FRESHWATER FISH ASSEMBLAGES IN CYPRUS WITH EMPHASIS ON THE EFFECTS OF DAMS

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Background. The distribution of freshwater fishes in Cyprus is poorly known. The island is particularly interesting because of its biogeographical isolation and the long-term influence of humans on the biota, especially due to the recent damming of many rivers. This study documents preliminary baseline freshwater fish assemblage patterns including insights on the impact of the dams.

Materials and methods. Site-specific fish presence data were gathered using a backpack electrofishing device, literature reviews and unstructured expert interviews.

Results. A total of 53 aquatic sites in 18 river basins of Cyprus were surveyed, most of which have dam reservoirs along parts of their channels. The survey confirms the existence of sixteen fish species of which 12 are non-indigenous. Native species were found at very few sites, although the European eel was reported to be ubiquitous. Twenty-four sites sustained non-indigenous fish (45% occurrence at all sites, or 60% at all sites with fish present). Reservoir dams were the most species-rich generic habitats but hosted almost exclusively non-indigenous species.

Conclusion. Cyprus' streams are characterized by a scarcity of fishes. The absence of primary- and primary-like native species is attributed to the palaeogeography of the island which has not been connected to the continent since the Messinian Salinity Crisis. At present, only two peripheral (*Anguilla anguilla* and *Salaria fluviatilis*) and one secondary (*Aphanius fasciatus*) native inland fish species are reported. These, along with euryhaline marine transient species suffer from the extensive degradation of natural riverine habitats. Dams influence riverine fish assemblages by degrading downstream aquatic habitats, impeding fish movements, and by providing refuges for non-indigenous fish populations.

Keywords: freshwater fishes, fish communities, non-indigenous species, native species conservation, reservoirs

INTRODUCTION

Cyprus is an eastern Mediterranean island-state that hosts an estimated 108 dams; it therefore has one of the densest dam reservoir concentrations in the European Union (Anonymous 2006). The majority of dams have been developed in Cyprus in the 1960s and 1980s facilitating extensive river water abstraction, primarily for irrigation (Omorphos et al. 2005). Therefore, most rivers are intersected by dams and have altered natural flow regimes. Moreover, there is a remarkable lack of knowledge of natural flow conditions and aquatic biotic communities before the dam building (Charalambidou and Gücel 2009), including baseline knowledge of the native inland fish fauna (Zogaris et al. 2011).

Taking biogeographic factors first, Cyprus' inland waters have a distinctly insular geological history, being

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located on an island within a semi-arid region. Cyprus arose from the sea due to tectonic changes during the Mesozoic (22 million year ago) and has been isolated from the surrounding mainland with the exception for a short-term connection with the arid Levantine coast of western Asia during the Messinian Salinity Crisis, about 5 million year ago (Böhme and Wiedl 1994, Hadjisterikotis et al. 2000). There is no evidence that Cyprus' rivers ever had river-confluences with basins of the adjacent mainland during this short period when the eastern Mediterranean Sea sea bed resembled a vast saline desert (Baier et al. 2009). However, fossil evidence shows that extensive inland freshwaters did exist on Cyprus during this time (Hadjisterikotis et al. 2000, Kassapis 2011) and we can assume some fish species could have colonized them. Today, Cyprus' inland freshwater fish fauna is known to comprise solely of three native inland water fishes, namely, only two peripheral: European eel, *Anguilla anguilla* (L.) and freshwater blenny, *Salaria fluviatilis* (Asso, 1801) and one secondary: Mediterranean toothcarp, *Aphanius fasciatus* (Valenciennes, 1821) (see Bianco et al. 1996, Kottelat and Freyhof 2007). Euryhaline marine fish such as mugilids are also known to enter inland waters locally. It is not known if the depauperate freshwater fish fauna of Cyprus is solely a result of biogeographic isolation or related to extended periods of local aridity, and/or recent anthropogenic habitat degradation.

There is no doubt that humans have greatly altered aquatic environments on Cyprus for hundreds of years. Cyprus' inland waters currently host several non-indigenous fish (Anonymous 1998) introduced recently by humans, but specific distributions of most of these are very poorly recorded (Elvira 2001, Froese and Pauly 2012). One of the most important biodiversity conservation issues facing Cyprus concerns the ecological integrity of its inland waters; and building fundamental knowledge baselines utilizing fish is now a policy-relevant imperative (Anonymous 2000).

We surveyed fish assemblages in various inland water bodies in Cyprus, particularly focusing on basins with perennial streams and dams, especially in the more humid western part of the island. Our aim here is to provide the island's first description of current freshwater fish distribution patterns, and to explore the effects of the many dams on the fish assemblage composition.

MATERIALS AND METHODS

We conducted the first broad-scale survey of freshwater fish in Cyprus (Fig. 1, Table 1) using both site-based electrofishing, expert interviews, and a literature search during the spring/summer periods of 2009, 2010, and spring of 2011. Two backpack electro-fishers (Bulgarian custom-made unit, 700 v. and a Smith-Root L24 980 v.) were used to collect fish presence/absence data. Sampling site selection was based on aquatic feature representativeness and accessibility. The fish recording technique followed a rapid search-find procedure where stream site fish were collected by a two- or three-person team in a procedure similar to standard river fish sampling protocol (Anonymous 2004). Only one sampling run was conducted at each site and the longitudinal distance usually covered was at least 30 m of river stretch. All wadable habitats were carefully sampled for fish and if no fish were found sampling usually continued for at least 120 m of the river stretch. The size of sampling area varied with the stream size and local accessibility. At some sampling locations inaccessibility or lack of water forced the research team to sample less than the standard 100 m length; but 30 m was the bare minimum. All fish specimens were immediately released once numbers and size classes of each species were recorded. Habitat features were carefully recorded at each site; categorizing each sampling site by dominant generic habitat type.

To complement electrofishing, a species presence-absence review was conducted through the available grey literature and through interviews with knowledgeable local researchers (see acknowledgements). Expert naturalists and professional biologists reviewed all the sites that were visited during sampling and provided data on presence-absence of species. Obviously, wherever ambiguous or questionable anecdotal information existed, the interview responses are ignored; and, we clearly state data acquisition method for each species record in each site.

Relative degradation pressures imposed by the proximity of dams, situated upstream and/or downstream of the researched sampling sites were provisionally assessed by expressing the distance of each sampling site to a dam or major water obstruction (i.e., the irrigation reservoir or water diversion structure). An arbitrary scaling assessment is applied in order to outline conspicuous fish distribution attributes relative to the positions of the dams in the longitudinal river dimension. In this way, a 5-point scale pressure categorization was implemented as follows: 1 = no dam present upstream or downstream of sampling site; 2 = dam at least 10 river km away from sampling site; 3 = dam 5 km to 10 km away; 4 = dam less than 5 km; 5 = site located at or within dam's reservoir. This simple dam distance gradient relative to the position of the dams may assist in interpreting general fish distribution

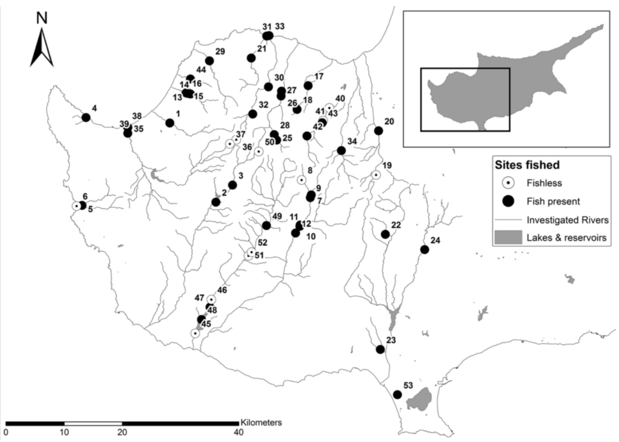

Fig. 1. Investigated sites and rivers in the western part of Cyprus (see Table 1)

Table 1

Detailed characteristics of individual sampling sites

Site No.	Site name	GIS coordinate X	GIS coordinate Y	Fish	Method	DPUS	DPDS	Basin
1	Fragma Argaka	454560.52	3878525.29	1	2	5	5	Makounta
2	Fragma Kannaviou	462490.65	3864912.93	1	2	5	5	Ezousa
3	Panagia Diakou Agia	465351.69	3867856.10	1	1	1	3	Ezousa
4	Aphrodites baths	440161.74	3879471.00	1	3	1	1	Agios Ioannis
5	Avakas	439479.86	3864356.37	1	1	1	1	Avgas
6	Avakas Mouth	438542.67	3864247.85	0	2	1	1	Avgas
7	Agios Avvakoum	478886.68	3866158.68	1	1	1	2	Diarizos
8	Milikouri Spring	477228.42	3868733.36	0	2	1	2	Diarizos
9	Pareklissoudi	478716.13	3865697.33	1	1	1	2	Diarizos
10	Us Gef Kelefou	476960.13	3860969.25	1	1	1	4	Diarizos
11	Ds Gef Kelefou	476924.72	3860767.23	1	1	1	4	Diarizos
12	Fragma Arminou	476924.72	3860767.23	1	1	5	5	Diarizos
13	Gialia Seep Pond	457738.80	3883704.35	0	1	1	1	Gialia
14	Gialia Us Spring	458113.43	3883520.98	1	1	1	1	Gialia
15	Gialia Spring	457616.55	3883626.42	1	1	1	1	Gialia
16	Gialia Ds spring	457354.51	3883709.65	1	1	1	1	Gialia
17	Fragma Galinis	478453.04	3885114.12	1	4	5	5	Kampos
18	Kampos 1	476441.38	3880873.97	1	1	1	1	Kampos
19	Us fishfarm Kargotis	490010.14	3869600.61	0	1	1	1	Kargotis
20	Gef Evrychou	490445.95	3877193.73	1	1	1	1	Kargotis
21	Fragma Katouri	468565.96	3889715.91	1	4	5	5	Katouris
22	Mesa potamos Kouri	491613.06	3859368.56	1	1	1	2	Kouris
23	Frag Kantou	490749.67	3839562.52	1	2	5	5	Kouris
24	AgMamas Limnatis	498364.06	3856743.97	1	1	1	2	Kouris
25	Fragma Tsakistras	472920.28	3875592.39	1	2	5	5	Limnitis
26	Kat Gef Limniti	473771.90	3884006.11	1	1	2	1	Limnitis
27	Gef Limniti	473685.56	3883173.89	1	2	2	1	Limnitis
28	Gef Mavres Sykies	472510.41	3876528.71	1	1	4	1	Limnitis
29	Fragma Pomou	461396.48	3889063.57	1	3	5	5	Livadi
30	Pirgos 1	471519.54	3884741.94	1	1	1	1	Pyrgos
31	Kato Pirgos	471217.59	3893488.52	1	2	1	1	Katouris
32	Vrondisia	468827.41	3880069.30	1	1	1	1	Pyrgos
33	Ekv PlatisPyrgoy	471624.33	3893566.73	1	1	1	1	Pyrgos
34	Fragma Kalopanagioti	484093.85	3873586.74	1	3	5	5	Marathasa
35	Polis Crys 1	447357.37	3877754.73	1	1	2	1	Chrysochou
36	Stavros kat camping	465988.66	3875664.23	0	2	1	2	Chrysochou
37	Stavros Psokas 1	464880.05	3874947.44	0	2	1	2	Chrysochou
38	Polis Mouth 1	447060.07	3878118.45	1	1	2	1	Chrysochou
39	Polis Mouth 2	447341.80	3876761.21	1	1	2	1	Chrysochou
40	Gef Xerou Lefkas	481985.53	3881119.62	0	2	4	4	Xeros(Lefkas)
41	Kat Fragma Kafiziedes	480818.84	3878699.20	0	1	4	3	Xeros(Lefkas)
42	Fragma Kamenou Paidiou	478140.95	3876296.33	1	4	5	5	Xeros(Lefkas)
43	Fragma Kafizides	480731.40	3878542.41	1	2	5	5	Xeros(Lefkas)

Table 1 (cont.)

Site No.	Site name	GIS coordinate X	GIS coordinate Y	Fish	Method	DPUS	DPDS	Basin
44	Fragma Ag Marina	458112.45	3886098.90	1	2	5	5	Xeros (Ag. Marina)
45	Asprokremma Ponds	458939.57	3842342.04	0	1	4	1	Xeros(Pafos)
46	Gef Choletria	461696.22	3848151.80	0	1	1	4	Xeros(Pafos)
47	Finikas d/s prodam	461476.01	3846841.79	1	1	4	4	Xeros(Pafos)
48	Frag Asprokremmou	458939.57	3842342.04	1	1	5	5	Xeros(Pafos)
49	Gef Roudias	471289.42	3860966.64	1	1	1	2	Xeros(Pafos)
50	Spring Dixaloi	469843.51	3873628.34	0	2	1	2	Ezousa
51	Gef Salamiou Xeros	468081.17	3855699.27	0	1	1	2	Xeros(Pafos)
52	Perasma Xeros	468626.36	3856313.56	0	1	1	2	Xeros(Pafos)
53	Alyki Akrotiri	495655.08	3830566.91	1	3	1	1	Kouris

Site No.—as presented on map in Fig. 1; Site name—the arbitrary name proposed by authors; Fish presence codes: 0 = no fish; 1 = fish confirmed; Method—data acquisition method (in progressively decreasing reliability of data): 1 = Electrofishing, 2 = visual observation at site and/or expert interview, 3 = expert documentation and/or literature, 4 = literature documentation; DPUS = dam proximity upstream, DPDS = dam proximity downstream; Dam proximity codes: 1 = no dam present upstream of sampling site, 2 = dam at least 10 river km; 3 = dam 5 km to 10 km; 4 = dam less than 5 km; 5 = site located at or within dam reservoir; Basin = site's watershed name.

patterns in relation to dams. All data were entered into a simple relational database supported by GIS site locations. SPSS 13.0 for Windows software and Primer (Ver. 6) software were used for statistical analysis for the presentation of relevant data.

RESULTS AND DISCUSSION

Species-richness: non-indigenous versus native. In total, 18 river basins were researched and ichthyological information was acquired from 53 sites; however only 35 sites were electrofished. Fourteen species of fish were collected during electrofishing, while another two taxa are confirmed in the grey literature review and/or through the expert interviews and field observations with respect to the specific inspected sites (Table 2). Of this list, two taxa remain unidentified to species level, a grey-mullet species (Mugilidae; reported by local experts at Chrysochou and Akrotiri) and a species of tilapia (*Oreochromis* sp.; recorded by local experts at Asprokremmos Reservoir and observed from shore at an adjacent artificial channel). Collectively, evidence regarding fish presence was recorded in 40 surveyed sites (75% of surveyed sites) (Fig. 1, Table 1). The average number of species per site was 1.9 ± 2.04 SD (range: 0–8). Dam type sites had an average of 4.2 ± 2.49 SD species (Fig. 2). By international standards Cyprus' stream site species-richness is considered very low for stream fish faunas, although, worldwide, islands are known to have very restricted numbers of freshwater fish (Bianco et al. 1996, Mathews 1998).

Twenty-four surveyed sites had non-indigenous fish (45% occurrence in all sites). Evidence for native fish presence was gathered at 28 sites (53% occurrence); nearly all of these sites were reported to host European eel (*Anguilla anguilla*), the most widespread native fish by far (51% occurrence). However, if we do not consider information from the interviews and the scant literature, the observed occurrence of native fish is surprisingly low. Eels were collected/observed at only four sites in three river systems, flathead grey mullet, *Mugil cephalus* L., were found at one river-mouth site, and the only other inland fish, Mediterranean toothcarp, *Aphanius fasciatus*, was found at only one lagunal site.

Species assemblages and inland water typology. A cluster analysis of sites with confirmed and documented fish presence (n = 40) clearly separates fish assemblages between reservoir and non-reservoir groups (cut-off of approximately 20% similarity) (Fig. 2). Within the non-reservoir group there are distinctive cold-water rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792), and brown trout, *Salmo trutta* L., groups, and a large eel-only cluster. The reservoirs show a heterogeneous array of assemblages among them, eel-only sites are obviously more similar to each other, while the trout-dominated sites are only slightly more similar to each other than the reservoir sites. Perhaps the remarkably low number of river-mouth or coastal wetland fish assemblages is a result of anthropogenic degradation in the river's connectivity to the sea (due to extensive water abstraction upstream of the river mouths).

The survey inspected sites belonging to nine generic habitat types (Fig. 3). The reservoir, perennial stream, and coastal lagoon generic habitat types have the majority of fish species (Fig. 4). The eel and rainbow trout are most widespread in a variety of habitats and sites; while eastern mosquitofish, *Gambusia holbrooki* Girard, 1859, and roach, *Rutilus rutilus* (L.), are the next most frequent and

Table 2

Distribution of the 16 freshwater fish taxa at specific sites (n = 53) in 18 river basins in Cyprus within 2009–2011

River (No. of sites)	*Anguilla anguilla*	*Gambusia holbrooki*	*Oncorhynchus mykiss*	*Cyprinus carpio*	*Rutilus rutilus*	*Salmo* cf. *trutta*	*Micropterus salmoides*	*Ictalurus punctatus*	*Blicca bjoerkna*	*Alburnus alburnus*	*Lepomis gibbosus*	Mugilidae gen. sp.	*Aphanius* cf. *fasciatus*	*Oreochromis* sp.	*Carassius auratus*	*Mugil cephalus*	Sum species/ basin
Xeros (Pafos) (7)	◊	◊	♦	◊	♦	♦	♦	♦	◊					♦			10
Diarizos (6)	♦	◊	♦	◊	♦	♦			◊		♦						8
Makounta(1)	◊	◊		◊	◊		◊	♦									6
Xeros (Ag. Marina) (1)	◊	◊		◊	♦		♦	♦									6
Ezousa (2)		◊	♦		♦					♦	♦						5
Kouris (4)		♦	♦			♦						◊	♦				5
Xeros (Lefkas) (4)		◊	♦	◊	♦										♦		5
Marathasa (1)		♦	♦	♦	♦	◊				♦							6
Limnitis (4)	◊	◊	♦	◊													4
Livadi (1)		◊		◊	♦		♦										4
Chrysochou (5)	♦											◊				♦	3
Kargotis (2)	◊		♦														2
Katouris (2)	◊	◊															2
Agios Ioannis (Akamas) (1)	◊																1
Avgas (2)	◊																1
Gialia (4)	◊																1
Kampos (2)	◊																1
Pyrgos (4)	♦																1
Sum basins/species	13	11	8	8	7	4	4	3	2	2	2	2	1	1	1	1	

◊ published- and unpublished sources, ♦ field observations.

widespread in a variety of habitat types (Fig. 4). The majority of species are located within the dam reservoirs or very close to them, especially those fishes typifying the reservoir lacustrine community. Typical lacustrine species are scarce beyond more than 5 km upstream or downstream of reservoirs (Fig. 5).

Several of the surveyed sites showed obvious hydromorphologically degraded conditions and although reference conditions cannot be documented, evidence for extensive recent anthropogenic changes in water surface conditions is widespread. Signs of severe waters stress are common in the lowland and mid-sections of rivers, as indicated by excessive anthropogenic abstraction that has lowered dry-season water levels and stream flow (see Zogaris et al. 2011). Several streams reported as being perennial flowing in the past were found to be in artificially intermittent state, where only pools and desiccated river beds were left behind by early summer, presumably due to anthropogenic overexploitation as is prevalent in many eastern Mediterranean rivers (Skoulikidis et al. 2011). Circumstantial observations provide evidence that anthropogenic obstacles impacting river connectivity such as weirs and flow-meters frequently impede native fish dispersion through river drainage networks; and this may stall non-indigenous fish species dispersal also. However, another reason for less surface water in streams and generally poorer fish habitats in Cyprus in recent years may also be related to recent climatic change phenomena. Since 1970 there has been a notable decrease in precipitation (Klohn, unpublished*), and several prolonged desiccating droughts have occurred (Michaelides and Pashiardis 2008). The combined pressures of widespread water retention in dams, river water transfers, obstacles to fish-movements, surface water over-exploitation, pollution and decreasing precipitation seem to have had a broad-scale impact on lotic ecosystems during the last three decades.

Native species. Freshwater fish are scarce in the streams of western Cyprus, and interviews with experts suggest that nearly all native fish have contracted their present-day distributions in recent decades, especially the eel. The presence of eel was not easily detected in our survey often due to difficulties in capturing this cryptic fish under conditions which were adverse for electrofishing.

* Klohn W. 2002. Reassessment of the island's water resources and demand of the island of Cyprus. Synthesis report. Water Development Department (WDD) and Food and Agriculture Organization of the United Nations (FAO), Ministry of Agriculture, Natural Resources and Environment, Nicosia, Cyprus.

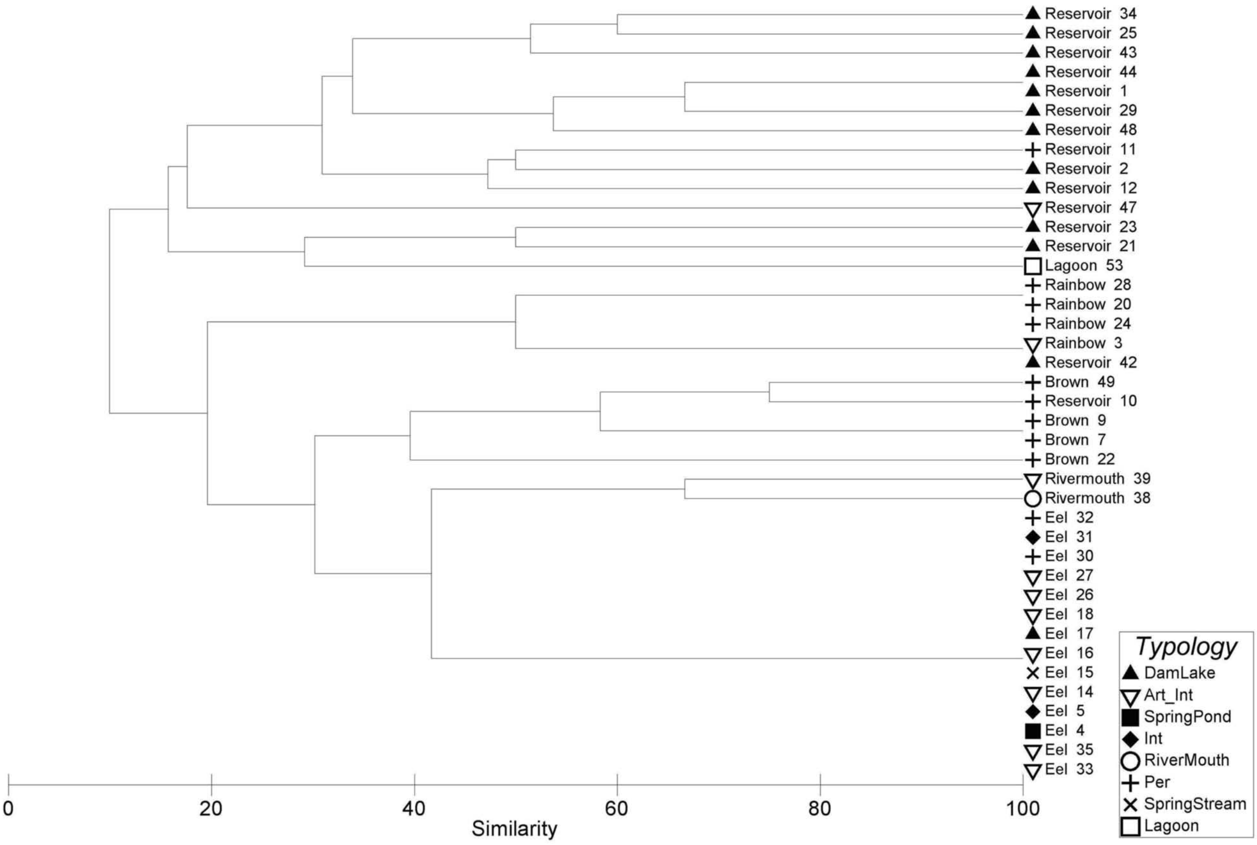

Fig. 2. Cluster analysis dendrogram using Jaccard coefficient of similarity classifying sites (n = 40) based on species assemblage similarity; Each site is presented with respect to its generic habitat type, the dominant assemblage identity as defined in this analysis and the specific site numerical location mapped on Fig. 1; Codes: Eel = sites dominated by *Anguilla anguilla*; Rivermouth = sites dominated by marine euryhaline species; Rainbow = sites dominated by *Oncorhynchus mykiss*; Brown = sites dominated by *Salmo trutta*; Reservoir = sites dominated by lacustrine fishes; Lagoon = hypersaline coastal wetlands

Eel capture with electricity was sometimes impeded by locally high conductivity waters, low water-levels potentially forcing eels to move to summer refugia, and habitat constraints such boulder-strewn substrates or reed beds. However, 13 of the 18 stream basins studied in this survey were reported to have eels. This may not, however, reflect the current state of eel distribution in western Cyprus. Twelve of the river basins investigated have high irrigation dams that probably block eel passage to the

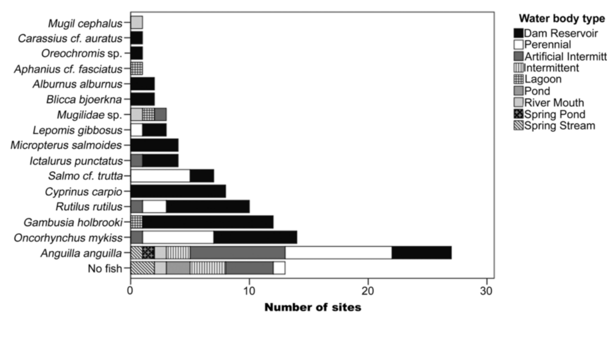

Fig. 3. The relative frequency of occurrence of fish species (presence in number of sites) in relation to the water body type

respective stream's upland sections. The majority of streams are effectively starved of their downstream summer flows due to water diversions for irrigation. As a result many lowland wetland and summer-refuge instream habitats have largely become unsuitable for eel survival. Obviously, many anthropogenic obstructions to eel movement become more permanent during long periods of drought. In fact, only two locations were detected where a stream had an open flowing outfall to the sea during early summer; and these coincided with the only locations where "glass eels" were recorded by us on the island. Moreover, this connectivity degradation is corroborated by the fact that fish species of marine origin (e.g., the Mugilidae) currently have an extremely restricted distribution in Cyprus' inland waters.

From a conservation standpoint, a mystery surrounds the low species richness of native freshwater fish. There are very few ways that Cyprus could be colonized/re-colonized by freshwater fish although it was connected to the Asian mainland for a relatively short period—during the Messinian Salinity Crisis (approximately 5.59–5.33 million years ago) (Baier et al. 2009). Apart from formerly euryhaline species or diadromous migration by salt-tolerant species (i.e., potentially salmonids during the glacial periods) only species that could be transported by man or other animals may have reached the island. The ancestor of the freshwater blenny (*Salaria fluviatilis*) for example, is said to have been a euryhaline species, allowing incursions into fresh water and subsequent dispersal via the sea (Almada et al. 2009). However the freshwater blenny on Cyprus is not reported in any recent survey (Bath 2003) and is not known by the island's ichthyologists. This species is extremely vulnerable to habitat degradation and longitudinal river connectivity changes (Côtė et al. 1999, Benejam et al. 2010) and may now be extremely rare on the island, if it still exists. Obviously the extinction pressure on semi-arid islands is heightened within restricted aquatic habitats, especially where only rather small isolated river basins exist, such as on Cyprus (Adams and Warren 2005). If Cyprus ever had native freshwater fish species it is nearly certain that they may have been lost due to increased aridity events or a combination of climatic and anthropogenic pressures (Davis et al. 1998, Hadjisterikotis et al. 2000).

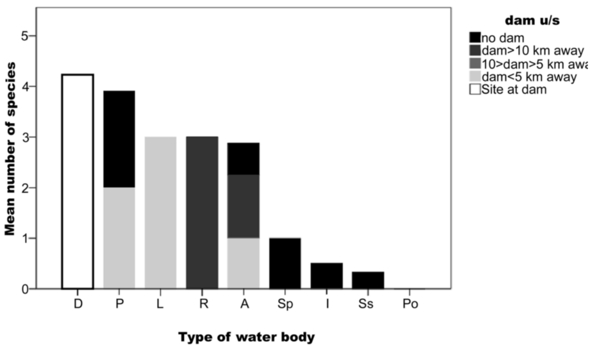

Fig. 4. Mean number of species found at 53 sites in Cyprus related to the proximity of dams upstream of site (dam u/s). On x-axis generic habitat types are given as: D = dam reservoir, P = perennial, L = lagoon, R = river mouth, A = artificial intermittent, Sp = spring pond, I = intermittent, Ss = spring stream, Po = pond.

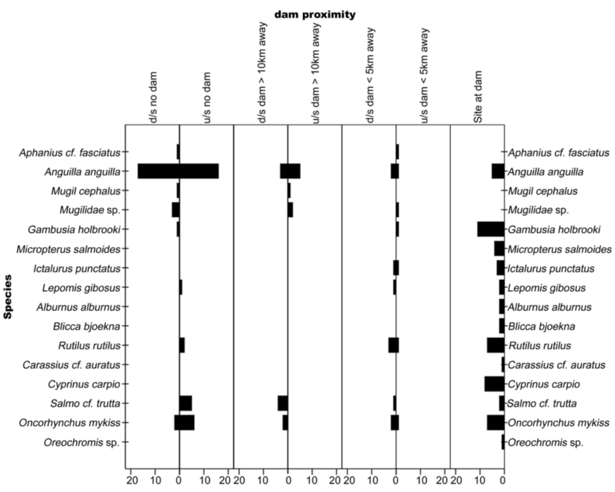

Fig. 5. The frequency of occurrence of fish species at individual sites ($n = 53$) in relation to the dam proximity (upstream and downstream); The *x* axis of this plot shows the number of sites where a species was recorded either upstream (u/s) or downstream (d/s) of a dam

Non-indigenous species. Our initial survey shows that several non-indigenous fishes maintain self-sustaining populations in reservoirs and locally in the related adjacent water bodies, immediately upstream or downstream of dams. Many of these species were allegedly introduced accidentally. A fairly common accidental means by which non-indigenous fishes are introduced is when species, most frequently cyprinids, are inadvertently transported with the juveniles of common carp, *Cyprinus carpio* L., (see Welcomme 1988). It has been documented that at least the bleak, *Alburnus alburnus* (L.), (see Welcomme 1988, Lever 1990) and white bream, *Blicca bjoerkna* (L.), (see Elvira 2001) have reached Cyprus in this way. Fish have also been indiscriminately and intentionally dispersed by humans in the dams of Cyprus, primarily for recreational angling, and it was stated by experts that there is very poor control over these private introductions. Furthermore, a state-run fish hatchery does exist on the island and it has propagated several species on an exploratory and experimental basis.

Some naturalized non-indigenous populations, especially the trout are of special interest because Cyprus does have rather substantial cold-water stream reaches in its southern mountain range and these would maintain self-sustaining trout populations in the adjacent Eurasian mainland. The presence of brown trout on the island is attributed to an introduction of continental *Salmo trutta* by R.R. Waterer (Conservator of Forests, 1937–1950) in the mid 1940s; and this was considered an important accomplishment of the British colonial government's forest conservation campaign (Thirgood 1987). During the present investigation we compiled evidence of reproducing brown trout in the upper Kouris River, this being the first documentation of wild salmonid reproduction on the island in recent times (several fry with size ranges 50–55 mm TL where found in early May 2011). We have no knowledge of the potential for the existence of native brown trout on Cyprus in the distant past, although native trout does exist in several other Mediterranean islands such as Corsica, Sardinia, and Sicily (Kottelat and Freyhof 2007), and may have existed until medieval times on Crete (Rackham and Moody 1996). Furthermore, genetic investigations have never been made to explore the specific provenance of Cyprus' trout populations, and this would be important for a conservation assessment (Laikre 1999).

Non-indigenous species are potentially harmful to native biota, and this has been confirmed with fish in inland waters in many Mediterranean climate-areas (Moyle and Light 1996, Smith and Darwall 2006). However, the degree of impact of non-indigenous fish on aquatic system biota still garners controversy with respect to assessing specific environmental impacts of fish introductions (Godinho and Ferreira 1998, Gherardi and Böhme 2000, Copp et al. 2005). It should be said that some long-established "naturalized non-indigenous species", such as the brown trout in the case of Cyprus, might fill a "vacant niche" that may have belonged to a salmonid species that has become extinct in the distant past. Although the idea of niche vacancy in terms of documenting "benign effects" of introduced species has been debated (Herbold and Moyle1986), it has been recently stated that some non-indigenous species do act as functional substitutes for extinct taxa, so in this case non-indigenous species can even be of benefit to insular aquatic ecosystems (Schlaepfer et al. 2011). In this respect, humans may act as vehicles for introducing or "re-introducing" ecological guilds that may evolve to have self-sustaining populations in streams that may have had ecologically equivalent fish species in the past. We must not forget that humans have successfully transported several reptiles, birds and mammals to many Mediterranean islands for centuries and some of these naturalized populations are now legally protected and considered "native" (Gherardi and Böhme 2000, Baier et al. 2009). Humans have also transported live fish throughout much of the Mediterranean in the past; for example common carp and the north African catfish, *Clarias gariepinus* (Burchell, 1822), have been found in Greco-Roman remains on Cyprus also (Van Neer et al. 2004). Obviously we cannot underestimate the threats non-indigenous fish species can cause; however, a new paradigm seems to be emerging with respect to how we assess the "aliens" place in Mediterranean and European aquatic ecosystems (Gherardi and Böhme 2000, Copp et al. 2005). How we interpret a naturalized species place in the largely anthropogenically-modified Mediterranean landscapes obviously influences conservation and management implications as well (Botkin 2001, Grove and Rackham 2001).

Conservation implications. Until now there has been scant documentation of fish distributions in Cyprus, even for reservoir waters where a recreational angling fishery has been thriving (Stephanou 1988) or within EU Water Framework Directive monitoring demands (Anonymous 2000, Bernez et al. 2002). Very little work has been done on stream fishes in semi-arid insular areas in the Mediterranean, especially compared to temperate river environments (Mathews 1998). Obviously important gaps in baseline knowledge persist on Cyprus and the present survey is necessarily a descriptive pioneering account. Important conservation research needs are however apparent.

Our work provides evidence of the influence of dams and the associated water management on fish assemblages in Cyprus. Dams have definitely affected fish populations, both native and introduced species, since irrigation dam reservoirs may seasonally starve downstream reaches creating artificially intermittent conditions that may contribute to the local range-constriction and extirpation of fishes. Even formerly widespread catadromous species such as the eel seem to have probably declined in Cyprus—perhaps also a reflection of a global decline of this species (Freyhof and Kottelat 2008). It is well known that dams may disrupt the river gradient and block upstream fish migration (Reyes-Gavilán et al. 1996) and thus subsequently affect natural zonation of fish faunas in river systems, and this has been observed in particularly pronounced ways on islands (Chang et al. 1999). In our survey we found that reservoirs host the richest species diversity and a varied lacustrine fish community. Since dams maintain lentic waters in upland areas that may never have had such water features, their non-indigenous fishes could potentially invade and infest upstream areas; these negative effects are well documented in other Mediterranean regions (Godinho and Ferreira 1998, Vinyoles et al. 2007).

In contrast, dams and reservoirs may also function as potential refuges for some native aquatic biota—especially in arid climates; although we did not document evidence of this in terms of the Cypriot ichthyofauna in our survey. The outstanding ornithological importance of certain artificial reservoirs in Cyprus (Charalambidou et al. 2008) indicates that they may be able to provide important refuges for native biodiversity and this situation seems to be confirmed in other Mediterranean islands and in reservoirs of the Middle East's arid lands as well (Evans 1994, Tourenq and Shuriqi 2010).

It would be important to determine if fish could be of interest for monitoring the ecological integrity of streams and reservoirs in Cyprus (Irz et al. 2006, Sabater and Tockner 2010) especially because it is well known that in semi-arid environments surface water bodies are "keystone ecosystems" in the landscape (deMaynadier and Hunter 1997). Even non-indigenous species are known to give important information for assessment and monitoring (Vila-Gispert et al. 2002) and there is a rise in the use of non-indigenous taxa within indices in several European countries (Vandekerkhove and Cardoso 2010).

The inland waters of Cyprus have many distinctive qualities and need careful conservation-relevant research. Recently, Abell et al. (2008) placed Cyprus within the Southern Anatolian Freshwater Ecoregion, yet in contrast to Anatolia, Cyprus has a remarkably depauperate fish and amphibian fauna (only three species of amphibians) and there is mounting evidence that one of its amphibians is a distinct endemic species (Baier et al. 2009). We suspect that ecoregional delineations in parts of the Middle East may need careful re-assessment, especially since biotic distributions of freshwater species are severely lacking as is the case in parts of the Balkans (Zogaris et al. 2009). Cyprus' inland aquatic biotic assemblages and its particular biogeographic identity should be further researched. Perhaps the island has a degree of biological distinctiveness, geological isolation and areal extent to comprise its own freshwater ecoregion.

Conclusion and recommendations. This preliminary survey reveals remarkable gaps in current knowledge on fish distributions in Cyprus; the impact of dams on the island's aquatic biota is especially poorly studied. Part of the reason for a lack of scientific study is the depauperate native fish fauna in Cyprus' inland waters. Furthermore, until recently there was presumably very little interest in non-indigenous species. Cyprus is unusual since it maintains approximately108 dams; and for its area, this represents one of the highest densities of dams in the European Union (Anonymous 2006). This remarkable situation within a semi-arid climate zone makes the use of biotic elements, such as fish especially interesting as a focal element for ecosystem studies, river monitoring and conservation management (Ferreira et al. 2007).

This survey and review of Cyprus' inland fishes indicates that there is substantial value in carefully recording fish distributions on the island. Fishes are potential indicators of surface water ecosystem integrity, they play an important role in local food webs, and non-indigenous fish certainly may impact native biodiversity. Understanding biodiversity patterns is a central issue for conservation scientists and water managers, especially in an environment with extreme water stress (Henrichs and Alcamo 2001). Integrated conservation research approaches are needed to best inform river basin management in the face of competing demands for water use across Cyprus. With respect to inland waters fish conservation, specific research should focus on the following: a) assessing environmental flow requirements below dams and surpassing barriers to stream connectivity, where native fish exist; b) attention to certain focal native species such as European eel, Mediterranean toothcarp, and freshwater blenny and associated habitat requirements; c) utilization of fish as biological quality indicators in order to monitor and restore natural river conditions; and, d) monitoring of non-indigenous fish and their impacts on aquatic systems.

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