (Watson, 1996). The species was found at four sites during this survey (4, 5, 14, d).

The river goby ranges south from South Carolina throughout most of the Antilles to Brazil. Adults occur in fresh water, feed mostly on algae, and grow to 30 cm SL.

13. *Evorthodus lyricus* (Girard, 1858) (ZMA
123.494, 123.495, 123.503)

The lyre goby was found at four freshwater sites (4, 5, 14, b). Metzelaar (1922) and Nagelkerken (unpubl. data) provide saltwater records for Curaçao. The lyre goby is found from the Chesapeake Bay south to the Greater Antilles and from the Gulf of Mexico to northern South America (Robins and Ray, 1986). Cervigon (1994) reported the species from muddy bottoms of fresh water habitats in Venezuela. Little is known about the species other than its occurrence in muddy backwaters of bays and estuaries. Maximum size is 9 cm.

DISCUSSION

This paper presents seven new fish records from natural and semi-natural fresh waters of the island of Curaçao, thus increasing the freshwater fish fauna of the

island to 13 species. Two fresh water records for Aruba and one for Bonaire are also included. Ten of the 13 species known for Curaçao were collected during this survey, eight of which are native and two were exotic.

Many other marine and estuarine species frequent fresh waters, but they have not been documented from fresh water in Curaçao. Two possible exceptions are the snook and the white mullet. Metzelaar (1919) provides a record of snook, *Centropomus undecimalis* (Bloch, 1792), from fresh water in Curaçao. De Boer et al. (1973) reports white mullet, *Mugil curema* Valenciennes, 1836, as entering salinas when these become inundated by fresh water (a common occurrence in Curaçao). These species were not included in the above listing because they do not ascend small streams to a significant extent and are normally not found in confined freshwater bodies such as cavern waters.

The record of *Erotelis armiger* for Aruba by De Beaufort (1940) must be erroneous because this species is only known to occur along the Pacific coast of Mexico south to Panama. Kristensen (unpubl. data) found two unidentified gobiids at Sta. Cruz, Curaçao, which he thought to be *Sicydium* spp., but the presence of this genus in Curaçao was not substantiated by the current survey.

Although the native freshwater fish fauna was dominated by predatory eleotrids and gobiids, the most frequently encountered species was the endemic *Poecilia vandepolli*. The second most frequent species was the native *Agonostomus monticola*, while the exotic *Oreochromis mossambicus* and the native *Erotelis smaragdus* tied for third position.

The presence of amphidromous native fishes in the fresh waters of Curaçao requires that species migrate into fresh water from the sea. Therefore, high dams, excessive damming, or channelization which eliminate or severely disrupt surface water flows can have a substantial impact on the native fauna. Of the 17 main sampling sites, three (6, 16, 17) had no fish and at six others (7, 9, 11, 12, 13, and 15) the fauna was limited to one or more of the three nonamphi-

dromous species commonly seeded for mosquito control. Seven of these nine impoverished sites were clearly isolated from the sea by dams and channelization that eliminated or severely disrupted surface flow.

The freshwater epigeal habitat in which most of these species were found is available seasonally. During the dry season, usually lasting anywhere from 8-10 months, fresh water is very scarce and the question arises as to how this fauna persists on the island. Six of the species are euryhaline, and often spend all or most of their life in brackish or saltwater. Many of these species, hence, are not amphidromous, but only opportunistically live in fresh water. The exotic species *Oreochromis mossambicus* and *Poecilia reticulata* also successfully complete their lifecycle in waters of a single salinity and are not amphidromous.

Aside from marine or brackish mangrove areas, possible habitats for dry season survival include accessible pools or wells along drainage areas, rare feeder springs, and subterranean karst waters. However, only three fish species have been found in karst waters (*Cyprinodon dearborni*, *Rivulus marmoratus* and *Eleotris perniger*) and probably none of them exclusively depend on karst waters for dry season survival.

Some species may not survive as adults, but recruit each season from pelagic larvae originating elsewhere. For instance, the larvae of *Anguilla rostrata* migrate large distances back to their natal streams. Other species with pelagic larvae are *Awaous banana*, *Agonostomus monticola*, and *Eleotris* (F. Pezold, pers. comm.).

Oreochromis mossambicus and *Poecilia reticulata* are relatively recent introductions to natural and/or semi-natural habitats in Curaçao, with regular seeding by the Public Health and Agricultural Services of Curaçao for mosquito control dating from the early 1980s (G. van Buurt, pers. comm.). Apart from seeding, their presence in natural/semi-natural habitat in Curaçao during the rainy season may be due to overflowing wells and agricultural water basins, where both species are present year-round. In addition, their survival during the dry season in natural fresh, brackish, or marine waters

is likely (Zaneveld, 1959, 1983; Kristensen, 1980; Lobel, 1980). *Oreochromis* adults are largely herbivorous but juveniles are carnivorous. Because of the species' ecological plasticity and tendency to dominate the fish biomass of systems it invades, *O. mossambicus* is generally considered to cause adverse ecological impacts (Randall, 1987; Bunkley-Williams et al., 1994). For instance, it has been indicated as a major factor in the decline of a desert pupfish in California (Fuller et al., 1999). In Curaçao this species dominated the fish biomass in the three marine-linked systems in which it was found (sites 3, 10, 12), while the native gobiid and eleotrid species were missing. *Oreochromis mossambicus* should be closely monitored and should not be seeded again; mosquito abatement programs should favor the small native species.

In Curaçao, naturally occurring freshwater habitat is limited and vulnerable to human impact, among which are water extraction, impoundment, channelization, and contamination (e.g., Sambeek et al., 2000). Aside from harboring the fish fauna documented here, the island's fresh waters include a rich endemic hypogean crustacean fauna (eg., Stock, 1977, 1980), nine species of freshwater shrimps (Debrot, in press), and two freshwater sponges (Debrot and Van Soest, 2001). The results of these and other studies indicate that the conservation of natural freshwater habitat and associated fauna in the Leeward Netherlands Antilles will have to provide special attention to the maintenance of a viable marine-freshwater linkage, the protection of water quality, and possibly even the control of non-native species.

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