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INSTITUTO SUPERIOR DE AGRONOMIA, UNIVERSIDADE TÉCNICA DE LISBOA - PORTUGAL

Assessment of Fish Assemblages in Cyprus Rivers for the Implementation of the Water Framework Directive 2000/60/EC

Submitted to:

WATER DEVELOPMENT DEPARTMENT,
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NATURAL RESOURCES AND ENVIRONMENT,
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(Cover Photograph; Brown Trout at Platys Tributary Diarizos, Underwater Photo: S. Zogaris, June 2010)

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PROJECT MISSION ABSTRACT

This is a research and development project designed to gain ichthyological knowledge base-lines set by local field survey foundations and further improve biological assessment procedures in rivers, in order to meet demands of the Water Framework Directive (WFD) in Cyprus. The immediate fore-runner to this project was initially launched under contract No.: TAY 49/2010 in February 2011 and its initial phase was completed within 17 months. The project team was awarded another contract, elaborated in this report, as an immediate extension for further field work and analysis. The current project lasted from July to November 2012 (contract No.: YY02/2012). This final report incorporates nearly all aspects documented in the first contract but proceeds with a more extensive database, literally covering more ground.

The WFD utilizes fish assemblages as biological quality elements (BQE) in running waters (rivers and streams); however inland water fishes have never before been researched for use as bioindicators or bioassessment tools in Cyprus. Due to the island's species-poor native fish fauna and the prevalence of alien fish species that are often artificially stocked, the Republic of Cyprus considered that it is not possible to base any type of ecological quality monitoring solely on fish species. Consequently, "fish" as WFD biological quality elements are not monitored on the island.

In this project we will investigate and evaluate the utilization of fish in assessment and monitoring procedures with scientific substantiation, as required by the European Commission. This supports the overall objective of fulfilment, at least partially, of the obligations of the Republic of Cyprus regarding the BQE fish in rivers, as required by the WFD.

This project comprises the following goals:

- The collection of information and field sampling data on fish populations in Cyprus' rivers, including an in-depth review of the distribution and historical occurrence of fish; a systematic sampling survey involveing 30 river catchments;
- The organisation of the collected ichthyological and environmental data in a database associated with cartographic reference (Geographic Information System);
- The presentation and systemization of the information and data in reports including the formulation of a substantiated Cyprus position regarding the applicability of the "BQE" fish in rivers in Cyprus;
- Evaluation of the applicability of the "BQE" fish in the rivers of Cyprus using analyses to test and ascertain that particular and relevant fish-based attributes respond to environmental degradation and may act as metrics (bioindicator elements).
- The potential application of selected biological assessment methods to the collected samples and the evaluation of the results from the applied assessment methods;
- The formulation of conclusions and recommendations regarding the applicability of the BQE "fish" in Cyprus' rivers for the assessment of their ecological status within the WFD application.

Finally the project provides practical proposals for utilizing fish within the wider WFD-directed management process in rivers. This includes the delineation of water bodies where fish could support and enrich the information used for the assessment and management of these specific water bodies, and specific issues relating to water conservation with respect to fish as biotic elements.

SUMMARY OF FINAL REPORT

This report is organized in the following five sections based on work done during two WDD contracts:

SECTION 1. Historical information and previous work regarding fish in Cyprus' rivers.
SECTION 2. Fish sampling and collection of supporting data.
SECTION 3. Evaluation and synthesis of collected data.
SECTION 4. Metrics calculation and application
SECTION 5. Conclusions and recommendations

The island of Cyprus presents a poorly-studied freshwater fish fauna, as it has largely intermittently-flowing lotic water bodies, many of which are heavily degraded by anthropogenic impacts. There are no completed baseline study dealing with the inland fishes or their specific distributions and population status on the island. Despite this, it is well known that the fish fauna of the inland waters of Cyprus is dominated by alien (non-indigenous) fish species, introduced in reservoirs for stocking purposes. Due to the reasons mentioned above the Republic of Cyprus considered that it is not possible to base any type of ecological quality assessment solely on fish species, for the purposes of the Water Framework Directive (WFD). Consequently, "fish" as a WFD Biological Quality Element (BQE) are not monitored; and Cyprus did not participate in the River-Fish Intercalibration Exercise. In order to research this consideration, an investigation was undertaken by the present research project.

Non-indigenous fish species in Cyprus are quite widespread in the reservoirs, but native fish species are remarkably scarce in the island's rivers. There is anecdotal evidence that native fish populations, especially the European Eel population, have declined. Among the total river systems investigated in 2011 and 2012, very few stretches of them had self-reproducing populations of inland water fishes, and in certain cases this is obviously caused by anthropogenic pressures that degrade the permanence of surface waters and specific habitats and/or the natural longitudinal connectivity of the river systems. Although stream fish assemblages were confirmed in isolated parts of many rivers, it is not yet known how predictable and self-enduring they are and if or how they will react to specific anthropogenic pressures. Since monitoring has never been practiced it is very difficult to explore communities that present high spatial variability. However, the present report shows that typological consistencies in the species assemblages do exist and we have defined three generic river types (mountain, middle course and coastal types) based on environmental and fish-based attributes. With respect to ichthyocentric assemblages these three abiotic types translate to salmonid, non-salmonid and euryhaline river-mouth communities respectively. In fact 8 distinct biotic groups (or communities) of fish were located in lotic and wetland habitats in Cyprus; these include 21 species of fish. In this respect, fish are an important part of inland waters in Cyprus.

The potential to use fish in a supplementary way or as wider "tool" within biological assessment and water management exists in Cyprus, due to the presence of some promising indicator species that are known to react to river degradation pressures; e.g. the localized European Eel and the naturalized Brown Trout. Both naturalized trout species (*Salmo trutta* and *Oncorhynchus mykiss*) present some theoretical problems in use as indicators, and further research is needed to explore these alien's interrelationships with the natural biota. Potentially, in the future, fish-based assessment and monitoring could be attempted in certain types or limited stretches of rivers. For example in stretches were the Eel exists the preservation of surface water habitat conditions and connectivity with the sea is an obvious unmet need in Cyprus. Nevertheless, the unique insular and environmental conditions on the island create serious obstacles to the development and practical application of the fish BQE. Although it is not possible to conclusively assess the use of fish for assessment and monitoring in Cyprus at this time, monitoring of fish assemblages should continue. Specific proposals for utilizing fish-base approaches are provided.

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SECTION 1. HISTORICAL INFORMATION AND PREVIOUS WORK REGARDING FISH IN CYPRUS' RIVERS

1.1. Introduction: Unmet needs and policy-relevant monitoring

The lack of available information on fish populations in Cyprus inland waters has been a major obstacle to the application of bioassessment procedures in integrated water management on the island. With respect to the information gaps its is important to note that:

- No standardized ichthyolgical surveying in inland waters of any kind has ever been done on a broad scale approach on Cyprus save for work within this teams efforts (see Zogaris et al 2012).
- No published or completed list of the country's inland water ichthyofauna exists;
- Until recently, the existence of several species of native fishes in inland waters was not understood, misrepresented or not widely accepted;
- Refrences to the country's inland ichthyfauna are remarkably scarce in the scientific and popular bibliography (Charalambidou & Gucel 2009).
- Cyprus does not have a National Non-Indigenous Species Strategy despite the fact that its inland waters harbour many alien fish species; some of which are invasive and have become naturalized in running waters as well.

As a member state of the European Union, the Republic of Cyprus is obliged to implement the Water Framework Directive 2000/60/EC (WFD) which requires EU member states to assess the status of water bodies using biological quality elements including fishes.

More specifically the WFD, amongst many others, requires:

- The development of assessment methods for the biological quality elements (BQEs) prescribed in the Directive
- The participation in the Intercalibration exercise (IC), which is facilitated by the European Commission in the framework of the Common Implementation Strategy (CIS) of the WFD. The Joint Research Centre (JRC) is coordinating the IC on behalf of the European Commission.

The Minister of Agriculture, Natural Resources and Environment of the Government of the Republic of Cyprus is the competent authority responsible for the implementation of the "Water Protection and Management Law of 2004 (N. 13(I)/2004)" which harmonised the national legislation with the WFD. On the executive level, the Water Development Department is responsible for the preparation and execution of Cyprus' WFD Monitoring Program. There are other governmental organizations that are also involved in riverine fish. Most prominently, the Department of Fisheries and Marine Research (DFMR) is the responsible authority for fishing in Cyprus (i.e. grants fishing permits, supporting conservation etc). Furthermore, many water resources are of concern to Department of Forests and the Game Fund due to their outstanding values for wildlife.

Until recently, governmental and research organizations were not involved in any form of fish fauna monitoring or other organisms in the island's rivers. Despite the environmental policy demands that rapidly intensified after Cyprus' ascession to the EU, the basic knowledge gaps creates difficulties in policy-relevant conservation. Much work remains to be done with respect to the WFD implementation on Cyprus. As outlined in the Commission Staff Working Document (2012) on the WFD River Basin Management Plan of Cyprus recommendations, it is important that the classification of ecological status and ecological potential should be further developed and completed, and that efforts should be made to improve the quality of WFD-relevant monitoring in Cyprus.

Bioassessment and standardized monitoring for the fish BQE on Cyprus and in other Mediterranean jurisdictions has incountered many problems. Problems with the Fish BQE are not unique to the Mediterranean states; each EU member state has had to deal with varied and often unique problems, a good example of problems roughly similar to those on Cyprus are seen in Ireland (Champ et al. 2009). Most jurisdictions in Europe lacked standardized approaches to fish monitoring before the implementation demands of the WFD, however such basic premises such as the defining refrence conditions is particularly difficult in Europe and has created many interpretation difficulties (Moss 2008).

Constructing reference base-lines of past "near-natural" fish communities is especially difficult in an Eastern Mediterranean island which has seen remarkable anthropogenic environmental change for many centuries. In Cyprus, historical data on species presence, population status, and/or site-specific fish-species assemblage information are missing. We reiterate that the problem of a lack of background knowledge is not unique to Cyprus; practical application of refrence conditions development has proven very difficult and with inconsistent procedures in Europe (Pardo et al. 2012). Often there is no standardized monitoring or any form of frequent relevant surveillance of fish communities where many indexes are being designed. Despite some fragmented details concerning recreational angling and stocking in the reservoirs, baseline information on fishes in rivers or wetlands has never before been reviewed in Cyprus.

This report initiates a fish-based policy-relevant research activity and sets a preliminary base-line for systematic inventory and survey work within the scope of exploring the use of fish for bioassessment purposes in lotic water bodies on Cyprus.

This work focuses on site-based fish assemblage data primarily through exploratory information collection methods and standared WFD-complient sampling surveys. It provides an opportunity for the organization of databases and geo-databases concerning fish, it reviews fish habitat data and environmental degradation of sampled sites, in order to construct a sound spatial framework for the research sampling survey and a baseline for future surveys. Furthermore, this initial activity of the project reviews existing information (i.e. existing unpublished information) and initiated an interview survey (surveys to review historic conditions and fish occurrence in Cyprus rivers, using a questionnaire and unstructured interviews). Every possible effort has been made to review natural history, ecological history and to construct species assemblage reference condition attributes within the investigated water bodies of the studied streams; and this kind of information was gradually built-up in incremental steps throughout the duration of the project.

1.2. Initial collection of background information, former studies and inception survey work

This first section of the report outlines aspects of the preliminary knowledge gained concerning fish species' distributions, the survey scheme development and reports on specific priorities and progress within the first three work packages. This work includes the following work packages:

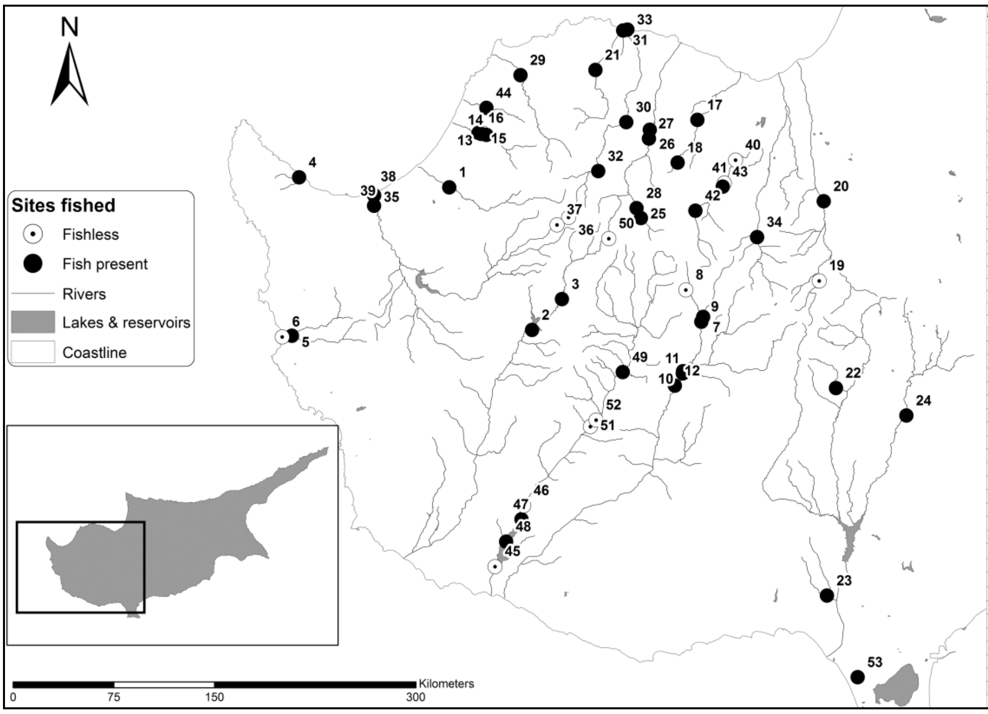
- ⇒ **Work package 1:** Compilation and organization of historic ichthyological reference conditions and current knowledge on occurrence and distribution of fish in the rivers of Cyprus. RESULTS: Data about fish species distributions were gathered and inserted into a database. Reference conditions issues were initially researched as were the dominant hydrological degradation pressures of dams.
- ⇒ **Work package 2**: Geographical information compilation and initial literature survey. RESULTS: A GIS system was developed and initial literature survey organized. A questionnaire was designed to be administered to locals. Interviews with authorities and local naturalists begun.
- ⇒ **Work package 3:** Review Investigation and pre-selection of sampling sites. RESULTS: The proposed selected site locations were reviewed. More river basin areas were included in the final design based on available sampling data. During the early spring of 2011 initial sampling was also initiated and results are also incorporated here. Initial descriptive statistics where done on the available presence/absence sampling data; especially the relationship of fish assemblages to dams was investigated.

Firstly, a review of methods to be used was gathered and a preliminary analysis of fish data was realised. We are providing this preliminary analysis in order to assist in the discussion of a substantiated Cyprus position regarding the BQE "fish" in Cyprus rivers within the framework of the implementation of the WFD and the related Intercalibration Exercise. What follows is based on only a fraction of the material and sampling information already collected but could be instructional and useful.

The initial species presence/absence data from recent site-based work is primarily from the following projects:

1. *2009-2010. Consulting services for the application of articles 11, 13 and 15 of the European Union Water Framework Directive (2000/60/EC) in the Republic of Cyprus. River Basin Management Pre-plan. Contract TAY-WDD 97/2007. Development Department, Ministry of Agriculture, Natural Resources and Environment. (S. Zogaris and G. Michaelidis visited reservoirs, wetland and rivers recorded observation and inquired about aquatic biota in 2009).*
2. *2009-2010. Management of the Pafos Forest Reserve, Cyprus. Monitoring scheme development and aquatic fauna inventory. Funding: EEA Grant and the Republic of Cyprus. Participants: S. Gatzogiannis, SYSTADA, Kalisto. [http://www.pafosforest.eu]. (S. Zogaris visited rivers in 2010 and electrofished for the first time in Cyprus).*

3. *Reconnaissance work for the present project (5-10th May 2011). This Project. (S. Zogaris and A. Vidalis visited and electrofished 23 sites).*



a/a	Site Name	River Basin
1	Fragma_Argaka	Ag. Merkourios
2	Fragma_Kannaviou	Agia
3	Panagia Diakou_Agia	Agia
4	Aphrodite_baths	Akamas
5	Avakas	Avakas
6	Avakas_mouth	Avakas
7	Agios Avvakoum_Diarizos	Diarizos
8	Milikouri_Spring	Diarizos
9	Pareklissoudi_Diarizos	Diarizos
10	Us_Gef_Kelefou	Diarizos
11	Ds_Gef_Kelefou	Diarizos
12	Fragma_Arminou	Diarizos
13	Gialia_seep_pond	Gialia
14	Gialia_us_spring	Gialia
15	Gialia_spring	Gialia
16	Galia_ds_spring	Gialia
17	Fragma_Gallinis	Kambou
18	Kampos_1	Kambou
19	Us_Fishfarm_Kargotis	Kargotis
20	Gef_Evrychou	Kargotis
21	Fragma_Katouri	Katouris
22	MesaPotamos_Kouri	Kouris
23	Frag_Kantou	Kouris
24	AgMamas_Limnatis	Kouris
25	Frag_Tsakistras	Limnitis
26	Kat_Gef_Limniti	Limnitis
27	Gef_Limniti	Limnitis
28	Gef_Mavres_Sykies	Limnitis
29	Fragma_Pomou	Livadi
30	Pirgos_1	Pyrgos
31	Kato_Pirgos	Potamoui Pyrgou
32	Vrondisia	Pyrgos
33	Ek_Platis_Pyrgou	Pyrgos
34	Fragma_Kalopanagioti	Makountas
35	Polis_chrys_1	Stavros Psokas
36	Stavros_Kat_Camping	Stavros Psokas
37	Stavros_Psokas_1	Stavros Psokas
38	Polis_Mouth1	Stavros Psokas
39	Polis_Mouth2	Stavros Psokas
40	Gef_Xerou_Lefkas	Xeros
41	Kat_Fragma_Kafizides	Xeros
42	Fragma_Kamenou Pediou	Xeros
43	Fragma_Kafizides	Xeros
44	Fragma_Ag Marina	Xeros (Ag. Marina)
45	Asrpokremma Ponds	Xeros (Pafos)
46	Gef_Choletria	Xeros (Pafos)
47	Finikas_ds_prodam	Xeros (Pafos)
48	Frag_Asprokremmou	Xeros (Pafos)
49	Gef_Roudias	Xeros (Pafos)
50	Spring_Dihaloi	Diarizos
51	Gef_salamiou_xeros	Xeros (Pafos)
52	Perasma_xeros	Xeros (Pafos)
53	Alyki Akrotiri	Kouris

Fig. 1.1 *The 53 sites where fish assemblage data has been collected, primarily through fish sampling during 2009, 2010 and the initial survey of this project in early 2011. Sites that had no fish during sampling (i.e. fishless sites) are also shown.*

1.3. Materials and methods for research on historical work

Information was collected for all available fish samplings in inland waters in the past. Furthermore, a broad-scale survey of freshwater fish distributions was conducted using site-based fish sampling and expert interviews. The collected data was from the spring/summer periods of 2009, 2010 and included the first spring survey of 2011. Systematic fish observations were made primarily through the use of backpack electro-fisher (Bulgarian costume-made unit, 700 v. and a Smith-Root L24 980 v.). Electrofishing was practiced following specifications developed during the EU FAME project however the recording technique followed a rapid assessment procedure were fish numbers and size-class lengths were collected rapidly in a two or three-person team; and all specimens were released. Only one sampling run was conducted at each site and the longitudinal distance usually covered was at least 30 m of river stretch. In some sites where fish were not detected the electrofishing search continued on until at least 200 m river length. Site selection was based on aquatic feature representativeness, especially with respect to generic habitat characteristics (i.e. sampling homogenous reaches and searching lateral barriers such as bridge-bases and weirs for fish presence).

At this initial phase of the research, ichthyological information was initially acquired from 53 sites in 18 river basins. A total of 36 sites were surveyed in late June 2010; while only 15 of these sites were electrofished. In early May 2011, 23 sites were inspected, while 20 were electrofished (including two from the former trial). Fish observations were also conducted from shore using binoculars and locally through snorkeling. Amateur fishermen's catches were also inspected on an incidental basis, in order to document fish species presence in the reservoirs. Habitat features of the sites were carefully recorded at each site and a total of nine generic aquatic habitat types were defined, thus categorizing each sampling site by habitat.

To complement the site-specific sampling, a species presence review was conducted through investigating the available gray literature and conducting interviews with knowledgeable local researchers. Obviously important gaps in baseline knowledge still exist and wherever ambiguous or questionable species' distribution data or identification records exist, we clearly state data acquisition method and suspected record reliability within this site-based review (see Appendix).

1.4. Initial pressure analysis of dam proximity

Relative disturbance pressures imposed by the proximity of dams, situated upstream and/or downstream of the researched sampling sites, were assessed solely 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 kilometers away from sampling site; 3= dam 5 km to 10 km away from site; 4= dam less than 5 km of site; 5= site located at or within dam's reservoir. Since a thorough pressure-analysis was not possible with the available data at this time, this simple pressure gradient relative to the position of the dams may assist in interpreting general fish distributions patterns in relation to dams. All data that were acquired were entered into a simple relational database supported by GIS site locations. SPSS 13.0 for Windows software and Primer (vers. 6) software were used for statistical analysis for the presentation of relevant data.

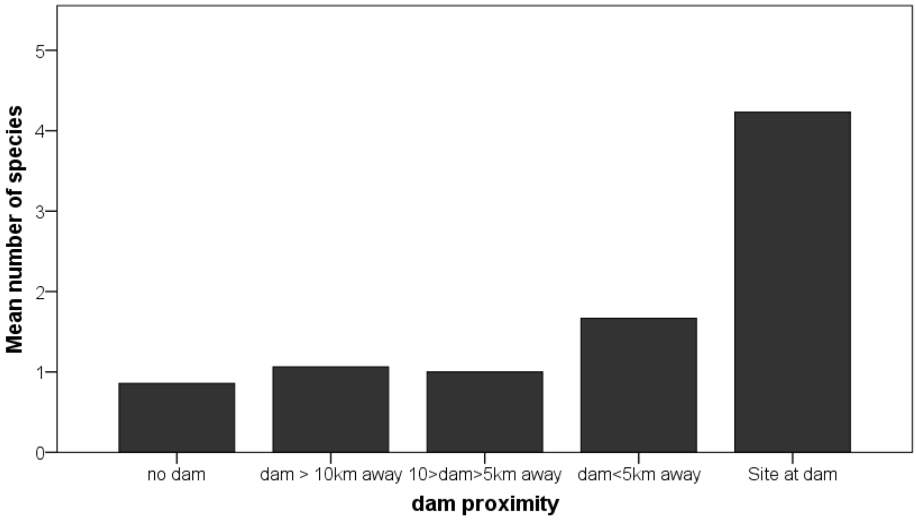


Fig. 1.2*. Mean number of species found at 53 sites in Cyprus' inland waters (data from electrofishing, interviews and literature are combined). Most fish species are restricted to the dams. In many instances barriers above the dam (e.g. pro-dam obstacles, weirs, bridges, road-passes etc) do not allow fish to move upstream of stream confluences.*

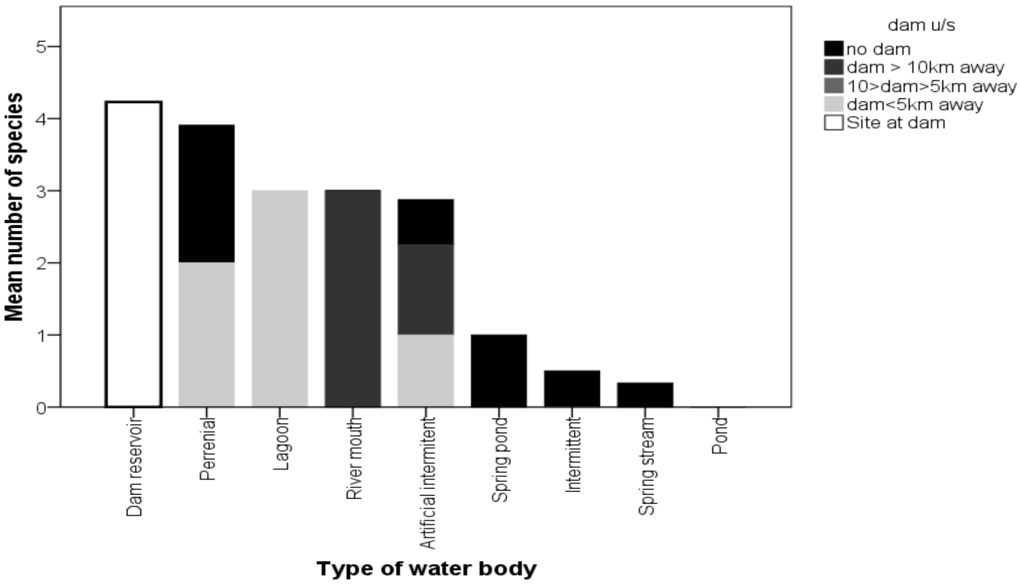


Fig. 1.3*. Mean number of species found in Cyprus' water body types, in relation to the proximity of dams (N=53). Most species were documented in dam reservoirs and perennial streams. Very few species where found in isolated spring ponds, intermittent streams, small spring-fed headwaters or ponds.*

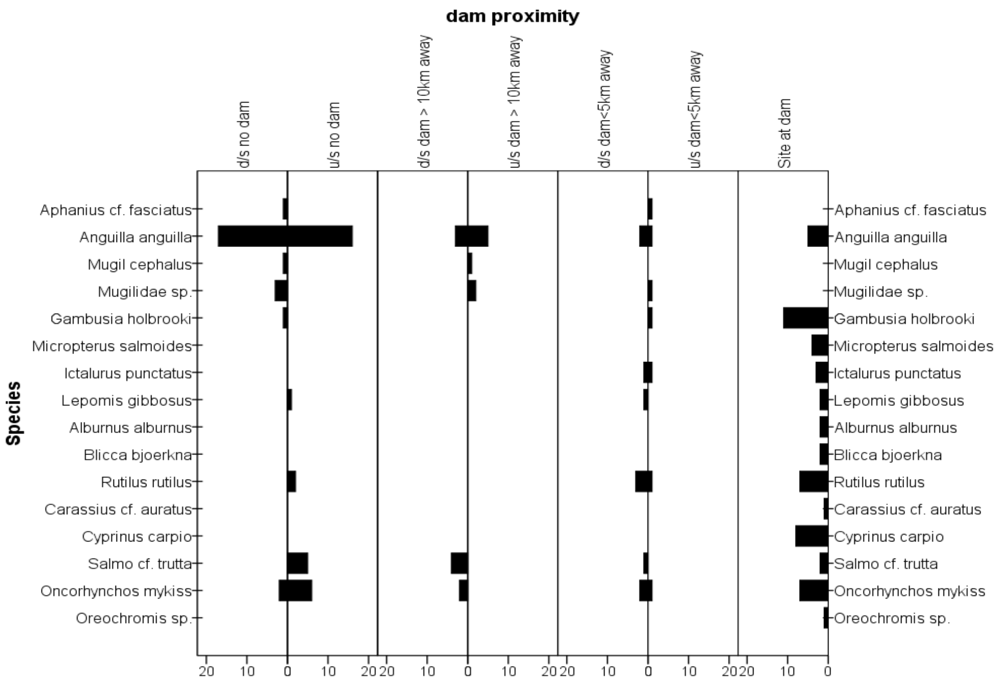


Fig. 1.4. *The frequency of occurrence of fish species in sites, in relation to the proximity of dams upstream and downstream of the investigated sites (N=53). Eels and Salmonids (Salmo* cf. *trutta*, *Oncorhynchus mykiss) seem to shun low-elevation dams. Many of the lacustrine species (i.e. "lake fish") are found primarily or only within dam reservoirs and are not distributed in the river network within the specific system, either upstream or downstream of the dam. 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.*

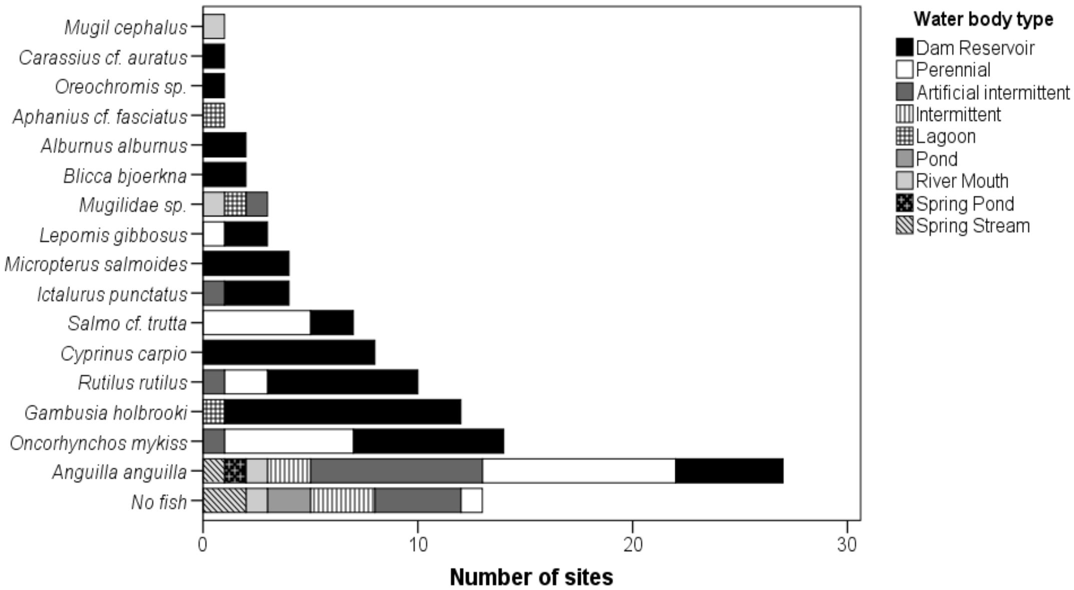


***Fig. 1.5**. The relative frequency of occurrence of fish species (presence in number of sites), in relation to the water body type. Most species are found within dams and perennial water body types. Eels are found in a large variety of habitat types (and were reported to exist in many different sites) in contrast to other species.*

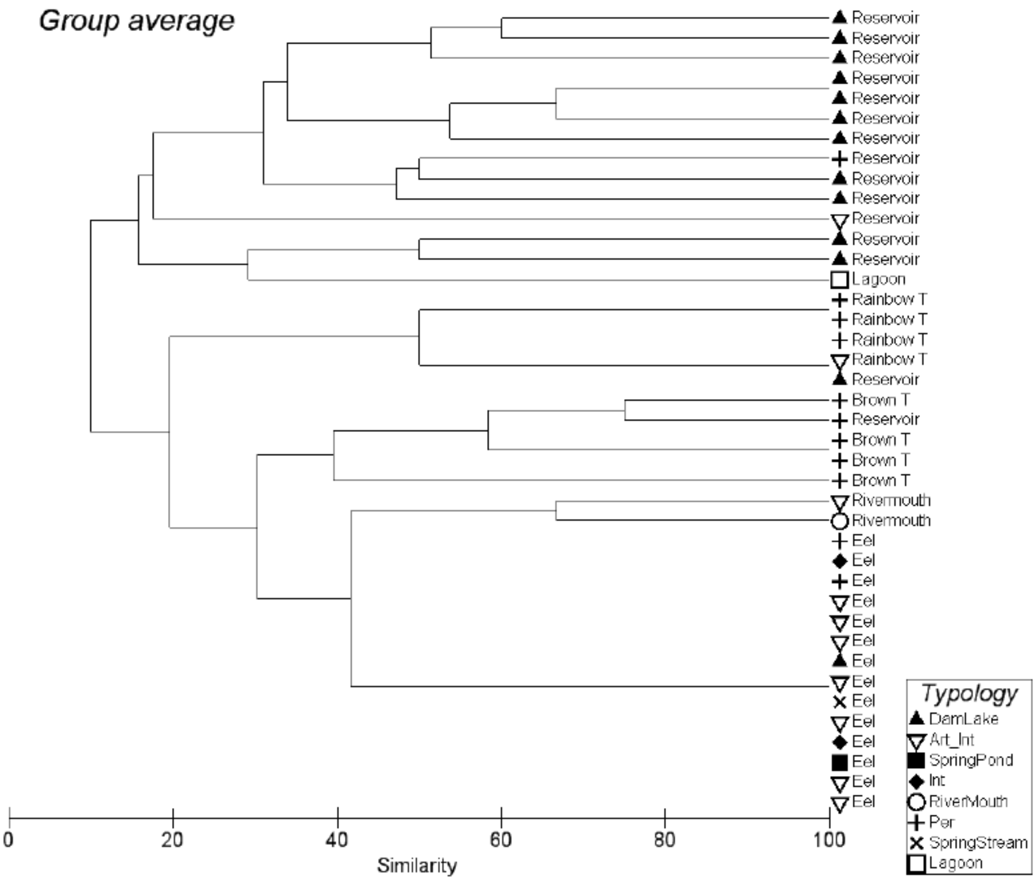


Fig. 1.6. *Initial fish biotic group patterns in Cyprus' inland waters indicating the structure of fish communities for the first time in Cyprus. Cluster analysis dendrogram using Jaccard coefficient of similarity classifying sites with fishes (N=40) based on species assemblage similarity. Each site is presented with respect to its generic habitat type, the dominant assemblage identity as defined in this analysis (i.e.* ***Eel****=Anguilla dominated;* ***River mouth****= Marine euryhaline spp.,* ***Rainbow****=Oncorhynchus dominated;* ***Brown****= Salmo trutta dominated;* ***Reservoir****= Lacustrine fish dominated;* ***Lagoon****= Aphanius etc.).*

1.5. Preliminary results of the survey

The initial bibliographic, interview-research, and site-based survey using data from 2009 to early 2011 confirms the existence of sixteen fish species in Cyprus' inland waters. 12 species are non-indigenous. Non-indigenous species are widespread: 24 surveyed sites sustained non-indigenous fish (45% occurrence in all sites, or 60% at all sites with fish present). Although most species are found within dams and perennial water body types (Fig. 1.2 & Fig. 1.3), most native species as well as migratory species such as Eel are not found near or inside dams (Fig. 1.4).

This initial analysis of all available data documents the first baseline freshwater fish distributions and assemblage patterns on the island. The survey inspected sites belonging to nine generic habitat types: dam reservoirs, perennial streams, artificially-intermittent streams, intermittent streams, river mouths, lagoons or coastal wetland pools, inland ponds, spring ponds and spring-fed headwaters. Most species were located in very close proximity to the dams, especially those species typifying the reservoir lacustrine community. Typical lacustrine species are rather rare beyond more than 5 km upstream or downstream of reservoirs.

Important questions arise with respect to the scarcity of native species in Cyprus' inland waters. We hypotheis this is probably directly attributed to extensive anthropogenic degradation of the natural riverine and wetland habitats. The presence of numerous dams seems to play an important role in adversely affecting native fish distributions on the island. The large number of irrigation dams starves downstream river stretches of surface water; creates barriers to fish movement, and hosts large numbers of alien fish species. Artificially intermittently flowing or artificially ephemeral streams below dams and water abstraction points are currently the norm in Cyprus lowlands and coastal areas – and this alone disables a natural longitudinal connectivity, impacting the existance of marine euryhaline species and migratory species such as the Eel. Another biogeographical enigma is the lack of true freshwater fishes on such a large island so close to the Asia Minor mainland.

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 (approx. 5.59-5.33 mya) (Baier et al., 2009; Plötner et al. 2012). The classical interpretation (Banarescu, 1960) suggests that the major Mediterranean islands did have river connections and freshwater fishes during the upper Miocene. This is further proven by freshwater fish fossils that have been found on Crete for example (Doadrio and Bohme, unpublished). Thus, it is very likely that Cyprus preserved primary freshwater fish populations for many millennia after its connection to the Asiatic mainland – and a review of the fossil record may prove this hypothesis. However extinction and an “extinction rate” is prevelant on dry Mediterranean islands and peninsulas (Foufopoulos et al. 2011). In the southern parts of the European peninsulas the faunas are depauperate and endemic-rich due to extinctions, however many species have been isolated for at least a few million years – so it is normal to speak about endemic freshwater fish faunas that have been isolated since the Messinian Salinity Crisis in the Mediterranean. It is very likely, that freshwater fishes did exist on Cyprus, howver these species could have become extinct from Cyprus a few centuries or a few millennia ago.

Apart from formerly euryhaline species or diadromous migration by salt-tolerant species (i.e. 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 River Blenny for example, is said to have been originally a true euryhaline species, allowing incursions into fresh water and subsequent dispersal via the sea (Almada et al., 2009). However, the River Blenny lived and reproduced in freshwaters in Cyprus but its population came to a catastrophic decline in the 20th Centrury. It 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 (Benejam et al., 2010; Côtė et al., 1999) and it may now be extremely rare and localized on Cyprus, if it still exists. The inspection of the only known museum specimes and the archived notes from the collector of the species from Cyprus (Fig.1.7) proves that they were indeed collected in the Lemessos District streams in the beginning of the 1900s. Persistant searches in this area revealed no River Blennies, yet in Crete and Corsica for example the species survives in rather small spring-fed streams. It is very likely that the River Blenny is extinct on Cyprus and if it is it represents one of the last native fishes thata has become extinct – this one in recent years.

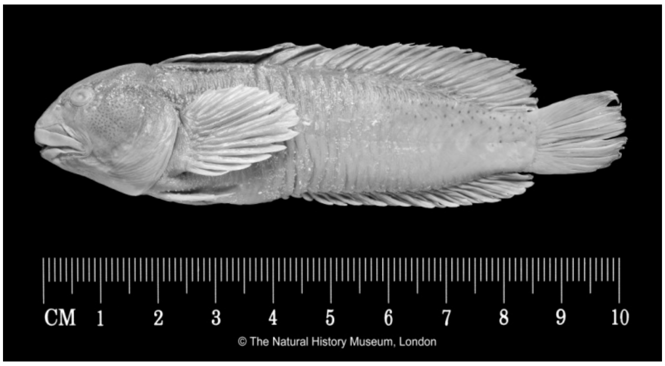


Fig. 1.7. *River Blenny Salaria fluviatilis specimen collected in the streams of the Limassol District and deposited in the Natural History Museum, London, in 1907. Three specimens in the museum along with the collectors' hand-written letters specifically mentioning the "torrents" of Limassol. This is the only evidence of the species on Cyprus. It is very likely that this species was widespread in several of the perennial flowing streams of the island – very much as it is on 9 other Mediterranean islands which also have perennial streams. (Photo is courtesy of Dr. James Maclaine, Natural History Museum, London)*.

Only the Eel and the River Blenny are species frequently living and widespread in Mediterranean island streams. In fact, this freshwater blenny is documented to exist in only 10 Mediterranean islands; it has a pan-Mediterranean distribution and its evolutionary persistence in island streams may be a good criterian for defining islands that have adequate river/lotic environments that can sustain fishes (Zogaris et al. (in Review)). Figure 1.17 shows the islands where the River Blenny has been recorded in the Mediterranean. The parameters of the each island's maximum altitudinal height and distance from the mainland are plotted in order to express relationships based on these parameter and the areal size as well.

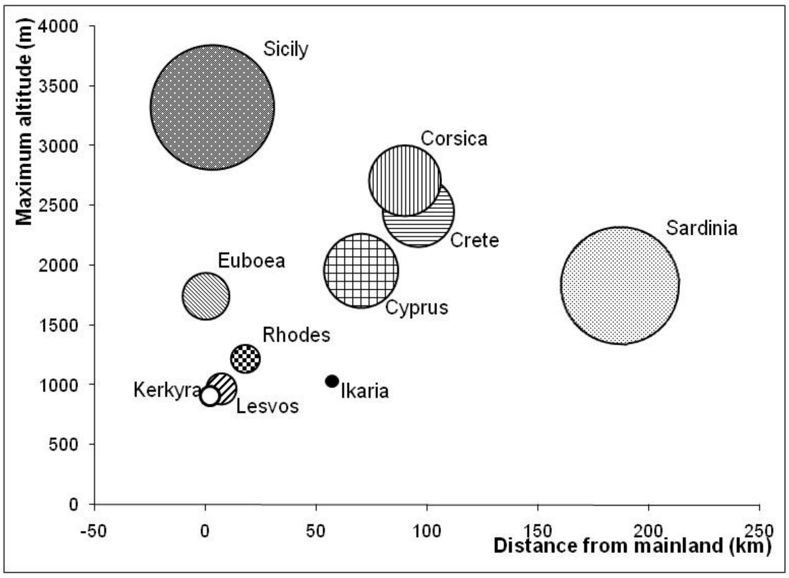


Fig. 1.17. Graph showing islands where the River Blenny is known to be present in the Mediterranean Islands. Maximum altitude may function as a surrogate to show that island may have perennial stream environments while the distance from the mainland is a key biogeographical determinant for freshwater fishes. The relative areal size of the islands, another key biogeographical determinant, is also depicted here. Note that following these aspects Cyprus, Corsica and Crete are most similar in these respects.Nearly all islands that host the species have high mountains, most being closer to the mainland (Sardinia is the exception).

Obviously, the “extinction rate” 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 in recent times it is nearly certain that they may have been lost due to increased climatic aridity or a combination of climatic and anthropogenic pressures (Hadjisterikotis et al., 2000; Davis et al., 1998). This has been proven to occur on many Mediterranean island with reptiles – species that are also poor dispersers in space (Foufopoulos et al 2011). Further research on this issue concerning the history of species present on Cyprus is needed. It is important to review the fossil record and the potential biogeographical pathways fishes would take during the Messinian Salinity Crisis. Whatever the case- the primary freshwater fish species probably did exist on the island and some transient species – such as salmonids –may very well have existed until quite recently also. Information from historical research and the fossil record may be able to answer these questions in the near future.

Cyprus inland waters are evolving. Nature adapts to available habitats. And humans have been transporting fishes into Cyprus and other lands since classical times (i.e. Nile Catfish and Carp; see Waelkens et al. 2004). One of the new fish assemblages developed in Cyprus in recent times concerns naturalized fishes in reservoirs. Only qualitative ichthyofaunal information was compiled for the dam reservoirs but this includes 12 dams in total during this initial survey. The influence of dam reservoirs on fish distributions is particularly interesting and important for exploring anthropogenic pressures on fish communities. Dam reservoirs held several times more fish species than rivers. Considering a provisional subset of the data (N=53 sites), the average number of species per stream site was low: 1,91 (range: 0-8, SD: ±2,04) but dam reservoir type sites had an average of 4,23 species (SD: ±2,49). As is to be expected most fishes, and the richest inland fish communities are within the reservoirs. Since Cyprus has more than 108 such reservoir sites, the issue of fishes within these inland water environments should gain some prominence.

1.6. GIS database development

ArcGIS was used in order to produce maps and to extract site based information of the watersheds for:

- the pressure/impact analysis: road density, upstream impervious area, upstream irrigated area, BOD load, TP load, TN load
- the attributes: watershed area, altitude of site, distance to source, distance to mouth, altitude of source, channel slope, mean annual temperature, annual precipitation, mean annual precipitation, upstream permeable substrate watershed ratio.

The DEM, provided by the Hydrometry Division of WWD was used in order to create the direction of flow raster map. Next the accumulation of flow raster map was created. Finally, the surveyed sites were overlain on the maps to create the individual watersheds. Once the sites' individual watersheds were produced then the provided geological, land-use, meteorological, hydrological, contours, sub-basin maps with the pollution loads (BOD, TP, TN) were used to create the necessary site-based information.

Table 1.1 **GIS Data sources and fields developed**

Sources for Pressures	**Parameters for Pressures**		**Sources for Typology**	**Environmental parameters for Typology**
DEM	Impoundment		DEM	Distance from source (km)
Corine land cover	Artificial substrate		Corine land cover	Distance from mouth (km)
River WBs chemical classification	Embankment		Geology	Altitude (m.a.s.l)
River WBs	Riparian degradation		Hydrogeology (Hydrogeological Map of Cyprus)	Height of source (m.a.s.l)
Lake WBs	Canalization		River WBs	Ratio of altitude/height of source
Roads	Road density		Climatic data	Watershed area (km^2)
Ponds & Dams	Flow pattern deviation			Temperature_annual average
Urban areas	Flow quantity deviation			Precipitation_annual_mean
	Discontinuity upstream			Precipitation_annual_sum

	Discontinuity downstream			Channel slope
	Impervious area%			Upstream watershed % of permeable substrate
	Chemical classification			
	Irrigation upstream area %			
	BOD load			
	TN load			
	TP load			

1.7. Questionnaire application

It must be reiterated, that the question of the status of fish in Cyprus, including Eels was totally unexplored. Government and non-government organizations have given no real interest in Eels or inland native fishes. The reason for this is threefold:

-Water resources are traditionally seen as priority anthropocentric resource issues, nature conservation has been segregated to forest areas and thus wetlands were poorly researched for biodiversity conservation purposes.

-The use of biocides such as DDT from 1946 to 1978 created a wholescale decline of inland water biota and for this reason most authorities were not aware of the issue of biodiversity since many of the waters were until recently significantly impacted by the biocides.

-The political instability, civil strife and invasion of the island by Turkey in 1974 created a situation where natural environment conservation issues were forced to be considered luxury for at least three decades. Biodiversity conservation issues rose rapidly after 2004. An exception to this is forest management on Cyprus which contains provision for biodiversity conservation since the colonial period.

The lack of knowledge about the nature of inland water biodiversity has created problems. Cyprus was excluded from compiling with the EU regulation on the European Eel (as Eels are not commercially fished on the island). One may surmise that Eels are naturally rare in Cyprus since they are near the eastern limit of their Mediterranean distribution. Could they have ever been common or widespread in the island's rivers? A small questionnaire was created and administered to superficially explore this issue.

Generalizations from the questionnaire

A small questionnaire was created and administered to superficially explore the issue of Eels and other fishes in the rivers. It asks seven simple questions and also incorporates comments made by respondents during the interview. The questionnaire document was drafted in the Greek language and could be completed in less than 5 minutes (see Appendix). It was administered primarily to professional, naturalists and workers who enter the forest or have some contact with rivers. Questionnaires were sent over the internet and hand administered during short interviews with locals. It was sent to many relevant government agency personnel by the WDD and during the field sampling campaign it was used to query locals and anyone who seemed knowledgeable about fishes. Many WDD workers and foresters replied as well as many members of the public in the villages.

In total, 149 responses were analyzed by the end of November 2012. The majority of the respondents were male (90%), just 15 respondents were female while 3 respondents did not specify their sex; all but five were Greek-Cypriots (two are Turkish-Cypriot, other nationalities had minimal involvement); Fig. 1.8. shows the age distribution of the respondents. Most of the respondents were over 55 years old (46%)

Most questionnaires were distributed in the Pafos and Lemessos districts; many were sent to individuals in Lefkosia also but only three respondents were located within the Occupied Territory and very few were located in the Larnaka or Ammochostos district. In this respect the distribution of respondents is biased toward the western half of the island. However respondents collectively mentioned no less than 26 of the major river basins (watershed) of Cyprus. The survey sample was small and not constructed for specific statistical analyses; however it is indicative of important aspects of inland water issues, especially the critical questions pertaining to the status of the Eel. Furthermore, very important anecdotal evidence was collected in this way, especially from older experienced respondents and resident naturalists.

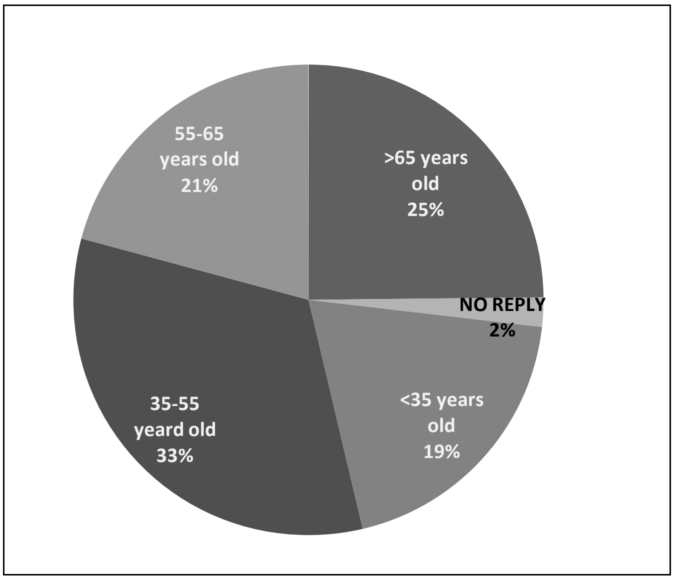


Fig. 1.8. *Age distribution of the 149 respondents of the questionnaire.*

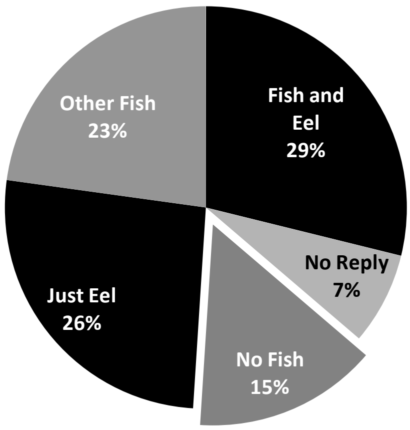


Fig. 1.9. *Answers of the 149 respondents relative to the presence of fish in any particular area, 55% were aware of eel presence in the river segment they were referring to.*

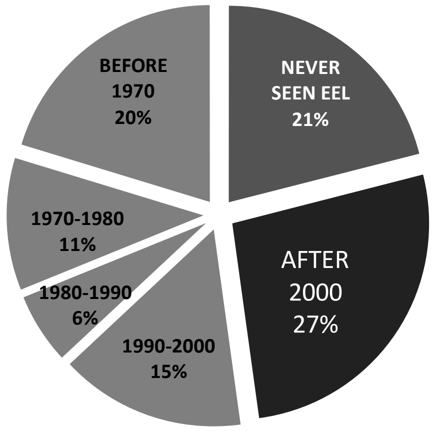


Fig.1.10. *The frequencies of last sightings of eel in the wild by 149 respondents. Many have reported eel sightings recently (i.e. 27% in the last 12 years)*

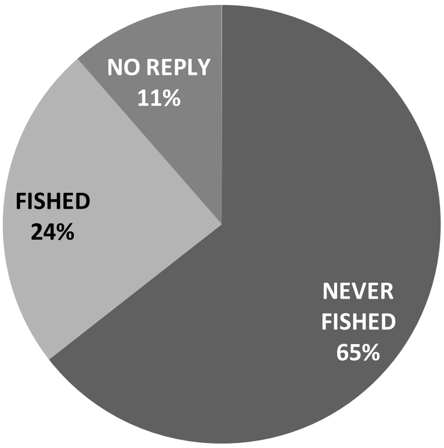


Fig. 1.11. *Answers of the 149 respondents to the question "Have you ever fished for Eel?"*

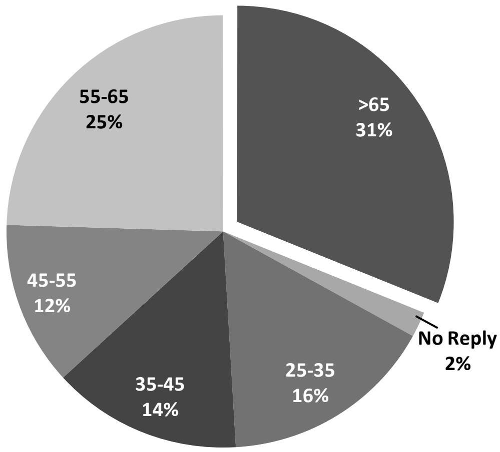


Fig. 1.12. *Age distribution of respondents that have fished for eel, 56% are over 55 years old.*

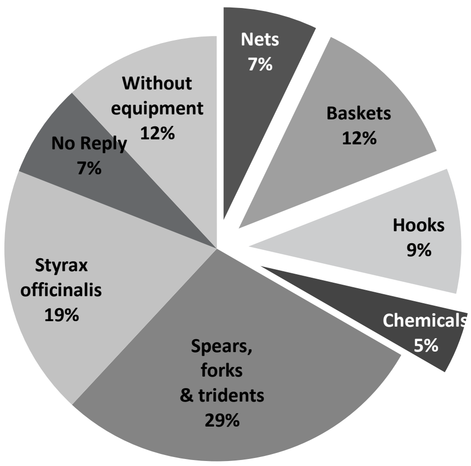


Fig. 1.13. *42 respondents answered the questions "How did you fish for Eels?"*

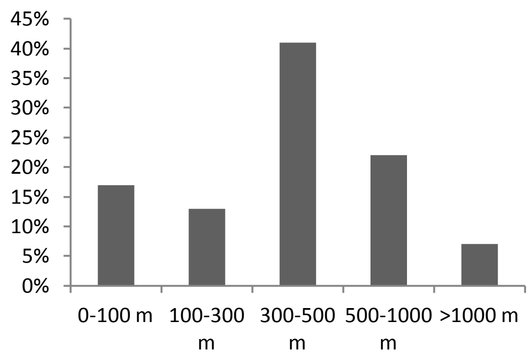


Fig. 1.14*. Frequencies of the 62 responses to the question "What is the highest altitude that you have encountered or know of presence of Eel?"*

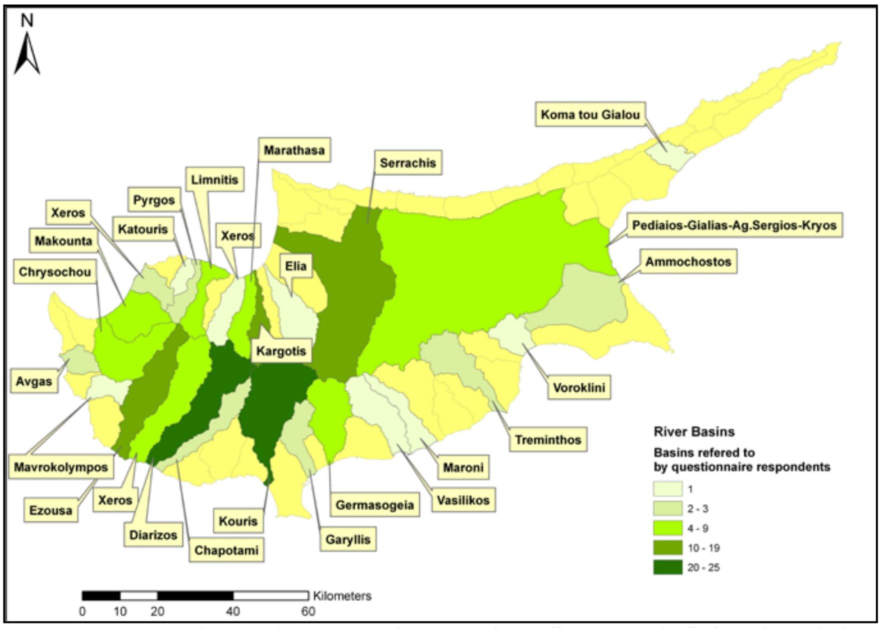


Fig. 1.15. *Number of respondents who discussed fish-related information about specific reaches at the river basin scale. Most respondents were from the Pafos and Lemessos districts.*

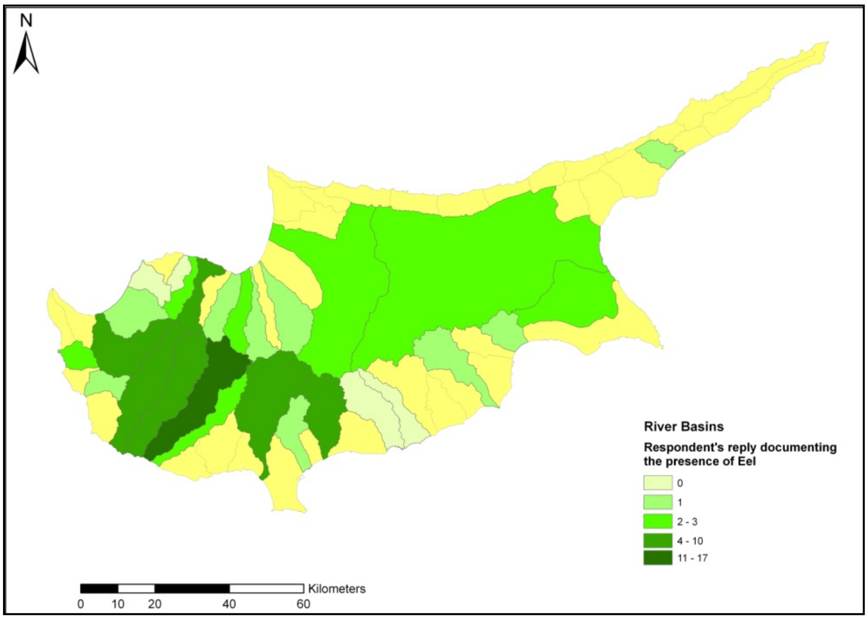


Fig. 1.16. *Number of respondents who replied that they had seen eel in specific river basins. The similarity with Fig 1.15 attests to the widespread distributional pattern of the species.*

The following important information was retrieved from the answers and comments section of the questionnaires:

Concening the Eel

⇒ A large number of respondents had knowledge of particular sites with the Eel present. The locations are scattered throughout Cyprus, not just in the west where most of the relevant sampling basins were located (several respondents referred to sites in the occupied territory e.g. Upper Pediaios, Mesaoria, Ammochostos etc). This widespread natural distribution of the Eels is evident when both number of respondents refereeing to specific basins and reference to eels are mapped (Fig. 1.15, Fig. 1.16).

⇒ With respect to information about particular river segments or river sites – 55% were said to have or have had Eels.

⇒ A rather high number of respondents stated they had personally seen Eels: 42% during the last 22 years; 27% of the respondents responded that they had seen Eels in the particular river segments or the particular river sites their response was referring to in the last 12 years (Fig. 1.9, 1.10). This is a high number considering the alleged scarcity of the species and the fact that nowadays far fewer individuals are interested in hunting/gathering food in stream environments.

⇒ Some, particularly younger-aged respondents (<25 years old) were not aware of Eels (in contrast to older-aged respondents who confirmed sightings, Eel fishing etc. in the rivers of the same area).

⇒ 24% of respondents had actually fished for Eels; 56% of those who had were over 55 years old and only 16% were under 35 years old (Fig. 1,12). However many of the respondents that had never fished for Eel noted that they knew someone who had. This is a remarkably large number which shows that the Eels survived and were widespread on the island even during the “difficult years” for stream biota during the prolonged DDT poisoning campaign (1946-1978).

⇒ Approximately 1/5 of all respondents who have fished for eels use *Styrax officinalis* seeds (picked in summer and available for eel hunting in autumn) (Fig. 1.13). Another plant that was used is the so-called “Tsouna” (Τσούννα) – a herbaceous species, probably pertaining to *Euphorbia veneris* that is probably widespread. It is interesting to note that using plants as fish-anesthetics was very widespread in the past. During the colonial years, fishing with plant poisons was illegal (Πατσιάς 2004).

⇒ Eels were important as a food source for village people in the past (as were crabs). Several responses on how Eels were caught are given; of these seven generic types are categorized (Fig. 1.13). It is interesting that in the past specially-weaved baskets where used to capture, trap, and collect-store Eels (this practice is also found in other European countries, even in Britain).

⇒ Many respondents mentioned Eels in low elevation coastal wetland/ river mouth locations and they often referred to large numbers of Eels (e.g. at the Germasogia lower course, Akrotiri, Oroklini lagoon).

⇒ Eels were said to inhabit high elevation streams in many localities in the Troodos and Pafos area, often above 800 meters (up to approximately 1000 m). This information had never before been recorded on Cyprus since contemporary knowledge was that Eels were located only in the lower parts of streams. 62 responses to the question "What is the highest altitude you have encountered/ know of presence of Eel" revealed the presence of Eels in altitudes greater than 500 m was not infrequent (Fig. 1.14). 7% of the respondents answered that they were aware of Eel presence in altitudes greater than 1000 m (i.e. close to Kyperounta and Spilia villages). This is not unusual if one realized that the upland waters are more stable perennially flowing than the many lowland waters – so this could situation could have forced eels upstream. Amphibians which may provide a steady food source for large Eels, such as the ubiquitous Cyprus Frog (*Pelophylax cypriensi*s), are common in many streams at high elevation also.

⇒ Most respondents, who mentioned Eels in some way, were confident (even adamant) that Eels have declined. Not a single respondent mentioned that Eels have maintained stable populations or have increased (however very few younger people would go fishing for Eels nowadays). In some sites; respondents stated clearly and with confidence that a certain river definitely has no more Eels (usually due to a water abstraction/water transfer project or unknown reasons). Most referred to water development/dams and aquatic habitat destruction as the cause, many referred to poisoning by DDT or other chemicals as the key reasons for the Eel decline.

⇒ Some rivers and sites are very well known for large concentrations of Eels – but in all these locations residents mentioned that their numbers had also dropped (often declined dramatically). It is often difficult to specify when the species declined. Most mentioned sites include: Baths of Aphrodite, Chrysochou River, Ezousas River (e.g. Amati springs), Diarizos, Chapotami, Pyrgos River, and Gialia River. At some river basins, such as the Gialia river our field survey team persisted (especially after hearing the allegations of eel being present) in sampling several sites with negative results; so this may also provide evidence for an Eel decline.

⇒ Interesting behavioral details for Eels were given in the "Observations" section of the questionnaire. For example:

a) Eels are known to surpass small dams with low-inclined spillways by the respondents. Moreover, frequent mention was made of Eels being "trapped" in the dams such as at Agia Marina and Livadi (Pafos).

b) Eels have also been found underground or under river beds; for example in the Kiti-Zygi area where numerous Eels were found when a bore-hole was opened. Similar observations concerned the streams of Western Cyprus where river gravel and cobble are mined (e.g. at Ezousa). Also road works or pathway-making near streams has also revealed the presence of Eels (Avgos-Avakas, Karpasia). In some cases hundreds of Eels were observed under river gravel. All these recent observation of eels "underground" are testimony to the widespread presence of eels in the aquatic network of Cyprus inland waters.

c) People were aware of the fact that afte the first autumn rains there was a rush of catadromous eels downstream and at this time they were caught (the period lasting from early autumn to late winter depending on rains).

d) Eels survive in reservoirs and grow very big. For example specimens have been recently caught in Arminou Reservoir.

e) Eels were allegedly "threatened" by spraying campaigns that take place even today; one narrative related to a large number of Eels being found dead after routine mosquito spraying in the Pyrgos River (within the Buffer Zone) in 2008.

⇒ There is much anecdotal proof to indicate that nearly all rivers in Cyprus therefore had Eels – and this was also indicated by short interviews with locals that were conducted during the realization of the fish sampling survey and are not included in the questionnaire analysis. Even very small streams and wetlands were known to have had Eel or often said to still have Eel.

Concening aspects other than the Eel

⇒ The vast majority of respondents are very clearly aware of environmental change in river ecosystems, especially the degradation brought by water abstraction, damming and "poisoning" due to anti-malarial (initially DDT) and refrence to more recent anti-mosquito campaigns.

⇒ Many respondents pointed to the "devastation" of aquatic and semi-aquatic biota brought on by the intensive anti-malarial DDT spraying period (c. 1946-1978). It is interesting that many respondents mentioned that nearly all life in the rivers suffered from this poisoning.

⇒ The lack of freshwater crabs after the spraying is prominant –crabs were important as a food source, as were Eels. Crabs were hit hard by DDT in Cyprus and this is well documented in many cases. It was often said that in some streams the numbers of crabs were so high one could collect a "basket-full in a short stroll". The DDT created a mass die-out and certain places had no crabs at all (especially the small streams, or springs). The issue of the crab's decline was reiterated in many places through Cyprus, even in the occupied territory. It was made clear in at least two cases, were a respondent had personally assisted in translocating crabs after the cessation of DDT spraying. Finally, in several cases the locals are aware of the crab's population comeback and this is well known by forestry workers as well (see Αντωνίου 2005). Contrary to the past, the species is not widely collected as a delicacy as it was before about 1980.

⇒ Amphibians were allegedly hard hit by the DDT poisoning. One respondent from Fini reported that in the late 1970s due to past poisoning die-out, there were no frogs in the streams and rivers around the area. He mentioned that before this period, frogs were considered as a delicacy[1] at Fini (but crabs were the main target when gathering food from rivers). A relative of this man brought the frogs back to the Fini area from Lefkosia in the early 1980s (an act of transplanting). This piece of information is important and shows the problem of DDT mass biota die-out[2].

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[1] This is the only refrence to eating frogs (genus Pelophylax/Rana) that we found from Cyprus.

[2] This issue of former amphibian decline is corroborated by several herpetologists who in the early '1980s mentioned that some amphibian species may be nearing extinction on the island (Schmidtler 1984; Roth & Brauer 1986, as cited in Baier et al 2009). Today it should be said the amphibians are widespread and often abundant so for most of the three species involved the come-back is obvious. Amphibians, the tadpoles and adults are important prey items for Eels (and also for larger-sized trout).

⇒ The respondents who currently spray for mosquitoes are often very knowledgeable about the stream conditions and biota. Two such individuals in the Diarizos area gave specific and interesting details (at Fini and Kouklia). One of these individuals is active in translocating fishes (Roach and Mosquitofish to river stretches); he keeps the fish himself.

⇒ Reference to other fishes was rather scant. Some respondents mentioned marine transients (mugilids, sea bass, "Atherina") swimming from the sea into river mouths in the recent past (i.e. at Diarizos river mouth, Chrysochou river mouth, and Ammochostos area - including lagoon environments next to Ammochostos city (occupied territory). The individuals who usually mentioned this were older and were referring to pre-1970 conditions. This is important proof that marine transients or euryhaline fishes made up an important faunal element of the coastal /river-mouth sections of Cypriot rivers in the past.

⇒ It is notable that little attention to historical conditions exists pertaining to fishes in streams. Most younger-aged respondents "accept" that the rivers "go dry" and are fishless, nearly "not rivers" but ephemeral torrents. Most resource scientists (water, forest, conservation scientists) do not explore or seem to deeply care to explore how rivers were a century ago.

General comments

An important issue brought up by the questionnaire interviews relates to a "temporal myopia"[3] with respect to a lack of awareness of the conditions and resources in rivers more than two or three generations back. A distinct lack of a sense of history of periods longer than ones' career was evident in some younger Cypriot resource scientists (foresters, fisheries biologists) and also of younger farmers. This attitude and focus on the "present" is dominant in ecology and resource management, and it has been criticized in many recent accounts (Crowder, 2005). Residents who recall the rivers before 1970 mention details with vivid and lively scenes of often very different conditions from today (more surface waters; perennial flows where there are intermittent conditions today; richer aquatic biota; frequent river connectivity with the sea; etc.). Of course, we cannot base scientific descriptions solely on these memories. In some cases, the "good-old-days" are magnified. For example natural climatic desiccation in nearly all lowland rivers is obviously the norm for most of the rivers in the lowlands and this is sometimes confused when wet periods are referred to as a norm. Also the period of DDT spraying spans a very long time and it is difficult to find many people who recall the pre-1946 conditions. If the DDT poisoning caused a widespread die-out, as we hypothesize is surprising some much refrence to a rather richer stream life exists even before 1970. In this light, it is surprising so much reference to Eel was made by the respondents – since most were referring to Cyprus' conditions after WWII (i.e. after the widespread use of DDT which obviously had negatively impacted eel abundance in Cyprus). The use of questionnaires is extremely important for searching for refrences of conditions before the widespread use of DDT and the intensive water management that took place in the 1960s. In short, the questionnaire was instructive but more work and specifically targeted investigations of this type are needed.

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[3] Term used by Jackson et al., (2001).

1.8. Generalizations from the initial collection of background information in view of organizing the scheme to use fishes for bioassessment on Cyprus

The initial survey of past research (including recent sampling by the HCMR team in other projects in 2009 and 2010), the bibliographic review, expert interviews/ questionnaire application and intial field survey were combined to provide an informative background and an initial account of the ichthyology of inland waters in Cyprus. Expert interviews and cooperation with the WDD personnel, the Department of Fisheries and Marine Research (DFMR) and Forest Department also greatly augmented information acquisition and confirmation of fish presence in river sites and associated water bodies. The application of a simple questionnaire was extremely important in providing important insights into aspects of recent historical change in inland waters. Particularly important is the first organized collection of evidence pertaining to widespread aquatic “DDT poisoning” during the period between 1946 and 1978. Evidence of widespread extirpation of fishes and other aquatic life was commonplace during this prolonged anti-malarial campaign. The effects of dams, hydrological degradation from abstractions, in combination with the DDT poisoning create a “shifting base-line” problem for the aquatic biota that makes predictable patterns if fish distribution and abundance challenging on Cyprus’ rivers. The issue of very variable climatic/percipitation conditions and severe water stress is also particularly important when utilizing fish as bioindicators on this Mediterranean island.

An important realization in this initial survey is that the number of native species on the Cyprus is limited; and this is found to be a biogeographical phenomenon widespread on other Mediterranean islands (Bianco et al.1996). Extinction is a “natural” phenomenon on islands; aquatic environments and poorly dispersing vertebrate animals are extremely vulnerable to extinction (Foufopoulos et al. 2011).

Most river systems on Cyprus display seasonally semi-arid intermittent surface-flow conditions not typically found in most European states, while in contrast many upland sites are similar to temperate cold-water streams. Naturally intermittent streams, or so-called temporary rivers, predominate and these are often difficult to define and map with the available geographical information. Intermittently flowing river systems flow only during times when they receive water from springs and surface runoff, while during seasonally dry periods they may cease to flow entirely or are reduced to stream pools or desiccated riverbeds.

The effects of this natural variation in surface water features, the climate-driven desiccation (meteorological droughts), together with the effects of direct (water resources exploitation) and potentially indirect (climate change) anthropogenic degradation on hydrological functions have created ‘water stress’ conditions. These conditions have been considerably affecting the rivers’ natural flow regime on Cyprus during the past half century. Although rivers and their aquatic and riparian biota in semi-arid climate regions are extremely sensitive to hydrological and an array of anthropogenic pressures, the behaviour of the biota in streams of this type on islands have been poorly studied. In fact, temporary rivers constitute one of the least known types of fluvial ecosystems woldwide (Uys and O’Keeffe, 1997; Jacobson et al., 2004; Ryder and Boulton, 2005; TempQsim Consortium, 2006).

Water stress causes deterioration of freshwater resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (organic pollution, eutrophication, saline intrusion, etc.). Water stress can also have major ecological effects on aquatic biota and ecosystem functioning. In fact, the alteration of flow regimes is considered to be the most serious and continuing threats to ecological integrity of natural river ecosystems (Bunn and Arthington, 2002). Numerous studies have indicated that drought episodes can significantly alter the fish community structure and dynamics, through influencing fish growth, survival and reproductive activities, and thereby affecting the species composition, abundance, and age structure of local fish assemblages (Matthews, 1998; Lake, 2003; Magoulick and Kobza, 2003). Research in species-impoverished streams in southern Greece has also shown that fish may be good indicators of water stress (Skoulikidis et al., 2011). In Cyprus the effects of water stress on fish have never been explored. Obviously one of the difficulties in building fish-based tools in species-poor variably intermittently flowing streams in an island such as Cyprus is the heterogeneous nature of surface flow patterns, be they natural or anthropogenically degraded (i.e. artificially intermittent stream flows due to abstraction and impoundments).

The WFD does not particularly address intermittent rivers. Recently, in view of increased human demands, potential climate change impacts, and ecosystem conservation requirements, temporary running waters have gained increasingly high economic and ecological interest (Larned et al., 2010) and specific approaches are being developed in all states were the WFD is being implemented. Therefore, it is necessary to include intermittent rivers and intermittent and even ephemerally flowing reaches of river basins in the ecosystem-based integrated water resources management scheme dictated by the WFD. To develop effective River Basin Management Plans for intermittent rivers, it is essential to enhance scientific knowledge on their structural and functional characteristics. This holds particularly true for intermittent rivers which have been largely created by human-induced water stress

SECTION 2.

FISH SAMPLING AND COLLECTION OF SUPPORTING DATA

2.1. Fish sampling organization

This project was obligated to conduct fish sampling in several study rivers, primarily focusing on perennial stretches or formerly perennial reaches (i.e. reaches that are currently degraded due to water-transfers, engineering projects, and abstractions). In fact due to the lack of fish at many investigated sites the survey expanded to 18 river basins.

This section of the report outlines aspects of fish sampling. This work includes the following work packages:

- **Work package 1**: Standardized fish survey sampling. RESULTS: Quantitative sampling and environmental data initiated.
- **Work package 2:** Anthropogenic Pressures. RESULTS: Collection initiated.
- **Work package 3**: Descriptive study of fish species and populations in Cyprus rivers. RESULTS: Cyprus' first review of inland water ichthyology completed.
- **Work package 4**: Substantiated Cyprus position regarding the BQE "fish" in Cyprus Rivers within the framework of the implementation of the WFD and the related Intercalibration Exercise: RESULTS: In June 2011 and in October 2011 particular position communicated with IC process.

2.2. Environmental data on stream conditions in Cyprus

An important aspect of the project is recognizing the extent to which the sampling and assessment procedure we are undertaking with fish is broadly relevant to Cyprus streams. Firstly, we should be primarily interested in the naturally occurring perennial river reaches of Cyprus. Percent of river stretches categorized (mapped) in the free part of the Republic are shown in Table 1. This work is indicative of the study team's attempts to use existing data on water bodies and to incorporate corrections also. The hypothetical perennial river reaches were corrected with interviews with WDD and Forestry Department personnel.

Table 2.1. *Perennial versus Temporary River reaches on Cyprus: an initial assessment.*

Type	***Kilometers in Cyprus (Free part only)***	***Percent cover***	***Comments***
Temporary river reaches: Intermittent/ Ephemeral reaches	*2.297 km*	*87%*	*No effort has ever been made to distinguish perennial from ephemeral flowing reaches in Cyprus; most of these are assumed to be Perennial since they are mapped as "water bodies" in the WFD application.*
Perennial rivers	*341 km*	*13%*	*Primarily in the western part of the island; many formerly perennial reaches not mapped.*

However Table 1 and Fig. 1 are also indicative of the problematic cartography of surface waters in Cyprus. There is a large extent of temporary rivers that may be "artificially perennial" or that may also have very small perennial reaches. It must be noted that in other analogous mapping exercises (e.g. in the USA), even very small perennial reaches are mapped. In Cyprus and in many parts of the Mediterranean even the terminology concerning the temporary nature of streams is poorly defined. The diagram that follows (Fig. 41) refers to a continuum of natural surface water hydrological states ranging from perennial, intermittent, ephemeral and episodic.

<u>The following pertinent definitions are provided:</u>

<u>Perennial Stream</u> – A well-defined channel that contains water year round during a year of normal rainfall with the aquatic bed located below the water table for most of the year. Groundwater is the primary source of water for a perennial stream, but it also carries storm-water runoff. A perennial stream exhibits the typical biological,

The flow may be heavily supplemented by storm-water runoff. An intermittent stream often lacks the biological and hydrological characteristics commonly associated with the conveyance of water. Hydrological and physical characteristics commonly associated with the continuous conveyance of water.

<u>Intermittent Stream</u> – A well-defined channel that contains water for only part of the year, typically during winter and spring when the aquatic bed is below the water table.

<u>Ephemeral Stream</u> – Ephemeral (storm-water) stream means a feature that carries only storm-water in direct response to precipitation with water flowing only during and shortly after large precipitation events. An ephemeral stream may or may not have a well-defined channel, the aquatic bed is always above the water table, and storm-water runoff is the primary source of water. An ephemeral stream typically lacks the biological, hydrological, and physical characteristics commonly associated with the continuous or intermittent conveyance of water.

In Cyprus, there is a lack of cartographic information on the state of perennially flowing rivers and this creates immediate problems with fish-based approaches. Some Hydrogeological studies (Geological Survey Department, 1970) do distinguish between perennial and “seasonal” streams, but this information is at very coarse level and severely outdated.

Methodologies to identify geomorphic, hydrological and biological stream features that distinguish between ephemeral, intermittent and perennial streams have been developed in other countries and are frequently applied for policy-relevant cartography and taxonomic of streams (see Leopold 1994; NC Division of Water Quality, 2005).

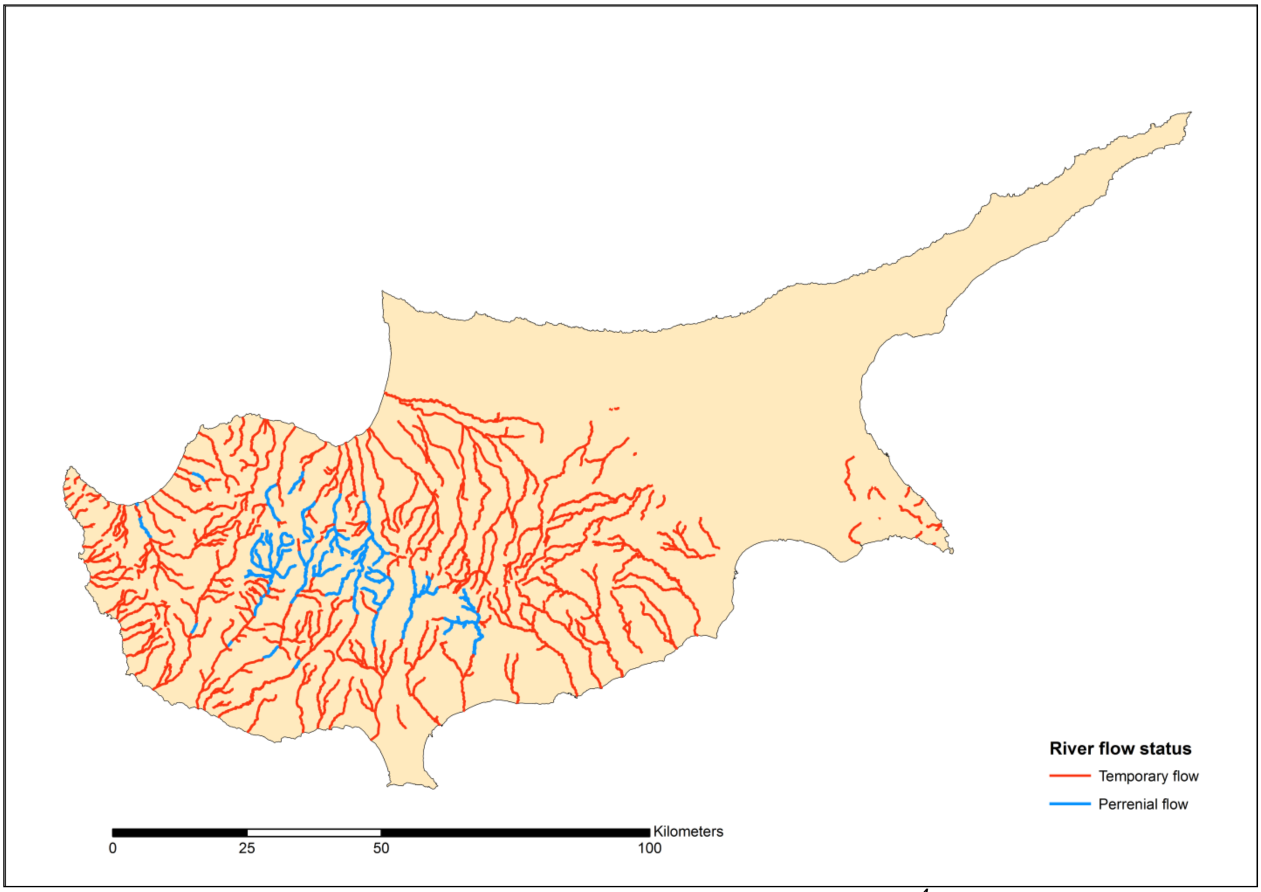


Fig. 2.1. *Map of hypothetical flow status of streams on Cyprus[4]. Blue pertains to areas perceived to be in a state of perennial flow (even during the dry season there is water in most of the riverbed although in exceptional drought years these may go dry but for no more than a few months. Red shows all reaches that have temporary flow – usually intermittent flows (i.e. flowing during the wet season for a large part of the winter and spring (>5 months). Red areas also include some natural and artificially degraded ephemeral flowing streams (i.e. water present only after precipitation events; but usually dry for most of the year).*

[4] This map has been corrected after interviews and field observations by the author team and by members of the WDD in 2012. The verification of stream flow character is a very important theme that remains poorly researched in Cyprus.

2.3. Fish Sampling

Three key attributes of the fish community—species composition, abundance and age structure (Annex V of 2000/60/EC)—must be included in the scheme(s) for fish-based classification in order to be WFD compliant. The classification must be based on an evaluation of current status of the fish community relative to the value at reference conditions—the ecological quality ratio (EQR)—for rivers. So in this respect fish sampling in Cyprus must aim to comply and to research basic natural history attriubutes since no such survey work or monitoring has ever been developed.

Fish sampling was conducted using a two-tiered survey approach:

a) Qualitative rapid sampling-observational records (accorded here as "*investigative sampling*" which also includes past sampling data) and

b) standardized sampling electrofishing following standardized European bioassessment approaches (accorded here as "*quantitative sampling*").

Selecting sampling sites based on representative river type segments, and macro-habitat categories in relation to biophysical and/or meso-habitat features is especially challenging in Mediterranean streams due to the remarkable heterogeneity, widespread anthropogenic pressues and seasonal variability of conditions in lotic systems.

Site selection ensured that nearly all river water body biophysical units are covered (usually given by changes in geology, river-branching order number and altitude/slope) and that some sites are in good/high condition (based on a pre-classification of condition, using anthropogenic pressure analysis, literature review and expert judgment). This type of representative sampling regime must include sites in good and poor/bad condition (relative to anthropogenic pressures) for each of the river units/ water bodies (i.e. sub-region separations can be set, i.e. mountain east, mountain west, middle course and plain).

Also, whenever a site is sampled at a regulated river segment (degraded site; i.e. beneath a dam), a similar unregulated site should be sampled to compare fish assemblages and to explore pressure-specific impacts.This activity will organize and implement the fish sampling (population, fish assemblage data) and collection of all site-specific supporting environmental data.

The approach in sampling for bioassessment capacity evaluation of the BQE fish will follow typical multimetric development approaches as the spatially-based approach in FAME or IBI approaches that have been developed for intra state applications.

2.4. Number of samples

From Table 2.1 it is clear that the number of samples per river surpasses the number originally foreseen and this provided added power to the analyses and interpretations. Of course, large number of sites (67 sites) were fish-less and this could not have been forseen without sampling.

Details of the sampling rationale:

- Electrofishing was the standard method (however the fry-net was used in several sites as an alternative)
- At least 100 meters of river stretch were sampled using electricity and a catch-per-unit-effort estimate was made using the areal coverage of the site. Where no fish were located more than 100 meters were often sampled.
- Site habitat representativeness; longitudinal position and accessibility were the main criteria for selection.
- An attempt was made to select sites based on an assumed gradient of anthropogenic degradation (i.e. sites of good/high conditions versus sites of poor/bad conditions in similar type-specific condtions).
- On each of the studied river catchments at least two sites were quantitatively sampled, while at some river catchments at least three sites were sampled.
- Very few reaches were sampled repeatedly; only 8 sites were sampled using the electrofishing method twice over the three year period of work. However many sites were sampled within very close proximity of each other.
- Finally, because scarce catadromous species (i.e. Eel) and other marine migrants use Cyprus lowland rivers and river mouths (e.g. Mugilids), other sites beyond the contract's obligation were also investigated for the presence and abundance of these native species.

2.5. Protocols

Acquisition of information about fish species, populations, population density, reproduction and other attributes relevant to the implementation of the WFD were collected primarily using electrofishing (for technical details please see Economou et al., 2007 and Zogaris et al., 2011). The electrofishing sampling method is considered a standardized technique for sampling stream fishes for bioassessment (CEN, 2003; Beaumont, 2011).

Quantitative fish sampling was performed according to:

- Quantitative fish sampling relied solely on standardized electrofishing sampling. The standard CEN EN 14011 "Water quality - Sampling of fish with electricity".
- Quantitative fish sampling employed the "Standardized Sampling procedure" that was developed by the FAME project, which was subsequently adopted also by the EFI+ project.
- Stop nets were not used; the sampling team utilized natural or existing artificial barriers (drops, weirs, etc) instead to prevent fish from escaping within the sampled sites.
- A fry net (4 mm; 6 m long); a kind of drag-net device, was used to collect fish where conditions did not allow the use of electrofishing (e.g. high conductivity).
- The quantitative samplings undertaken in late spring or early summer to allow catching YOY fish (young-of-year juvenile specimens).
- All fish were identified at least to species level and to subspecies level where and if appropriate. Fish size-class and age-class classification was determined for all caught fish. Size-class increments (i.e. not detailed increment measurements to the centimetre) allow a faster processing of the collected fish samples[5]. Nearly all fish were returned alive to the exact place they were sampled.
- Some fish samples were collected for laboratory analysis and genetic research (for investigating taxonomy).
- All sampling sites have to be characterized according to "pre-classification ecological condition"; the data collected during the project was compatible with the Common Fish Database kept for IC purposes at Cemagref/France. To accomplish this, the following information has been collected as a minimum:
  - Fishing occasion data, site description & in-stream environmental variables.
  - Anthropogenic pressures description.
  - Fish catch data.
  - Diadromous species data.
  - Riparian zone condition data (using the QBR protocol)

[5] This method of rapidly counting and measuring specimens (to size-class) and to relative age-class is widely applied in Germany and on a research basins in Greece also. If fish samples a processed for counting and precise measuring outside the river channel (in containers and buckets and after treatment with anesthetics) the field processing may be two or three times longer.

- All sampling sites/stretches have to be characterized according to the “criteria for undisturbed sites” as used in the River Fish IC Exercise.

Sampling has followed approaches and protocols promoted by the FAME project procedure (FAME, 2004) in order to explore the use of fishes as Biological Quality Elements (BQEs) as a priority. The purpose of BQE indices is to determine the reaction of the ecosystem components to human pressure and concomitantly to the absence of it; and, this has yet to be investigated statistically using fish in many Mediterranean island rivers.

Field protocols follow the standardized method used for the implementation of the WFD in Greece. Three protocols (habitat details, fish measurements and the QBR) were completed at each site. The three protocol field forms are provided in the Appendix.

2.6. Study Areas – River sites

This work has provided the WDD with an important database of fish-based knowledge from specific river/reservoir and wetland sites in 31 river basins, involving 170 aquatic sites in total; 103 of these had fish (Fig. 2.2 & Fig. 2.3). Table 2.2 gives summary results.

Fig. 2.2. *Sampling with electricity in a three-person team on the lower Diarizos opposite Souskiou Village. This reach like many others was fish-less. The standardized documentation that no fish are present is valuable information; the site is carefully investigated and a habitat field form is completed, even if fish are not present. Each “fish-less” sampled site should take no less than 50 minutes of persistant sampling since very small populations may persist (Photo: V.Hatzirvassanis July 2012).*

***Table 2.2** Sampling site numbers and relevant characteristics of the study rivers in Cyprus*

1*	2*	3*	4*	5*	6*
Akrotiri	*4*	*1*	*4*	*5*	*3*
Argaki tou Pyrgou	*1*	*0*	*1*	*5*	*2*
Avgas	*2*	*1*	*0*	*1*	*0*
Agios Ioannis	*1*	*1*	*0*	*1*	*0*
Chapotami	*2*	*0*	*2*	*3*	*2*
Chrysochou	*13*	*0*	*11*	*11*	*5*
Diarizos	*21*	*1*	*17*	*11*	*7*
Elia	*2*	*0*	*1*	*7*	*0*
Ezousas	*7*	*1*	*5*	*10*	*5*
Germasogeia	*14*	*0*	*7*	*13*	*6*
Kampos	*2*	*0*	*0*	*2*	*0*
Kargotis	*8*	*0*	*4*	*4*	*1*
Katouris	*2*	*0*	*1*	*2*	-
Kouris	*26*	*1*	*11*	*15*	*6*
Limnitis	*6*	*1*	*2*	*6*	*1*
Makounda	*6*	*0*	*2*	*10*	*1*
Marathasa	*5*	*0*	*5*	*10*	*3*
Maroni	*1*	*0*	*0*	*1*	*0*
Pediaios	*4*	*0*	*4*	*13*	*7*
Pentaschoinos	*2*	*0*	*1*	*11*	*2*
Serrachis	*1*	*0*	*1*	*10*	-
Pouzis	*2*	*0*	*1*	*3*	*2*
Pyrgos	*4*	*1*	*1*	*4*	*1*
Tremithos	*3*	*0*	*0*	*2*	*0*
Voroklini	*2*	*0*	*2*	*5*	*4*
Xeros (Ag. Marinas)	*1*	*0*	*1*	*9*	-
Xeros (Gialias)	*2*	*0*	*1*	*1*	*1*
Xeros (Lefkas)	*7*	*0*	*6*	*7*	*4*
Xeros (Livadi)	*3*	*0*	*2*	*2*	*2*
Xeros (Mazotos)	*1*	*0*	*1*	*1*	*0*
Xeros (Pafou)	*15*	*1*	*9*	*14*	*6*

***Legend to columns**:*

1. River basin name. 2. Total number of sampled sites; 3. Sites sampled more than once; 4. Sites with fish present; 5. Number of fish species referred in bibliography and recent research; 6. Number of fish species confirmed through the field survey (2010-2012).

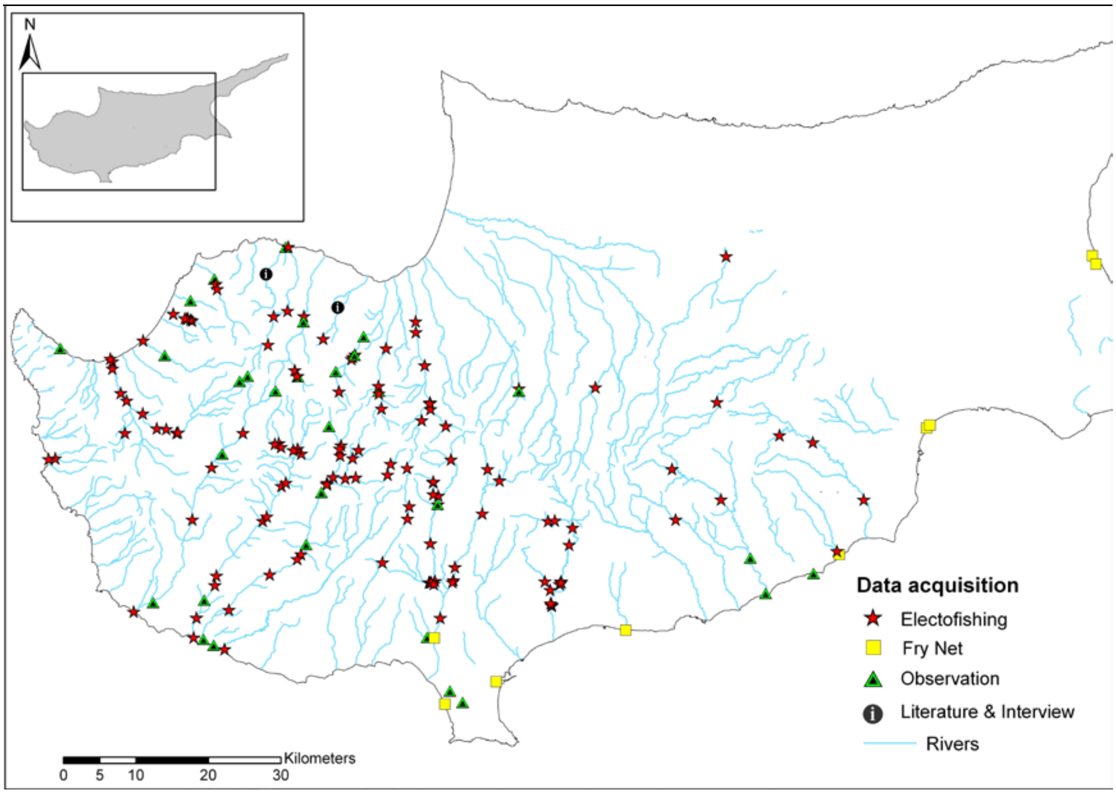


Fig. 2.3. *Methods of investigation for ichthyological and environmental data acquisition: star: electrofishing; asterisk: observations or other method other than electrofishing; yellow-circle-with-spot: Literature or report/reference from scientific personnel; yellow-circle-without-spot: interview of local informant (not confirmed by scientific report/literature or specialist)*

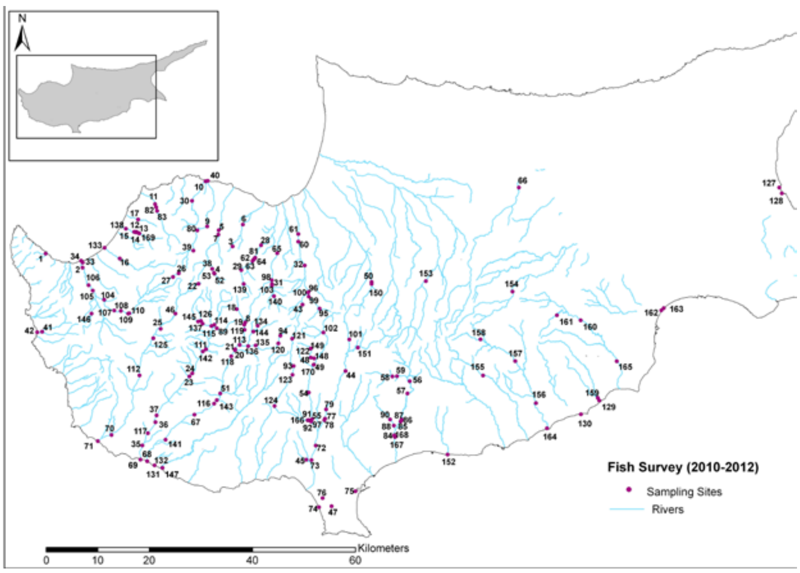


Fig. 2.4. *Total number of sites investigated during this project. Site names, sampling details, water body association etc. are provided in the Appendix where this map is also* reproduced at larger size

SECTION 3

EVALUATION AND SYNTHESIS OF COLLECTED DATA

3.1. Rationale for evaluation of collected material

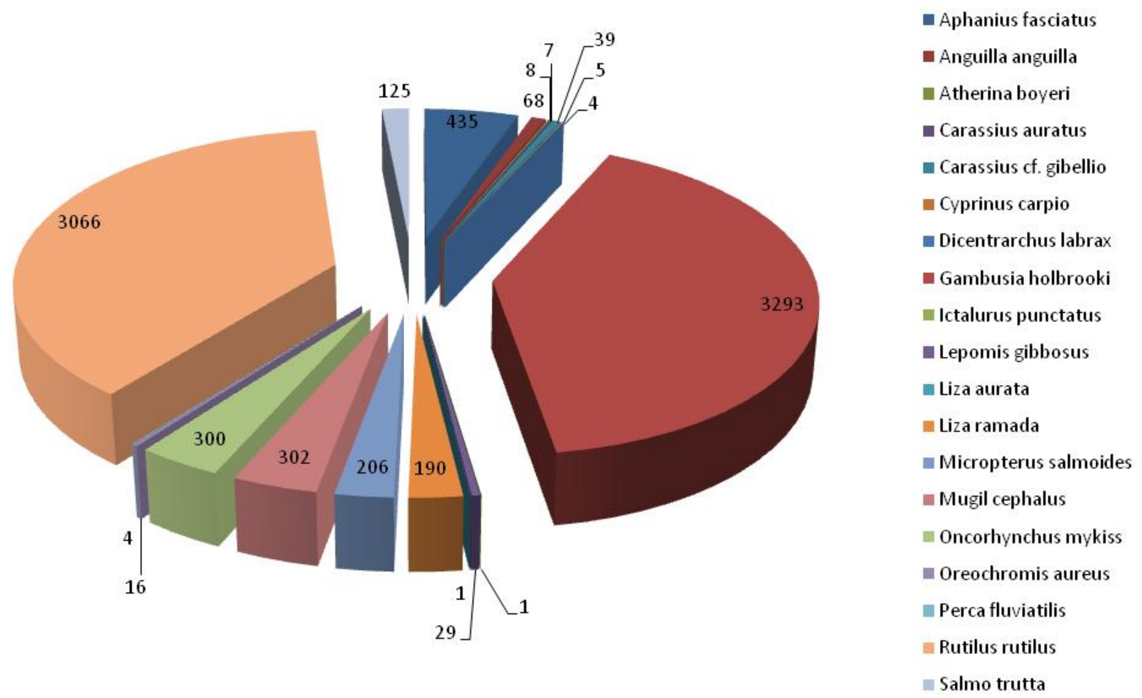
This section provides the results of the sampling campaign and an initial descriptive analysis, interpreting the degree to which the results can be used to develop fishes as Biological Quality Elements in the rivers of Cyprus.

- **Work package 1:** Results and evaluation. RESULTS: Fish survey results are analyzed. Site and habitat degradation information is analyzed and a relative disturbance gradient is established.
- **Work package 2:** Eligibility of fish as BQE. RESULTS: Fish attributes are utilized to test responses to degradation and specific pressures. Initial statements on the applicability of fish as BQE for rivers in Cyprus are developed.

3.2. Results of the complete sampling campaign

Eighty one (81) sites where sampled in a quantitative approach using the electrofishing method. Thirty one (31) other sites have been visited and information from optical assessment (direct observations), the literature and local specialists has contributed to base-line knowledge of their ichthyofauna. This survey represents the first widespread survey using electrofishing on Cyprus.

Other sites such as dam reservoirs or wetlands were also visited but information on the fish composition of these water bodies is qualitative and of varying accuracy. All sites are noted on Fig. 2.3 and presented in detail in the Appendix. Initial patterns pertaining to the community of fishes per site and at the basin scale are given bellow.



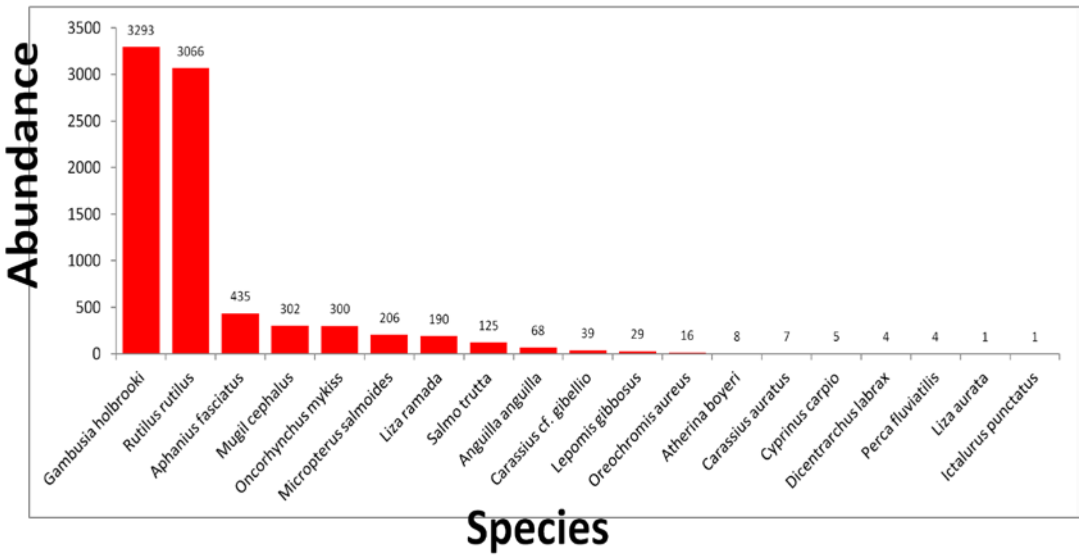


Fig. 3.1. *Relative species total abundance among the 19 species collected during the project; the overwhelming relative abundance is dominated by Gambusia holbrooki and Rutilus rutilus.*

Table 3.1. *Fish spp. per major basin. Specifically showing natives, naturalized, aliens (from interviews, bibliography and sampling).*

	Diarizos	*Xeros (Pafos)*	*Ezousa*	*Avgas*	*Agios Ioannis*	Chrysochou	Makounta	Xeros (Ag. Marina)	*Katouris*	*Pyrgos*	*Limnitis*	*Kampos*	*Xeros (Lefkas)*	*Marathasa*	*Kargotis*	*Pediaios*	*Germasogeia*	*Kouris/ Akrotiri*
Anguilla Anguilla	■	(■)	■	(■)	■	■	■	(■)	(■)	■	(■)	(■)	(■)	(■)	(■)	■	■	(■)
Mugil cephalus	■	■	■			(■)	(■)				(■)		(■)	(■)	(■)	(■)	(■)	(■)
Salaria fluviatilis	(■)					(■)											(■)	(■)
Dicentrarchus labrax	(■)	■	(■)								(■)					(■)	(■)	(■)
Mugilidae sp.(Liza spp.)	(■)	■	■			(■)	(■)				(■)				(■)	(■)	(■)	(■)
Aphanius fasciatus																■		■
Salmo trutta	□	□												○	○			□
Rutilus rutilus	◊	◊	◊			◊	○	◊					◊	◊			◊	◊
Gambusia holbrooki	◊	○	○			○	○	○	○		○		○	◊		◊	◊	◊
Carassius auratus													◊	◊		○	○	
Micropterus salmoides		◊				◊	○	○									◊	◊
Oreochromis sp.		○														○	◊	
Lepomis gibosus	◊		◊														◊	
Ictalurus punctatus		◊					◊	○						◊		○		
Perca fluviatilis																		◊
Oncorhynchus mykiss	○	○	◊			○	○	○		○	◊		◊	◊	◊	○	○	◊
Cyprinus carpio	○	○				○	○				○		○	◊			○	○
Abramis bjoerkna	○	○																
Alburnus alburnus			○											○				

■ Native species; (■) Native species but presence not confirmed; □ Naturalized species; ◊ Non indigenous (confirmed presence); ○ Non indigenous (presence not confirmed). N.B. Salaria fluviatilis is not included since its current status is unknown.

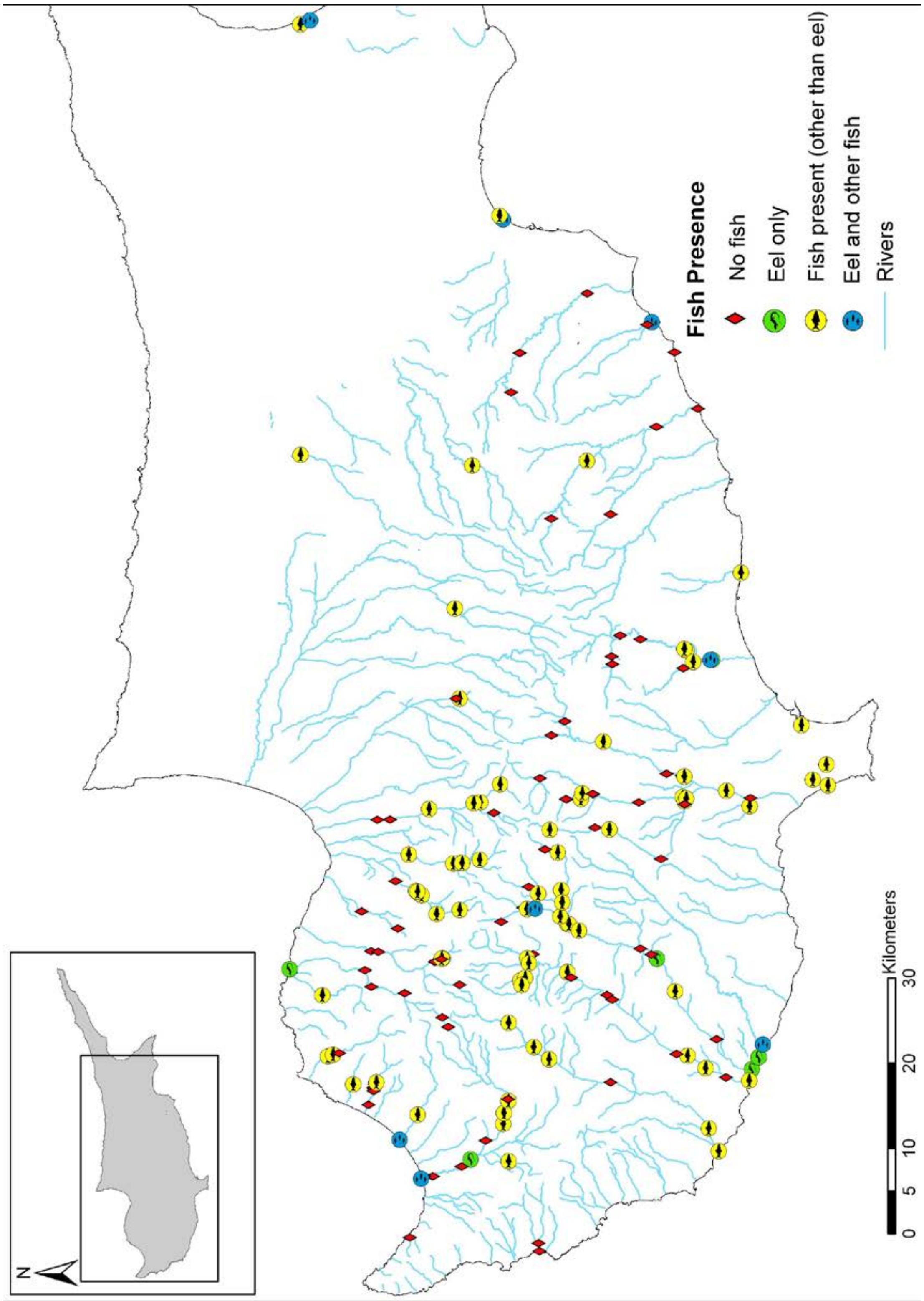


Fig. 3.2. *Cumulative results of fish presence survey based on sampling and observations by the HCMR team members (2010-2012).*

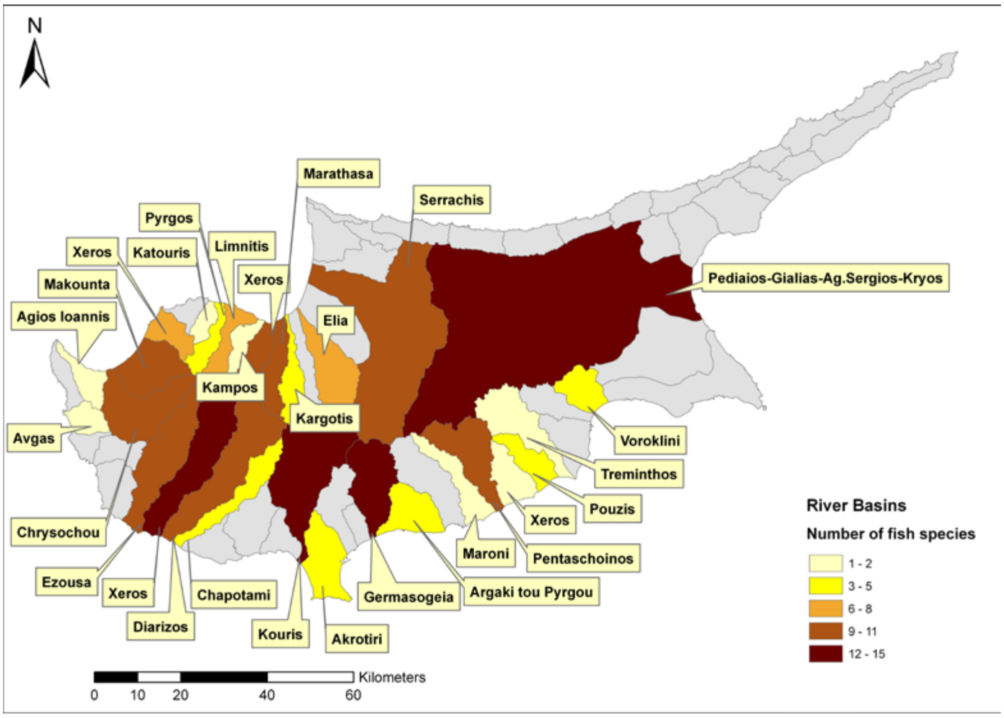


Fig. 3.3. *Total number of fish species recorded in studied basins during this project. Names of all basins as registered by WDD are also given for orientation (the Pediaos includes all watersheds within the wider Mesaoria and this is why it is labeled as such here).*

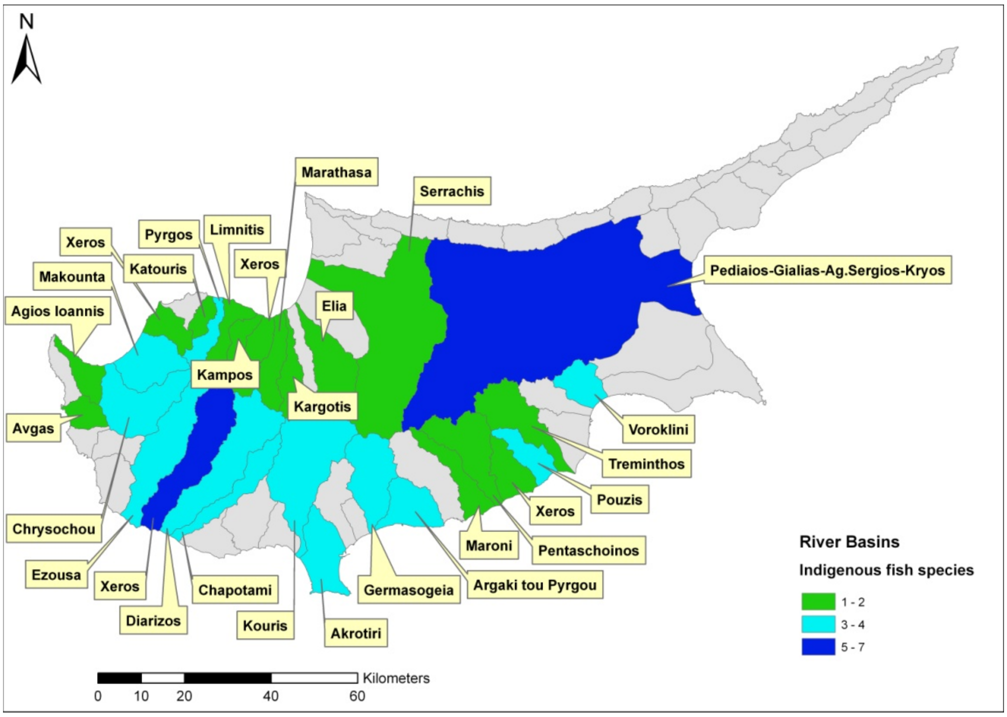


Fig. 3.4. *Total number of indigenous fish species recorded in studied basins during this project. Note that only the very small basins have very low diversity.*
Note in the above figures that the total native species diversity (5-7 taxa) is directly related to the basins natural connection to the sea(and most larger basins had a connection to the sea; even some small ones without dams still have; eg Pouzis). Also poorly researched basins

such as the Serrachis have an unusually low number. Native euryhaline species distributions are still poorly surveyed at the national level.

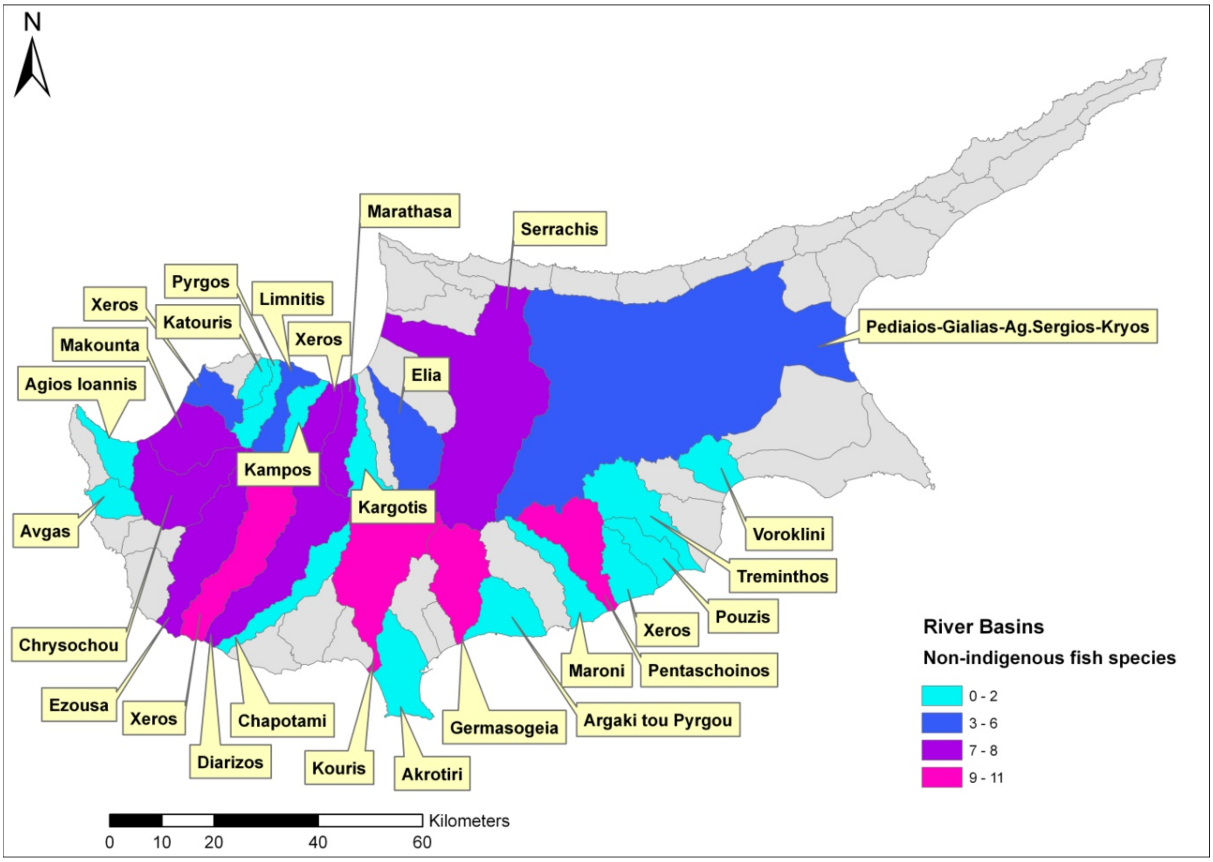


Fig.3.5. *Total number of non-indigenous fish species recorded in studied basins during this project.*

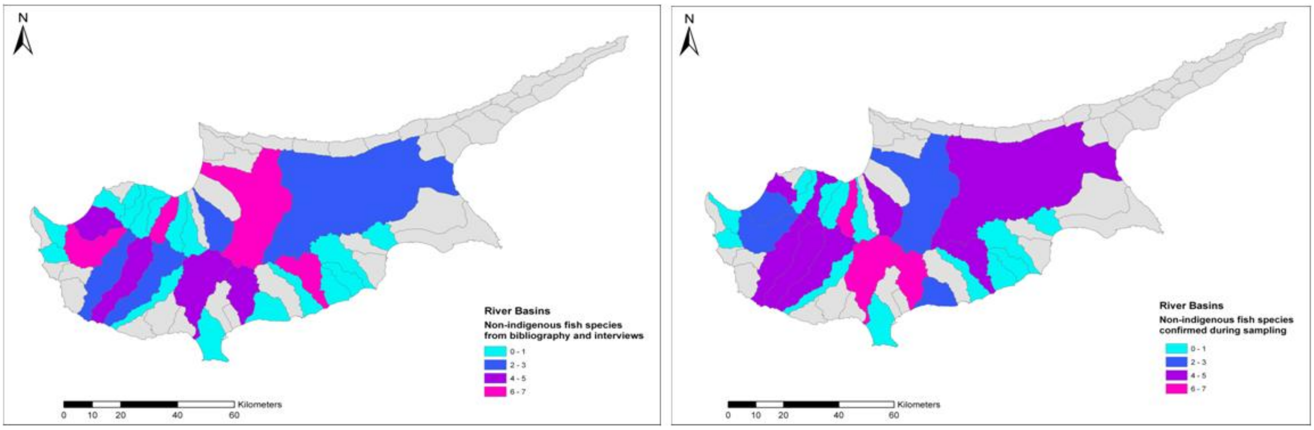


Fig. 3.6. *Total number of non-indigenous fish species recorded in studied basins solely through the bibliography and interviews (at left) and solely through sampling (at right). The above figures show that only the very small basins have very small numbers of fishes. Basin size and knowledge of the alien species established in reservoirs determines apparten interbasin species richness.*

3.3. Biotic groups and "Fish communities" in Cyprus' streams

Cluster analyses was used (Euclidean distances, Ward Method) to classify sites into similar biotic groups. The cut-off was arbitrarily chosen to be the Similarity level 37% for both analyses (one based on presence/absence of the species per site the other taking populations of fish into account as well). All sites with fish were used in the analyses. All Mugilidae were lumped together, and unidentified Cyprinidae fry were excluded from the analyses. In parallel, Non-Dimentional Scaling (NMDS) analysis (using Primer version 6) was done and the dendrogram cut-off was superimposed to show the relationships among sites.

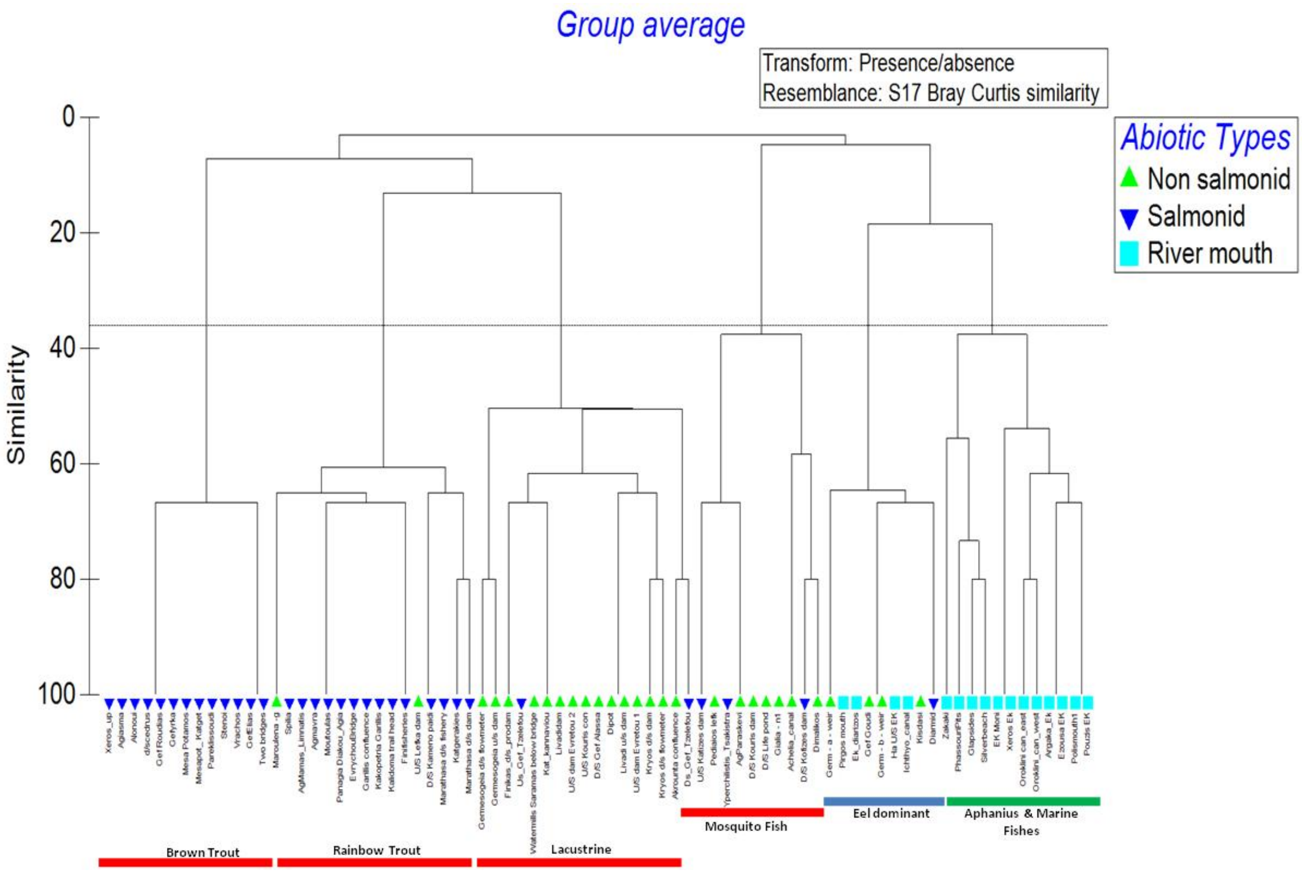


***Fig. 3.7.** Dendrogram of hierarchical clustering of all sites with fish, using group-averaging clustering from Bray-Curtis similarities on all fish species present (presence/absence). Six biotic groups are defined at an arbitrary 37% similarity threshold (the grey horizontal line at the 37% mark is superimposed on the dendrogram). Biotic groups are labeled on the bottom of the dendrogram – the red ones are non-indigenous assemblages.*

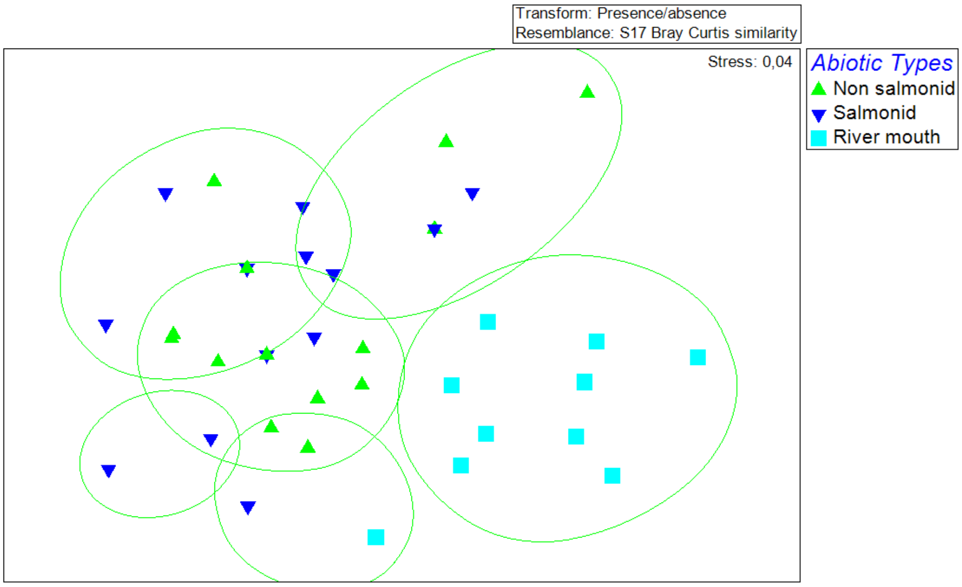


Fig. 3.8. *Non-Dimentional Scaling NMDS plot of the different sites that had fish populations. The configuration shows that the designated groups in the cluster classification dendrogram hold quite well. River mouth (=coastal communities area well defined). There is a very rough delineation of sites among Non-salmonid and Salmonid and quite a bit of spread (showing the variation in assemblages).*

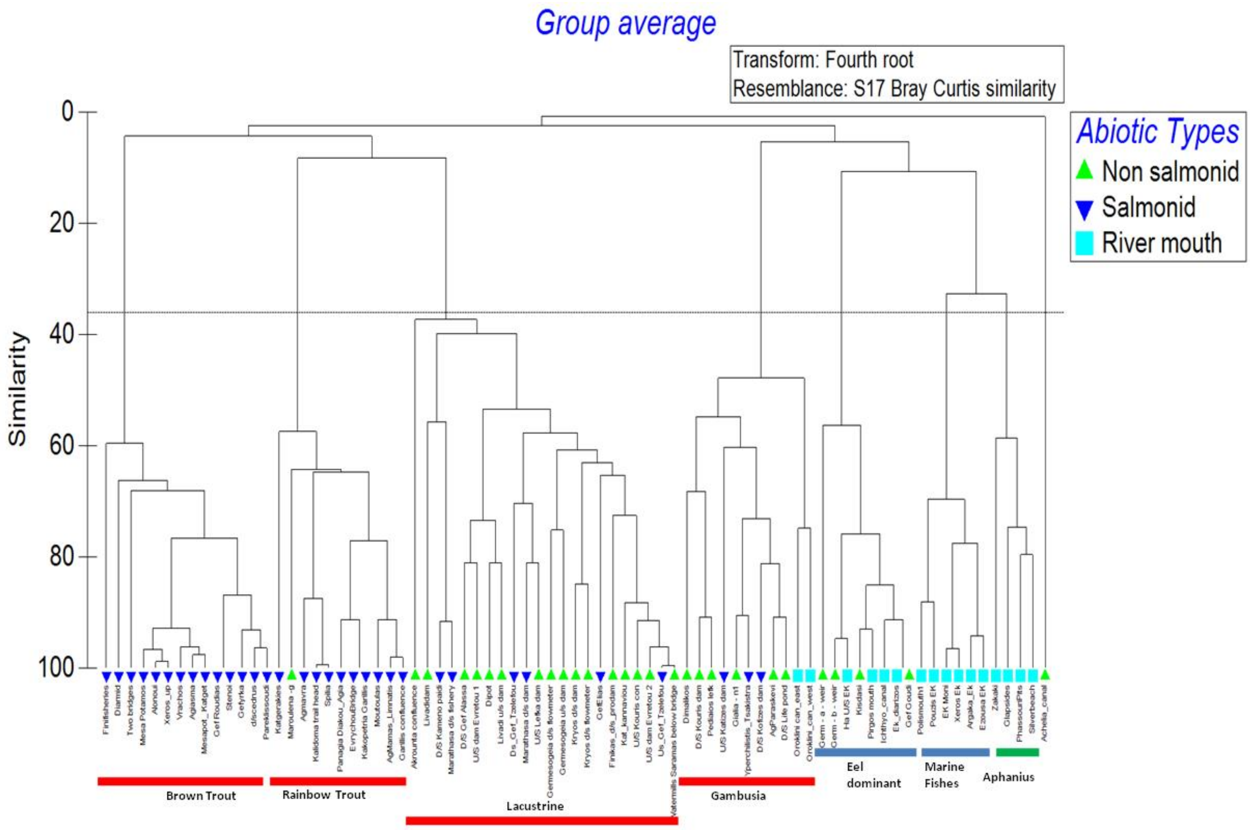


Fig. 3.9. *Dendrogram of hierarchical clustering of all sites with fish, using group-averaging clustering from Bray-Curtis similarities on all fish species present (with numbers of fish caught and with a fourth root transformation). Seven biotic groups are defined at an arbitrary 37% similarity threshold (the grey horizontal line at the 37% mark is superimposed on the dendrogram). Biotic groups are labeled on the bottom of the dendrogram – the red ones are non-indigenous assemblages. This classification is superior to the one using only presence/absence based on sampling experience.*

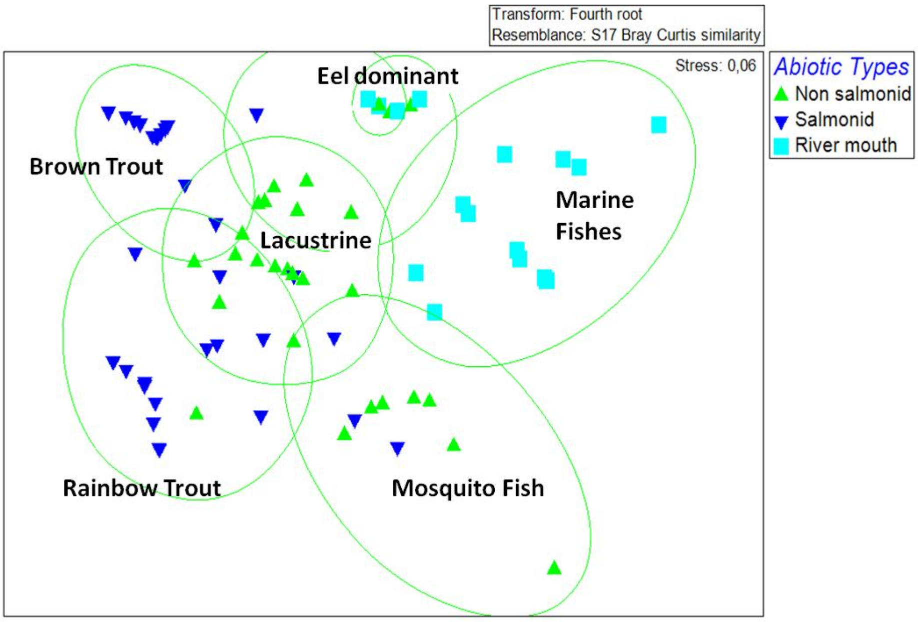
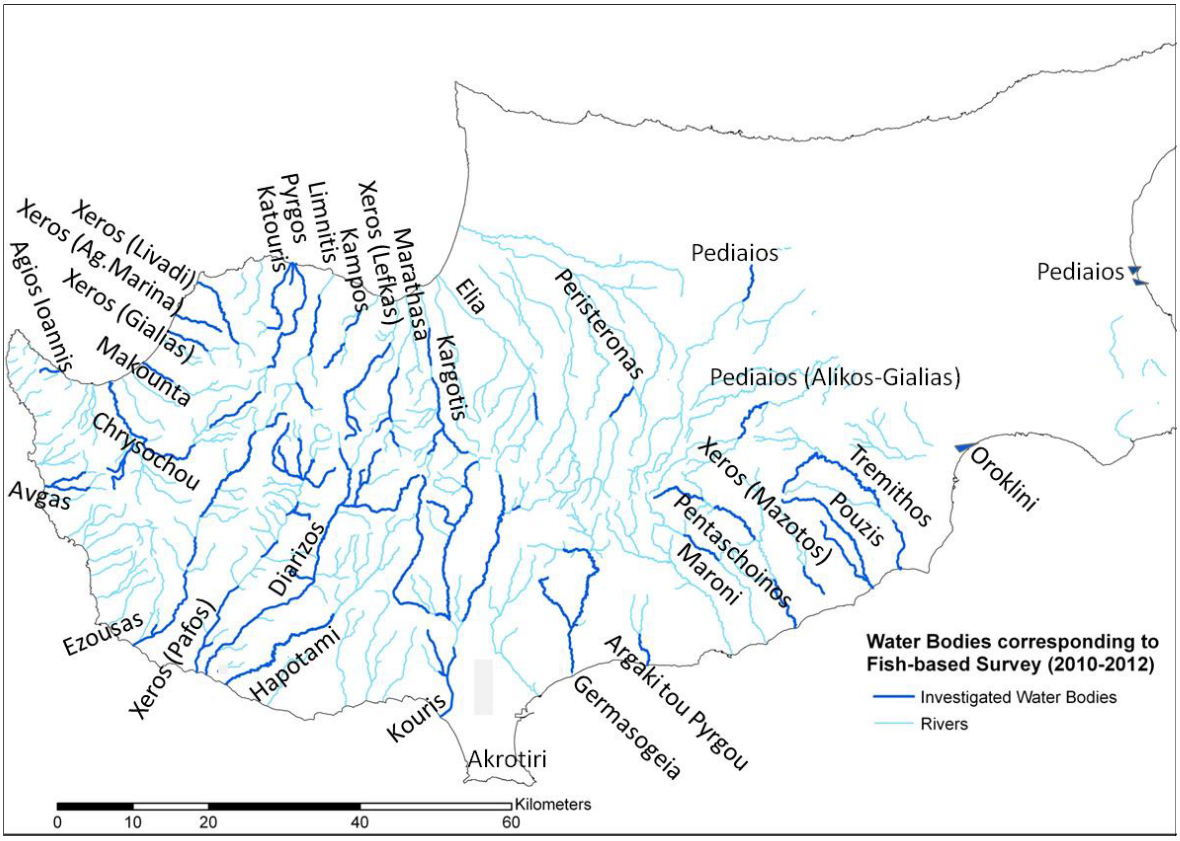


Fig. 3.10. *Non-Dimentional Scaling NMDS plot of the different sites that had fish populations. The configuration shows that the designated groups in the cluster classification dendrogram hold well (the stress factor of 0.06 documents a better ordination then the previous presence/absence plot). The 37% cut-off is superimposed to show groups and in this plot the groups are labeled (following the naming in the former classification analysis. River mouth (=coastal communities area well defined but they create two groups here – the eel dominant group clustering with the non-salmonid eel-only sites as well). All Salmonid sites (with very few exceptions cluster at the left part of the plot and the Rainbow is well defined from the Brown.*

The classification analysis here showed that biotic communities seem to hold well and these are good classifications. In the river mouth type the coastal community is defined by two types, one with and one without Eels. The non-eel dominated coastal community has a variety of fish community structural morphs, being spread out. Aphanius forms a very distinctive group but is not clear in the ordination. The Eel dominated community is nearly identical to the eel-only community found in the Middle courses of the rivers. At the other end (on the Left of the NMDS plot) we see two cold water mountain stream communities – Rainbow and Brown trout. In the middle are two diverse communities, both of lacustrine (i.e. lake origin). One of these is dominated by Roach (in the middle, and the other is more varied with less Roach). Finally Mosquitofish also create a distinct group with rather varied representation, including sites from both non-salmonid and salmonid types. It is surprising that very few Mosquitofish are bound in the river mouth abiotic type (and this is most probably due to frequent total desiccation and low dispersal ability of the Mosquitofish).

3.4. Synthesis of fish and environmental data for each surveyed river basin

Here we summarize key elements of knowledge gained from sampling, interviews and the grey literature about fish populations in the 30 sampled river basins[6]. Details of composition, abundance, and present fish populations of relevance to bioassessment are presented within the specific river basin context. Summary of habitats of each of the investigated rivers or water features is given. The order of reference for each river basin begins arbitrarily at Diarizos and proceeds in a clock-wise fashion. The rivers where we have ample evidence that fish attributes may be potentially useful in fish-based monitoring, assessment and management are given by an asterisk (*) beside the river name.



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[6] It is important to stress that there is a problem with river nomenclature. The GIS database "watershed" delineations at WDD sometimes group small independent watershed and name them as one basin; in our work here each independent river basin is refered to separately. For example, in northern Pafos District the Xeros account for three seperate basins. Since the name "Xeros" is given to many rivers we arbitrarily give the name of a nearby settlement to distinguish them (i.e. Xeros Ag.Marina, Xeros Livadi). In two cases indendent rivers basins are split and we do not follow this (i.e. Pediaios), but give distinction to the major tributaries (Pediaios(Alikos-Gialias)).

Fig. 3.11. *Map of the river water bodies of Cyprus which correspond to the sampled sites during the survey. Each independent river basin is named (see footnote). The map summarizes the water-body based geography of the current knowledge-base concerning fish in Cyprus rivers.*

Diarizos*

One of Cyprus' richest rivers in terms of species richness (12 species); most species being non-indigenous and resident in the recently-built Arminou Dam. Traditionally, this river is known to be one of the few which flowed all the way to the sea for the greater part of the year. Flow to about the level of Kidasi (where there are springs) was probably perennial until the dam was created. Refugia of wet areas existed along the river all the way to the sea during most summers. Small areas of in-stream and riparian wetland and deeply-scoured lowland riverbed held water even during drought periods in most years, especially near the river-mouth. Eels were found near the river-mouth in June 2011 in tiny drying pools (i.e. two recently dead individuals). However, very few Eels could survive after the Arminou Dam and the river diversion were created. The marshland habitat of the lower section of the river has also declined in areal extent and quality (altered hydroperiod, reduced wetness). These changes are easily perceptible in recent air photographs that show the rapid terrestrialization of parts of the lower section of the river channel and riparian area after the river-water transfer works. Even hardy non-indigenous fishes such as Mosquitofish have a localized distribution in the mid-section of the river, being absent from areas that now desiccate completely due to the altered flow regime.

The most important remnant perennial flowing stretch in the river's mid-section is at Kidasi (a remarkable spring-fed perennial flow of about four or more river kilometres in most years- flowing even in late summer). Eels were found in 2011 at the Kidasi stretch within the Oriental Alder forest (the exposed alder roots in the undercut banks providing excellent cover). Small patches of reed (*Phragmites australis*) also provided excellent conditions and silt substrate for cover. The Kidasi alder wood is a very important site for the conservation of Eels on Cyprus as the site held the highest recorded density and also several age-classes. However, despite searches upstream and downstream of the alder wood no Eels were observed in the stretch in summer 2012. Unexpectedly, in 2012 an Eel was collected during electrofishing in the middle section of the Platys section of the upper Diarizos, upstream of the Arminou Dam. However, locals have mentioned the occurrence of Eels upstream of Arminou dam many times in interviews. This specimen may involve a fish entrapped in the system after the Arminou Dam was completed (however it is not known if Eels can pass the Arminou Spillway during most years). Whatever the case, Eels are extremely rare now upstream of Arminou dam, although locals mention frequent Eels collection even in the stream reaches of Kaminaria, Fini, the upper Platys and even within the reservoir in the recent years. In fact, Diarizos is one of the most frequently mentioned rivers, in terms of traditional Eel fishing in the questionnaire survey.

Fig. 3.12. *75 cm Adult female "Silver Eel" near the river mouth of the Diarizos in early June 2011. This remarkable specimen is probably over 12 years old and has survived in the river but failed to reach the outlet to the sea. It was found freshly dead in drying turbid pools within the river bed near the river mouth. Before the construction of Arminou Dam the river mouth was open most years and many hundreds of eels infiltrated (Photo: E. Oikonomou, June 2011).*

Finally, the possibility of Diarizos harbouring River Blenny in the past is very high; and some of the stretches such as at Kidasi are optimal as River Blenny habitat. If the species ever existed here is unknown, however it does not currently exist as our thorough surveys prove.

The cold-water stretches of Diarizos are some of the most extensive and stable perennial flows on the island, holding the largest population of Brown Trout in Cyprus. The distribution of Brown Trout includes stretches in the Platys, Kaminaria and Fini tributaries; the highest densities of Brown Trout were observed in the Fini and the lower and mid Kaminaria stretches in 2012. Brown Trout are resident in the river since the British period- at least from the late '40s and were fished by locals at Arminou and below Agios Nikolaos as well as in the Platys for many years before the dam was created. The age-class distributions of trout in the electrofished catches show that there is an irregular dominance of middle aged fishes, fingerlings and young-of-the-year are usually missing, but severely long-lived large individuals have been caught (including one remarkably-large 40 cm specimen at Kaminaria). Escaped Rainbow Trout was found coexisting with the Brown Tout near the Fini Trout Fish farm (upstream of Fini village); but in this case the 'Browns' outnumbered 'Rainbows'. It should be reiterated that little is known about the trout population today in the river and it is unknown if Brown Trout exists in the new reservoir at Arminou – our work represents the first descriptive study.

Xeros (Pafos)*

One of Cyprus' richest rivers in terms of assemblage (12 species). Xeros is an unusual basin in that the upper part of the river has a remarkably extensive section with cold-water perennial flows within the wilderness landscape of the Pafos Forest. These cold-waters hold the island's second largest population of naturalized Brown Trout. Densities of these fish are normally remarkably low and the population is usually found upstream of the Roudias Bridge during the summer (poaching of fish in the clear-waters of the river is said to be rather frequent). Very few younger age-class fish were observed, but spawning habitats are optimal in many locations. No Rainbow Trout are found anywhere in the basin (and since there are no dams in the upland mountain reaches of the catchments they are not stocked by local authorities in this basin). Much of the upper part of the river's Roudias wilderness is within an extensive Natura 2000 protected area (Tripylos Area-Cedar Valley, Pafos Forest). Somewhere in mid-section of the river; downstream of the Agios Giannis area the river runs dry as a natural intermittent flow (hence the name "Xeros") during summer. This long stretch is even devoid of riparian vegetation in contrast to the remarkable Oriental Alder riparian woodlands upstream of Agios Giannis.

A very large dam, the Asprokremmos, blocks the river's access to the sea very close to its river-mouth, similar to the Germasogeia, Kouris, and Mavrokolymbos. The Asprokemmos reservoir has many established non-indigenous fish species, some of which enter the stream slightly upstream but do not pass into a major portion of the middle section of the river, so nearly all of the middle section is fishless. A small fore-dam with a chute-like structure upstream of Finikas is a major block to lacustrine fish movement upstream. The Asprokremmos Dam's placement excludes Eel passage upstream and starves the lower section and river-mouth of surface water. Although small pools exist immediately downstream of the dam, even hardy species such as Mosquitofish do not survive here (although they may be regularly stocked); so the conditions downstream of the dam and the river diversion may be described as "artificially ephemeral". In rather rare instances where there is dam-overflow during very wet years (as in 2012) the river mouth is open and marine-origin transients enter the lower stretch. In 2012 *Liza aurata, Mugil cephalus* and *Dicentrarchus labrax* were collected in the river mouth. This proves that an open river-mouth functions as an important coastal biodiversity hotspot even though the river system may be severely degraded by a dam.

Fig. 3.13. *Brown Trout in the Lazarides reach of the Xeros (Pafou) within the Pafos Forest. Ichthyologist W.R.C Beaumont who participated in the field research in 2011 is shown (Photo: S. Zogaris).*

Ezousa*

A rather rich river in terms of its fish species assemblage (9 species) again primarily restricted to a recently built dam. This is one of the rivers that have been traditionally known to hold large populations of Eels (as noted by many respondents from the area). In fact, the village of Achelia (near the river's mouth) gets its name from the formerly abundant Eels. One reason for this, is that large sections of the mid-course of the river had many riparian marshes and swamps, some being spring-fed and with extensive perennial wetlands (*Phragmites* reed-beds, pools, spring-fed alder thickets, backwaters etc). Our survey and optical assessment of habitats along the river shows that the habitats for eels are optimal in its natural state – perhaps even more extensive than at the lower Diarizos. Remnants of these habitats exist in several places downstream of Kannaviou village, and at the extensive spring-fed wetland of Amati (near Pitargou Village). The Amati springs wetland and Oriental Alder riparian woodland area covers an area of about 700 m. long along the river, creating optimal habitats for Eels. Eels have been spotted by residents here and are still actively fished by certain older residents in many sections of the river (at Kannaviou, Psathi, Polemi, and Pitargou for example). One questionnaire respondent noted that recently, many large Eels were seen also in remnant drying pools in the river near Episkopi. Despite all these references to Eels, none were observed or collected in the river by our study; primarily because of the very high conductivity of this river (not fishable using electrofishing gear). At the Ezousa river-mouth flow conditions in mid April 2012 were near flood levels and sampling using fine-meshed fry-net was not effective in catching eels. These negative sampling results do not mean eels are not present.

Fig. 3.14. *Fry net sampling at Ezousa river mouth (Photo: K. Moustakas, April 2012).*

However, conditions downstream of the Kannaviou dam are obviously negatively impacted by the decline in the frequency, regularity and quantity of flows. Roach (*Rutilus rutilus*) were observed in the river near Kannaviou (2012), these being fish that drifted down from the recent dam spillway overflow. It should be said that very little water survives the long drought near the river mouth on most years; 2012 was an exceptional year. During the spring flow of 2012, when the Ezousa stream was open and flowing to the sea, Mugilids along with other fish of marine origin actively entered the river mouth showing that the “natural” state for this river is one of having a winter-spring opening to the sea. The management of the dam – including the need to release winter and spring waters within the river channel downstream is important for the ecological integrity of the middle course and the river mouth. Finally it should be said that mountain stretches of the river have very few flowing cold-water environments compared to the Xeros or Diarizos; stocked Rainbow Trout have been found at on location in the Agia stretch in the 2010 (Zogaris pers. Collection; Fig. 3.14.). Large areas of the river are protected within the Nature 2000 network and because of its unique potamological conditions (riparian wetlands, springs etc) this river is a priority for ecological restoration actions and mitigation flows below the Kannaviou Dam.

Fig. 3.15. *Very young hatchery-reared Rainbow Trout at Agia; several kms above the Kannaviou Dam (Photo: S. Zogaris June 2010).*

Avgas

A very small intermittent stream which rarely flows continuously to the sea. Eels have been documented to exist in the stream's gorge (confirmed by Dr. A. Demetropoulos *pers. obs*. and referred to by forestry workers who recently constructed a pathway in the gorge). However during two trials of electrofishing in 2011 and 2012 they were not found in the stream's lower reaches or near the pooling water before the beach barrier. This does not necessary mean Eels do not inhabit the stream regularly. It is very possible that after the winter flooding of 2012 the adult eels were washed-out and migrated to the sea. Whatever the case, enough area was sampled to show that the eel population that may exist was at very low densities (if it existed) during sampling. Much water abstraction for agriculture – often close to the riparian zone takes place in parts of the stream (citrus plantations) – since is a very small stream it is susceptible to total desiccation during dry summers and this obviously will impact Eels.

Agios Ioannis (East Akamas)

An area of very small micro-springs and very short ephemeral streams including the Springs or Baths of Aphrodite. Eels have been repeatedly observed within the spring-fed pool here by many visitors including foresters, environmental scientists and ichthyologists. In fact, the site of the Baths of Aphrodite was one of the most frequently mentioned sites where respondents had observed Eels on the island. However, during two visits in 2010 and 2012 our researchers did not observe Eels (although electrofishing was not practiced since the site had many tourists during the visit). It is very likely Eels are present regularly here; however, the population dynamics, movements, and stability of frequency of occurrence are not known. No other fish are present in the Baths of Aphrodite. The area has very little regularly occurring surface water beyond these springs.

Chrysochou*

Another rather rich river in terms of its fish species assemblage (9 species). Also one of the popular questionnaire responses regarding eel sightings. Our electrofishing team observed Eels here and collected them during electrofishing both inland (Goudi Bridge) and on the river-mouth during late spring (early May 2011). It is very likely that Eels move upstream to many tributaries in this system; so this river is an extremely important habitat-area for Eels on the island. However, an electrofishing survey in high-conductivity stretches such as these is difficult and the population status remains unknown. Nevertheless habitat for Eels is optimal in many and extensive reaches of this river (extensive *Phragmites* marsh fringes). The river-mouth has a very small section which also attracts mugilids from the sea but much of the lower section is fragmented and degraded (over-abstraction of waters, channelization, presence of small weirs and road crossings, etc) and these problems impede fish movement upstream. Much of the river is within a Natura 2000 protected area.

A very interesting water feature in the basin is Evretou Reservoir which holds several species of non-indigenous fishes. Roach (*Rutilus rutilus*) is abundant upstream of the dam with thriving populations. The Stavros tis Psokas tributary is an area where there is currently intermittent and/or ephemeral flow, however some parts may have had perennial flow in the past (springs have been tapped for drinking water). Eels were said to exist before the Evretou dam was constructed upstream in the Stavros tis Psokas tributary.

Fig. 3.16. *The Chrysochou river at Goudi Bridge; channel is completely covered in Scirpus and lots of Phragmites reed also. Not thet stabilization works have recently taken place on the river's right bank and very little riparian vegetation is along the stretch. Theis site had Eels, but no other fishes (Photo: WRB Beaumont June 2011).*

Makounta

A small but also rather rich river in terms of its fish species assemblage (9 species) and this is due to this small basin's old dam. Despite this there is a small section with water near the river-mouth near Argaka and this attracts fish (Mugilids and glass Eels where observed in spring 2012). It is probable that springs exist in the river channel near the river-mouth since water lasted here until at least early summer in 2012, while the stretch above the Chrysochou-Pyrgos coastal road was dry. Otherwise most of the basin is intermittently and ephemerally flowing therefore it is dry most of the year. Pressure from holiday-home building at the river-mouth is a problem despite the fact that a sort section is within a protected area (Natura, 2000). Argaka dam is said by locals to have Eels and these may genuinely be Eels that have scaled the dam's spill way (this remains to be ascertained by further research, but seems very likely due to the low height and angle of the specific spillway).

Xeros (Gialias)

A very small river valley with two small weirs abstracting surface water for irrigation purposes, starving thus the downstream stretch. Much of the downstream stretch shows signs of riparian habitat terrestrialization (where hygrophilous vegetation is being replaced by invasive terrestrial and non-indigenous terrestrial species). This situation is common in lowland "artificially ephemeral" streams in Cyprus. Gialias is s stream which was rather well-known for its eels. And there is a deep spring near the upper part of the village where water is maintained throughout the year. However, electrofishing here was difficult in 2010 and in 2012 no eels were present as well. Mosquitofish have been introduced but were found only in one location in the upper part of the stream (probably recently translocated here). There is a good chance eels exist in the system, however this is difficult to prove; the eel population is certainly of very low density (if still existent). Gialias is an important system in that apart from the water-abstraction weirs it does not have a dam.

Fig. 3.17. *Electrofishing in the Gialias Spring in difficult overgrown conditions; no fish were recordd at this site which allegedly is known to be a refuge for Eels (Photo: G.Michaelides June 2010).*

Xeros (Ag. Marina)

Very small stream starved of water downstream of the dam. Agia Marina is said by locals to have Eels and these may genuinely be Eels that have scaled the dam's spill-way. No or very little water flows downstream or upstream of the dam even on a wet year such as observed during the summer of 2012. Agia Marina reservoir is stocked. Much of the riparian zone is severely degraded downstream of the dam (the river-mouth has not been visited).

Xeros (Livadi)

A very small stream starved of water downstream of the dam. No or very little water flows downstream or upstream of the dam even on a wet year such as observed during the summer of 2012. Agia Marina reservoir is stocked.

Katouris

Very small stream starved of water downstream of the small dam. The dam has non-indigenous crayfish. Mosquitofish living in the reservoir may have been extirpated due to a drought period in the recent past. No or very little water flows downstream of the dam. The Katouris stream is an artificially desiccated ephemeral stream with no potential for holding fish. The river mouth has not been visited but there was water there in the spring of 2012. Its estuary point is very close to the Pyrgos river mouth.

Pyrgos*

This is a very interesting stream for river ecosystem conservation in Cyprus, although its ecology is still poorly known. It is one of the few streams without a dam. Several respondents mentioned Eels all the way up Fleva and Frodisia (within he protected Pafos Forest area). Although electrofishing was attempted at several locations, no Eels were caught with the exception of the lower course near the river-mouth (beside Pyrgos village). In fact at the river-mouth two trials of electrofishing took place and only in one of the trials Eels were found. The estuarine area is excellent Eel habitat and is one of the few areas where we have a river-mouth open regularly to the sea (locals say that water levels and the state of river-mouth opening varies greatly from year-to-year). Locals insist that the presence of Eels is regular but populations vary (periodically residents still fish Eels here at the river-mouth using nets – especially during the autumn after the first rains when the Eels descend to return to the sea). One interesting potential barrier for Eel movement upstream is the extensive Selemani braided river bed where the river submerges below the gravel-cobble substrate (near the Green Line). In the past water levels were said to be higher. Locals also mentioned a recent mass death of Eels (more than 10 large individuals) after spraying insecticides in the Buffer Zone near Selemani. Electrofishing at two perennial stretches in the near-pristine mountain sections of the river revealed no fish. Large areas of the river are protected within the Nature 2000 network and a thorough investigation into the rivers ecology is justified since so little is known about the Eel movements.

Limnitis

Similar to Pyrgos, this is an interesting river since it has large stretches in the Tyllirian wilderness of the Pafos Forest. A small dam, known as the Tsakistra Dam above Mavres Sykies (at about 550 m. asl.), does not greatly impede perennial flow downstream. However near the Green Line the river runs dry early each summer. Barriers to fish movement in the Occupied Territory downstream are unknown. The river was said to have Eel yet none were observed or collected. Similarly, Rainbow Trout was said to definitely exist downstream of Tsakistra Dam, but none were captured or observed – except within the Dam reservoir itself. The dam hosts Mosquitofish which have also drifted downstream and are established only at the base of the dam itself due to unsuitable cold-water conditions for the subtropical non-indigenous species. Despite high-quality naturalness in large areas of this stream there are no fish in nearly all sections. Large areas of the river are protected within the Nature 2000 network.

Kampos

A very small stream artificially partially watered by a small river diversion bringing water into the valley from the Limnitis (Tsakistra Dam diversion). Eels were said to inhabit the river in the past but none were collected or observed. A possible barrier is the small dam at Galini on the Buffer Zone. The Galini Dam is full of reed and is totally unused, creating a step-like barrier. Despite the poorly known part in the occupied territory, the small river may once have had regular eel. The Galini Dam now acts as a definite barrier, especially if one is to consider that the flow regime is very low and irregular (abstraction for orchard irrigation upstream).

Xeros (Lefkas)

Much of the lower part of the river valley is intermittently flowing and usually total dry. Two small dams upstream may influence mountain and mid-section stream flow. In the upper part of the valleys (above Kafizides Dam) Rainbow Trout population had high densities in 2011 and 2012 and are found in an extensive area of the main stream course. Small fingerlings were located and collected and may indicate naturalized populations (spawning conditions seem near-optimal in the upper part of the valley). This is one of the four locations[7] where we presume Rainbow Trout may spawn as shown by the presence of several age-classes within the catches, including fingerlings (under 10 cm in May). The in-stream habitat conditions, apart from the presence of the very small dams, are almost pristine for these cold-water species; however whether the populations may be useful for assessment and management is unclear since the dams are being stocked. Monitoring and research should definitely continue here in order to confirm spawning, spawning habitats and frequency, the influence of the small dams, and to explore the population dynamics and influence of other non-indigenous species present in the dams. Roach, Goldfish, and MosquitoFish is the most common species that benefit by the dam's presence but they are not widely spread outside these small reservoirs. Much of the beautiful wild valley of the Xeros is within the Pafos Forest SPA (protected area).

Marathasa

This stream has extensive areas of perennial waters but is located in a fairly densely populated area. Water is abstracted for agriculture (very small traditional weirs block and abstract the waterway). Kalopanagiotis reservoir is famous for having a variety of non-indigenous species, often introduced by the adjacent DFMR fish hatchery. The river has high fish populations along its entire area within the free part of the Republic. It is very possible that the upper part of the river has self-sustaining Rainbow Trout (several individuals and different age-classes at good density collected in optimal habitat at Moutoula, for example). Downstream of Kalopanagiotis both Rainbow Trout and Roach are also abundant. The river also had Eel in the past (however, captive Eel may have been introduced locally in the mid-1980s from the DFMR hatchery here). Lefkas Dam may currently function as a barrier to Eel movement.

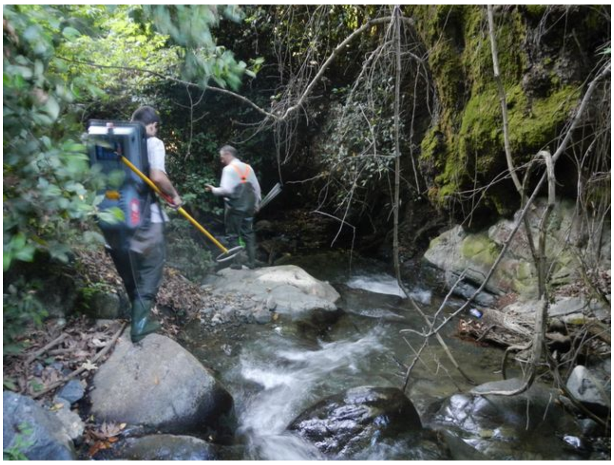


Fig. 3.17. *Electrofishing in the upper Marathasa river, near Moutoulas. This stream had a good population of Rainbow Trout (Photo: N.Chartosia July 2012).*

[7] Unconfirmed indication of Rainbow Trout spawning exist in the upper Kalidonia (Kryos), Garyllis (Kargotis), Upper Marathasa and Upper Xeros of Lefka. The problem of identifying and confirming wild-spawned Rainbow Trout need special study and is often confused by stocking or escaped farmed fish.

Kargotis

Similar to Marathasa, this stream network has extensive areas of perennial waters and is in an area that is densely inhabited. The upper Kargotis, near Agios Nikolaos is fishless due probably to mineral contamination. Fish farms upstream of Kakopetria may regularly release trout and may even infest the river with young Rainbow Trout. It is said by knowledgeable locals that Brown Trout also existed in the past (none was collected during this study in this river). Poaching of trout in streams around Kakopetria is commonplace and may affect populations –this may possibly be responsible for the decline/extirpation of Brown Trout. Locals insist that Rainbow Trout spawns in the upper Kargotis (the so-called Garyllis tributary upstream of Kakopetria); though confirming this speculation is very difficult due to the large number of seemingly escaped fish from an adjacent private fish farm (in 2011). Only a very few Rainbow Trout are found downstream of Kakopetria, but one escaped adult fish was found all the way down at Evrychou Bridge in 2011.

The mid-section of Kargotis often has a good flow of water and good in-stream and riparian habitats as observed in both 2011 and 2012. The habitats are good for both Eel and potentially for River Blenny. Although locals mention Eel in the lower river valley at least, none was located in this investigation– despite searches downstream to within the Buffer Zone (down to 195 m. asl. near Skouriotisa). Although there is no perceptible high barrier downstream of the buffer zone the river has an intermittent condition in the occupied territory. We consider it unusual that Eel was not found in the section immediately upstream of the Buffer Zone, due to the presence of good habitat, nevertheless water quantity in late spring 2011 was very good, perhaps not typical of most recent springs.

Fig. 3.18. The Kargotis immediately upstream of the Buffer Zone near Skouriotisa in June 2011. Although conditions were adequate for Eels none were found after a persistant search. There is much surface water abstraction immediately upstream and the river bed is often full of thick reed cane *Arundo donax (Photo: WBR Beaumont).*

Elia

Drier than the river valleys of the west there is very little evidence of water in the river segments during the long summer drought. Fish are restricted to the dams reservoirs, for example in the small dam of Xiliatos where the remarkably high-density of aliens species causes significant issues (Bigmouth Bass, Sunfish were abundant in July 2012). The stream entering the reservoir was completely dry during the summer period, even in the wet year of 2012. The flow below the dam is miniscule and not even Mosquitofish exist. So in this case the dam creates an aquatic system were the river is only winter flowing.

Peristeronas (=Serrachis)

Similar to Elia, but in this case the river is wider, ephemeral flowing wadi-like at mid elevations. The recently built dam at Klyrou creates degraded flows downstream (within the Occupied Territory). The river is known for its eels downstream in the past (e.g. Πατσιάς Χ.Γ. (2003); at present no ichtyological survey is being realised within the Occupied Territory.

Fig. 3.19. *Sampling on the Maroulena stream of the Peristeronas upstream of Klyrou Dam. This unusual reach – with peristant water even in midsummer- had two species of fish Sunfish and Rainbow Trout – fishes that presumably migrated upstream from the reservoir (Photo: V. Hatzirvassanis July 2012).*

Pediaios

This is Cyprus' largest river basin and one of its most atypical. Much of the river valley is in one of the driest areas of the island and much of it is naturally intermittent. Despite this, the habitats created in lowland reaches are excellent for Eel and this species has been observed recently just a few kilometres downstream of Lefkosia in the Occupied Territory (F. Beier, pers. obs. 2010). No Eels were observed or captured in Leflosia, probably due to the very high water conductivity which severely limited electrofishing capability. However fish presence was observed, Mosquitofish was found to be abundant and the presence of other non-indigenous species is very likely as well (e.g. Catfish have been collected in the recent past). The habitat conditions and presence of Eel should be explored (locals mention the presence and abundance of Eel in the past). Eels were observed by our team in 2012 in the river-mouth wetlands of Pediaios south of Ancient Salamis (near of Ammochostos City). The populations were probably rather low, but the area had a large number of mugilids (*Liza ramada, Mugil cephalus*) and *Aphanius fasciatus*. In fact, in Cyprus, *Aphanius fasciatus* is known to now exist only here and at Akrotiri. Empirical evidence shows that even in the Pediaios and Gialia rivers the presence of Eel indicate a very important property of integrity of this largely degraded river. The Eel presence shows a definite longitudinal connectivity with the sea, local aquatic habitat integrity (a flourishing food web since the Eel is a carnivore) and refugia of wetness during prolonged drought at the landscape scale. Exploring the habitat of the middle reaches (and lower reaches of the Pediaios such as within the occupied territory) it is clear that the presence of the Eels cannot be without the above positive river integrity characteristics.

Fig. 3.20. *River-mouth lagoon habitat in river valley distributory of the Pediaios delta at "Silver Beach" south of the Salamis ruins. This was a scene of mass death of thousands of Aphanius fasciatus in 2012. (Photo: S. Gucel, July 2012).*

Oroklini

A former wetland area, extensive coastal lagoon system but long since degraded and partially drained. Two artificial canals drain the area and largely flow through a developed touristic coastline. Small stream enter the lagoon-like marshy basin and it the distant past these probably augmented freshwater levels creating flow to the sea. The habitat here is perfect for Eel, and the locals are aware of this. Specifically in spring 2012 we found Eels, mugilids and extremely abundant Mosquitofish. Habitats are optimum for Aphanius but it was not found (we understand it probably has been extirpated, as it probably has in nearby Alyki Larnaka lagoonal system[8]).

Tremithos

A river in the drier bioclimatic zone which is very susceptible to complete desiccation. Fish was not found fish anywhere in the system, even in 2012 when spring conditions were favourable for fish. The small river mouth has been fragmented and is being developed into a sub-urban subdivision. No connection with the sea was seen even during the wet spring of 2012. The Kiti Dam is a huge wetland area of special biodiversity interest but its frequent total dry-out affects fish survival. Formerly, before the construction of the Dam Eels inhabitated the entire river system even up to the upland villages (e.g. Pseudas during the '50s).

Pouzis

This is a very small, mostly ephemerally flowing system. Very little water was in the river channel at its middle course section even during the very wet spring of 2012. There is no dam on the system so the river morphology retains something rather rare in Cypriot rivers, deep flood scouring of the lower river bed. Near the river mouth this creates a typical long-pool environment blocked by the cobble beach during low-flow (this is very

[8] We deduce the extirpation of *Aphanius fasciatus* from places such as Oroklini and Larnaka from the fact that the speceis survives in large coastal wetland sites and can communicate among coastal sites through the sea and through the connection of river and wetlands during former sea-level conditons as must have been during former glacial maxima- when global sea levels were lower than 120 m below current levels (i.e. 12 000 years ago wetland features must have covered more extensive and very different geography, probably allowing the species to be more widespread). HCMR and colleagues are currently researching the genetics of Cyprus' *Aphanius* populations.

common in many eastern Mediterranean small streams). Here, Mugilids and Eels were found – which may be locally abundant in the “long-pool” environment.

Fig. 3.21. *Pouzis river mouth in late April 2012. The beach cobble-pebble bars the mouth to the sea but mugilids and eels are abundant in the turbid waters of the river-bed pool. (Photo: S. Zogaris).*

Xeros (Mazotos)

This is an insignificant ephemeral ditch-like formation that floods only after heavey rains. No fish are present and the outlet to the sea is along a steep cliff-like situation. During 2012 the stream-line had tiny pools with many Green toad tadpoles.

Pentaschoinos

Two large dams starve the river of water and most flows are artificially ephemeral (water only after rainfall). Lefkara Dam has two tributaries entering it that may hold water for long periods during the wet season and both held water during the exceptionally wet year of 2012. No fish were seen here but at Kyprovasa a small cistern help Mosquito fish (there were written signs saying that the mosquitofish had been introduced by the Mosquito control operation and both the streams and the cistern were sprayed regularly). Below Lefkara dam there is a stretch of stream that has only a single spring almost in midway between this dam and the Dipotamos Reservoir; again conditions were very dry in the riverbed in July 2012 (the site was also visited in Spring 2012 and it was similarly dry). The river stretch between the two dams is located within and SPA and could be restored. Fish are present in the incoming stream immediately above the Dipotamos Reservoir. Below The Dipotamos Dam there is no water (artificially ephemeral streambed).

Maroni

Very small stream running almost completely with intermittent flow. In July 2012 the river was flowing slowly even in the upstream portion near the village of Valva. Industrial development has changed the coastal portion.

Argaki tou Pyrgou

Very small stream with a ditch-like structure most of it flowing ephemerally. No dams exist and the lower part was flowing in late spring 2012 into the sea. This attracted a few marine euryhaline species (Mugilids and Sea Bass) but the fish could not move upstream due to a coastal road. Near Moni there is a small quarry pit with ponds where Carp is stocked and Mosquitofish are extremely abundant.

Fig. 3.22. *Fry-net catch while sampling at the Moni stream (Argaki tou Pyrgou) rivermouth which was open to the sea and had large numbers of Liza ramada and some Dicentrarchus labrax. (Photo: S. Gucel, July 2012).*

Germasogeia*

In Germasogeia one of the highest fish assemblages was observed (13 species). There is a high dam just 6 km upstream of the river's mouth. The lower part of the river has a completely artificial cement river bed immediately upstream of the river mouth (about 1.1 km long); much of the lower part of the river is in an suburban landscape. Immediately below the dam irregular amounts of water flow in wet years. In 2012, a very wet year, the amount of water attracted a large number of Eels at the "glass Eel" stage (about 5-7 cm long) during the spring (the survey team collected observations in April-early May). Eels were not detected in July. Larger Eels were caught by locals in the river during spring 2012 (one was kept in captivity by a resident of Lemessos). Eels are probably scarce and survival is uncertain since even in the reedy refuge below the dam no eels were caught in 2011 by the survey team. So the river does have a population of Eels, however it is small since these fish cannot climb the high spillway of Germasogeia Dam. The conditions in the lower part of the stream are so unpredictable and variable that even hardy alien species may not survive when they colonize (although in 2012 both Mosquitofish and Roach where located in small populations). The lower section of the Germasogeia (below the dam) is a priority urban-suburban river situation and should be monitored and protected, not only because of the Eel population but also because it is the remnant of a significant river, one of the largest on the south coast of the island.

Upstream of Germasogeia Dam a remarkable steep ravine exists, the Kyparissia Gorge– with extensive areas of natural riverine habitat (within a protected area, the Lemessos Forest). This area is still poorly explored and usually does have water during the summer. Despite this, no signs of any native fish were present near the outlet of the gorge or the upper part, near Dierona. The Germasogia river may have been one of the "torrents" mentioned by the collector of the River Blenny *Salaria fluviatilis* specimens in the Lemessos district a few years before 1907. We believe the Kyparissia Gorge is one of the most likely locales that this species may have survived, and it does need a thorough investigation.

If we inspect habitat conditions, it is nearly certain that about 100 years ago the River Blenny existed at Germasogeia (as connoted in the archived notes by a British collector). However today we found no evidence of this fish anywhere. The decline and supposed extinction may be related to both DDT and habitat destruction (perhaps even pushed over the edge by a succession of very long drought years). Habitat for the species exists in the Kyparissia Gorge and even for a few kilometres below the Dam. If a survey was to confirm actual extinction on the island these sites are good candidates for a re-introduction program.

Akrotiri

The largest wetland area in Cyprus (located within the British Sovering Base Area). In the past the Garyllis and Kouris rivers flowed into this seemingly vast coastal lagoon system and their basins are still connected in terms of hydrogeology. Today the Garyllis is channled and flows in the western part of Lemessos and practically has no surface water connection with the wetlands west of the Harbour. Stormwater and drainage water from west of the city is dischared into the Zakaki area.

The Akrotiri wetlands hold important populations of marine euryhaline fish; and in two locations *Aphanius* populations were found in abundance. One of these is at Zakaki (near the new harbour of Lemessos); this population co-exists with Mosquitofish. The water fluctuations in the wetland areas (including the Phassouri reed bed and the semi-natural "Phassouri Pits") can cause *Aphanius* or Mosquitofish populations to be locally extirpated or decline catastrophically. The Phassouri Pits location is a series of semi-artificial pond-like features created by dredging cobble/gravel sediments behind the beach on Episkopi Bay. Marine fish enter the pits as well when storms may break or breach the beach barrier. Eel is most probably present in the system (probably at Zakaki) but little has ever been discussed recently about this.

Kouris*

Kouris is sometimes divided into three catchment watershed units (Kryos, Kouris, and Limnatis) but is treated as one river basin here since all are connect at the Kouris reservoir. Similar to Germasogeia, Kouris has one high dam (Cyprus' largest dam) very near its river-mouth and it too has a very high number of non-indigenous fish. However the dam and water diversion starves the river downstream in a more permanent way than at Germasogeia. Water does not flow to the sea during summer even on a wet year (e.g. 2012). Only one species of non-native fish (Mosquitofish) thrives downstream of the dam (and this fish is present only in fairly stable parts of the river near the dam base, not in the fluctuating artificially intermittent/ephemeral flowing sections). No native fish were found upstream although the Kryos, Kouris and Limnatis sections were well explored during this study. River Blenny may have occurred here in the past since optimal habitat is found in the river's mid-section. Kouris Dam is a definite barrier for Eel. Non-indigenous fish are found only in the sections close to the dam (near the river-reservoir confluences) in its mid-section reaches; the commonest and most widespread being Roach. Barriers such as road-crossings and flow-meters impede the movement of the Roach, Big Mouth Bass or other lake fish into the river's mid-sections.

The most remarkable aspect of this basin's ichthyology concerns its cold-water stretches. The Mesa Potamos (of the Kouris section) holds a population of Brown Trout - one of three self-sustaining reproducing populations discovered during this study. Young-of-the-year fry of Brown Trout were found here in May 2011. This tiny stream has a confluence with the Amiantos stretch of the Kouris were probably due to toxic mining/mineral leakages there are no fish. So the population of trout at Mesa Potamos probably have a river distribution coving only about 3 river kilometres (the Mesa Potamos cataract upstream is obviously impassable by trout and none were located upstream of this barrier). This is a vulnerable localized trout population that has survived for many decades, perhaps since it was introduced by the British in the late '40s. The Kryos from Platres to Agia Mavra in contrast has Rainbow Trout; and no Brown Trout were observed here. Near Platres and in the upper Kalidonia stretch in particular the numbers of Rainbow Trout are remarkably high and the presence of large numbers of fingerlings providing indication for a self-sustaining population. (Although frequent stocking cannot be excluded it is not practiced by Government Authorities such as DFMR). Fish farm escapees could not possibly swim upstream above the Kalidonia Cataracts. The unusually cold-water (c. 13^{o}C in early summer) create optimal conditions for survival, fry survival and a very good distribution of age-classes was observed. It is conceivable that the Rainbow Trout spawn in this stream and movements were observed in spring (fishes leaping small falls and rapids). Further research into the population dynamics of this seemingly established population are needed in order to explore its potential as an environmental indicator.

Hapotami

A small narrow valley with a long rocky gorge nearly all of it being with intermittent flow. Part of the river is abstracted for irrigation purposes and two very small reservoirs exist in the golf course area near the lower part of the valley. Two respondents mentioned that many eels exist in the valley were water is retained during summer; and we found a good influx of glass eels in April 2012. Mugilids entered the river mouth of the stream also. The Hapotami valley is poorly researched and more work is needed in the lower part in order to understand its importance to the Eel.

Fig. 3.23. *River-mouth at Hapotamin in April 2012; Mugilids and glass eels were present and later in July2012 Mugilids were abundant yet the glass Eels had migrated upstream.*

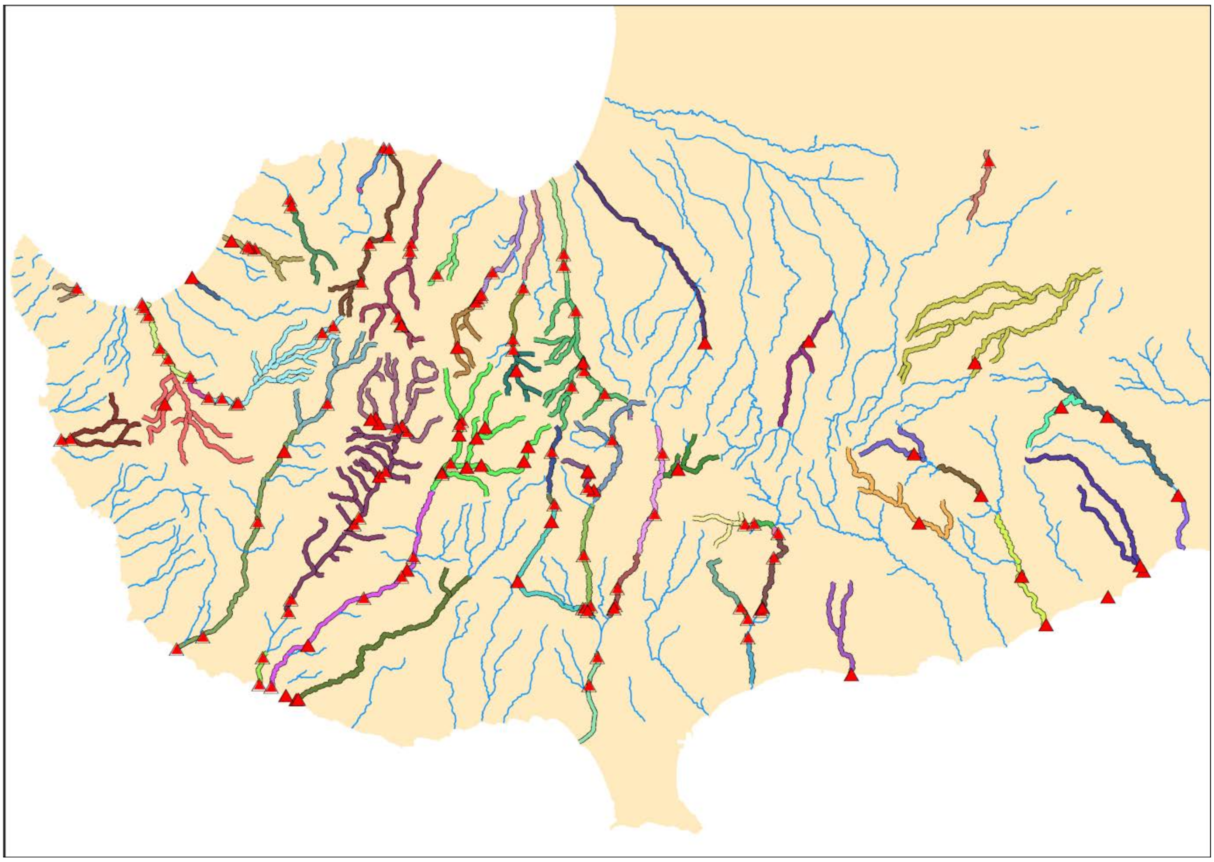


Fig 3.24. *The registered official delineation of the water bodies with respect to the majority of river sites sampled during the project. The map illustrates the positioning of the sites within the water body delineations. In many cases the biotically-relevant environmental conditions of the water bodies conform to proposed water body boundaries.*

3.5. Extrapolation of the results of the investigated river to all Cyprus rivers

The fish-based and associated environmental field work so far has been of an exploratory nature but it has set an important background framework. Although the number of sites surveyed is satisfactory for an initial overview, this work cannot be used to extrapolate results to all Cyprus' rivers. Through the perspective of bioassessment for water management and restoration we can see various important problems and challenges.

A) A satisfactory typology of Cyprus' rivers is far from complete because the key determinant parameter of perennial versus temporary flow regime is not yet mapped. This has negatively affected the development of the initial WFD typology, and the water body delineations in Cyprus. An initial estimation produced in this study states that approximately 341 kms of perennial streams exist on Cyprus – this gross estimation needs rigorous confirmation and precise mapping.

B) The cold-water / warm-water distinction is probably very important for affecting biota in streams but it requires specific research. If this is correct and can be substantiated in being a primary determinant of in-stream biotic communities, than after the flow regime state distinction, this parameter should also be used in a biotic classification of perennial rivers.

C) The fish-based approach does help to initially describe some prominent but generic biotic river types. Of the fish biotic groups described in this study it is clear that the following environments associate with particular native fish communities:
  - Coldwater perennial reaches (Inhabited by Salmonids)
  - Middle course perennial reaches (inhabited primarily by Eel)
  - River mouth and coastal wetland reaches (inhabited by euryhaline marine fish, Eel and in specific locations the Mediterranean Toothcarp- a native wetland specialist).

D) In terms of river biota Cyprus represents a single biogeographic unit. When sea levels were lower due to the Pleistocene glacial maxima several rivers and coastal wetland areas created confluences and some fish species such as River Blenny and Toothcarp were more widespread. The fish-based approach gives some important descriptive information about the surveyed reaches, however fish may not help in characterizing/classifying rivers at the inter basin scale (at a broader scale biogeographic approach; i.e. at the regional scale). The key characteristic in Cyprus' rivers is catchment-scale uniqueness of constituent lotic feaures. Geological, climatic and topographic parameters greately influence each catchment in uniques ways.

E) The long history of anthropogenic alterations for centuries has primarily affected specific river basins in distinct ways. This study has gathered evidence that shows that over the past 70 years the inland waters of Cyprus have undergone the most significant transformation they have experienced in the last ten thousand years. Each and every river basin surveyed shows varying degrees of ecological impoverishment related to anthropogenic changes. The most important and broadscale chages refer to:

-Dense reservoir water storage works and daming
-Irrigation and water transfers works
-A long DDT /insectide anti-mosquito campaign

F) The effect of a perceived decline in precipitation after 1970 ( ) on the surface waters and their flow regime has never been researched.

The above details show that basic hydrological and hydrographic understanding of surface waters on Cyprus is still poorly developed. Due to remarkable environmental change during the last 70 years (and a decreased precipitation phase after 1970) descriptive survey of surface water features (river corridor condition, flow regime conditions, basic river classification) has not progressed and has inherent challenges. Even policy-revent applications concerning river condition have had to confront such obstacles.

Water body delineation in Cyprus needs to be re-evaluated. And this is based on typological criteria of water permanency/ flow regime, the temperature conditions and the state of ecological degradation. A careful perusal of Fig. 3.24 with the specific fish sampling sites overlain may show that there seems to be inconsistency in extent and form of water body delineations (and much of this is a result of lack of baseline knowledge at the time of the delineations).

Examples of inconsistanceis in delineations of water bodies include:

- Limnitis River being one water body when conditions are very different in upland areas and tributaries (i.e. perennial versus intermittent flow). The same is observed in Pyrgos River.
- Parts of the upper Xeros (Pafos) valley are poorly delineated. (Again the issue of perennial versus intermittent flow was not applied; but tiny ephemeral tributaries are included as major water bodies and these may need to be treated as separate water bodies for management purposes)
- Small ephemeral rivers should be part of the river management but obviously in no case do they hold fishes, even fishes of the marine euryhaline group (this was made evident in spring 2012 when small ephemeral stream river mouth and flowing waters near the see where inspected in several sites on the south coast; i.e.at Pissouri).

3.6. Anthropogenic pressures impacting fish populations: a concise review

Each site was carefully assessed relative to several anthropogenic pressures (information gained from chemical status, former assessments, GIS interpretation, and site visits during the fish sampling).

Some of the most important pressures, that we have experience to believe may influence the fish species, are present, such as: artificial substrate (particularly in urban reaches), riparian degradation, flow pattern deviation, flow quantity deviation; embankment of the river banks; straightening or canalization of the river channel, longitudinal discontinuity due to dams upstream of the site, longitudinal discontinuity due to dams downstream of the site, irrigated area upstream of the site. These ten pressure attributes are displayed in the sites categorized within the three stream types (Salmonid = mountain, Non-salmonid = middle course; river mouth = coastal).

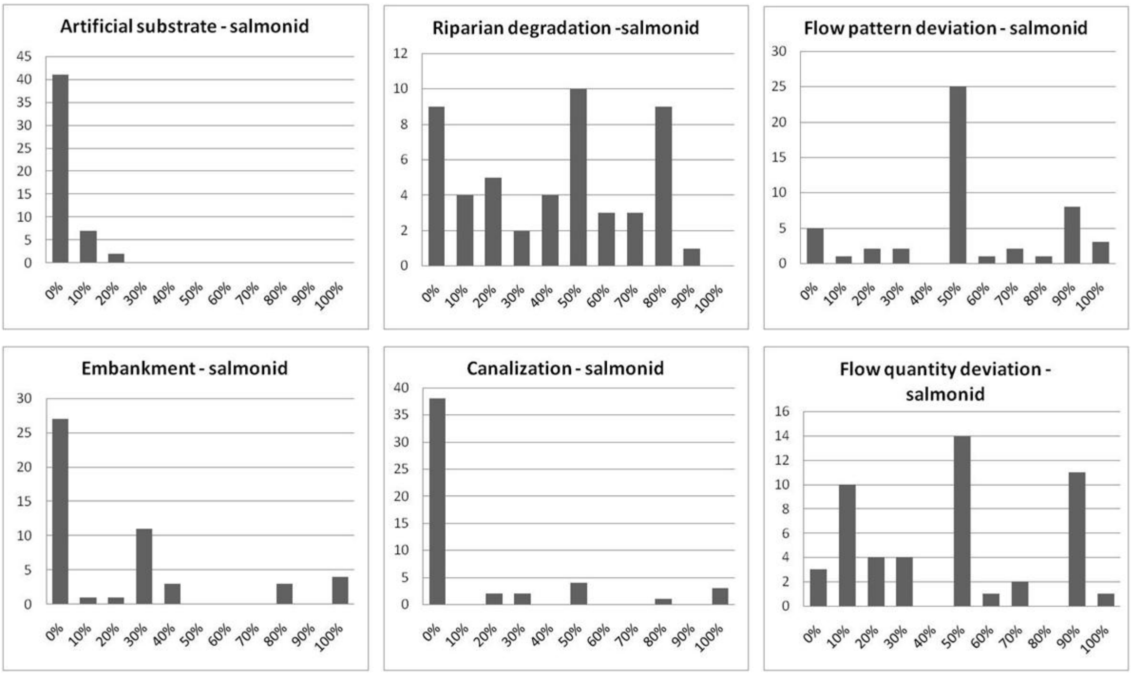


Fig. 3.25. *Six pressure categories on a gradient of degradation (natural to degraded from left to right on the x-axis) for salmonid sites (mountain abiotic type). Note that one of the most important pressures is flow pattern deviation, flow quantity deviation and riparian degradation.*

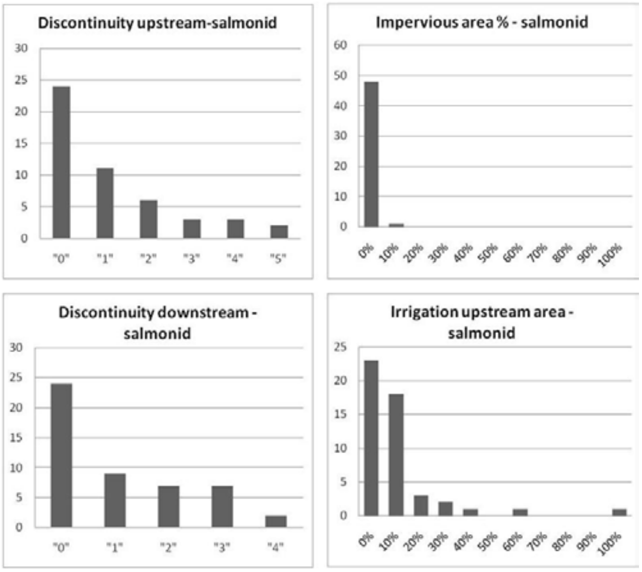


Fig. 3.26. *Four pressure categories on a gradient of degradation (natural to degraded from left to right on the x-axis) for salmonid sites. Note that many of the sites are impacted in terms of discontinuity but not in terms of irrigation or impervious area (urban cover) within the watershed. This is to be expected since most mountain type sites have little agriculture.*

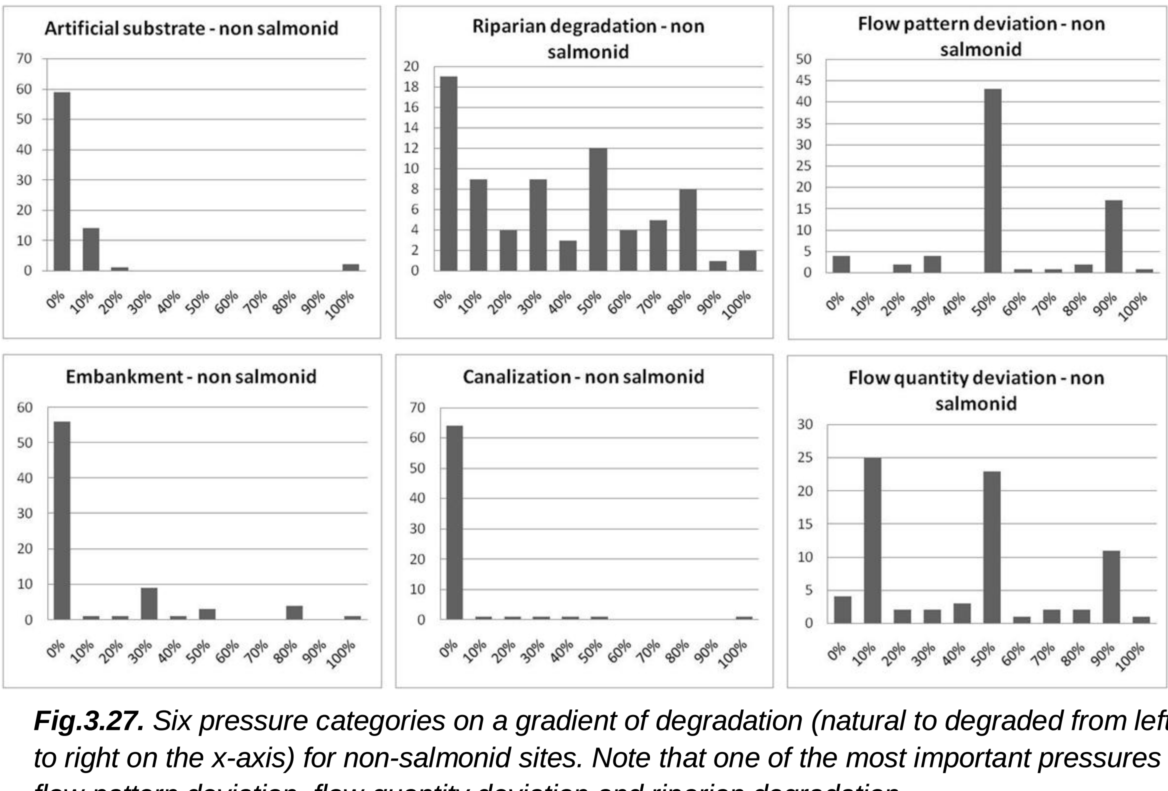


Fig.3.27. *Six pressure categories on a gradient of degradation (natural to degraded from left to right on the x-axis) for non-salmonid sites. Note that one of the most important pressures is flow pattern deviation, flow quantity deviation and riparian degradation.*

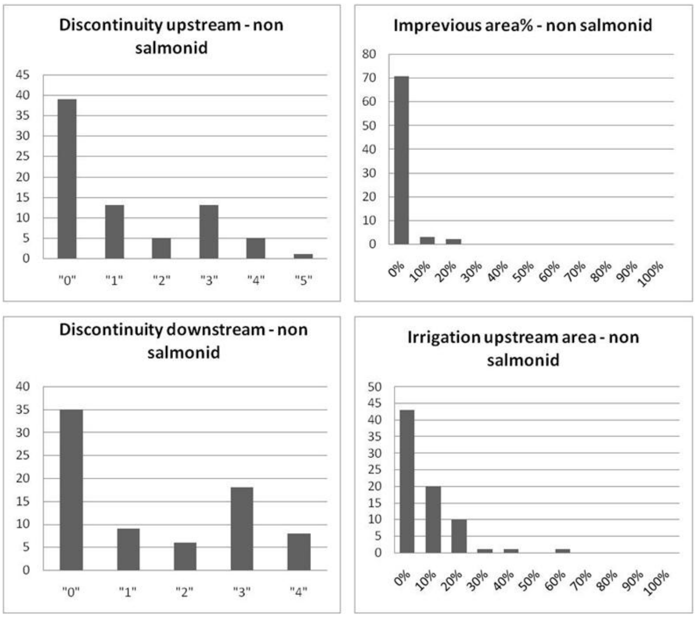


Fig. 3.28. *Four pressure categories in non-salmonid sites. Discontinuity upstream is a problem for a large proportion of sites as is discontinuity downstream.*

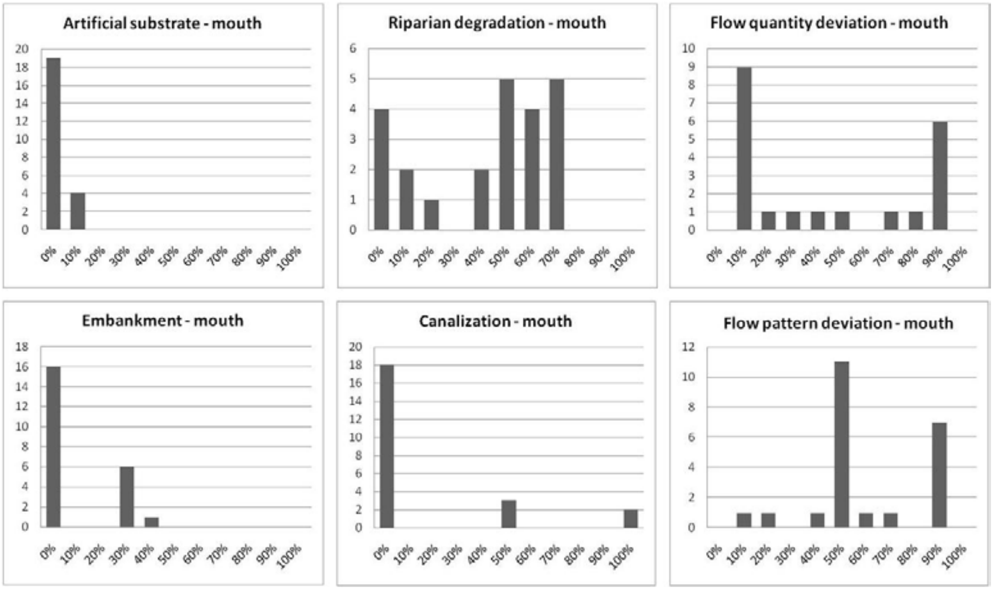


Fig. 3.29. *Six pressure categories on a gradient of degradation (natural to degraded from left to right on the x-axis) for river mouth sites. Note that one of the most important pressures is riparian degradation, flow pattern deviation, flow quantity deviation and embankment.*

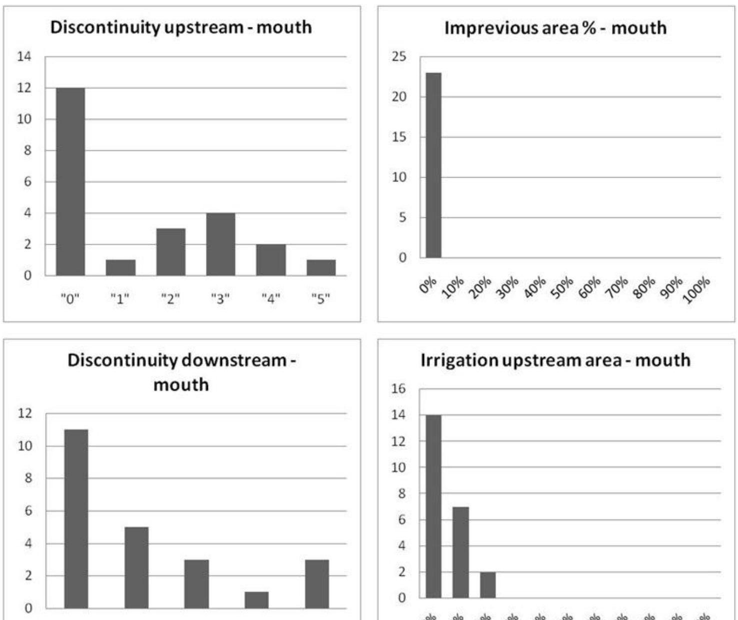


Fig. 3.30. *Four pressure categories in non-salmonid sites. Discontinuity upstream is a problem for a large proportion of sites as is discontinuity downstream.*

3.7. Chemical pollution and fish

It has been already stated that many species of fish (with the exception of most salmonids) can tolerate some levels of pollution and nutrient enrichment. The quantity of pesticides used from the early 1960s to the early 1990s has risen from 3.2 kg to 15.2 kg per year / ha of utilised agricultural land in Cyprus. The fivefold increase in average active pesticide use per ha/utilized agricultural land in the period 1960-94 is disturbing (Panayides, 2006) but it is unknown how much of this enters the river systems we studied since most sites have good chemical status.

A remarkable problem that has left a legacy in Cyprus streams is former insecticide use. Organochlorine pesticides, in particular dichlorodiphenyltrichloroethane (DDT), its degradation product DDE (p, p_-dichlorodiphenyldichloroethylene), γ-hexachlorocyclohexane (γ-HCH), also known as Lindane, as well as hexachlorobenzene (HCB) were widely used in Cyprus, particularly to combat the mosquitos.

In the past, unwise agrochemical use especially chlorinated hydrocarbon insecticides (DDT) may be accountable for the extinction of several species from Cyprus inland waters. One of these includes a rather famous extinction of a rare aquatic passerine bird, the dipper, in Cyprus.

Evidence from the literature shows that the following taxa were affected significantly by DDT on Cyprus:

- Reptiles; especially aquatic and semi-aquatic species particularly the Grass Snake and Dice Snake (if populations from the occupied territory are in fact native);
- Terrapin populations were reduced with the exception of three sites.
- Amphibians even the very widespread *Bufo viridis* toads were very scarce.
- River Crabs (*Potamon sp.*)
- Water birds (especially breeding waders, waterfowl and ground-dwelling birds; perhaps raptors as well) had very low breeding numbers in the 70s and early 80s as opposed to a remarkable come-back in the ‘90s despite drought and degradation of many sites. One resident subspecies of passerine water bird, the Dipper Cinclus *Cinclus ssp.olympicus*, became extinct in the late ‘40s or ‘50s allegedly due to DDT use.

Our interviews indicate that the wildlife (and often farm animals) was greatly affected during the DDT campaign. This situation was well known to the public throughout Cyprus and also recorded by scientific reports. Nonetheless the effects of DDT use on wildlife was never quantified. In reference *to the* freshwatrer fish fauna also became well known to the international scientific community. As early as the 1960’s Holway (1964) reported that the use of DDT larvicides during the campaign against malaria caused the elimination of all of the freshwater fish in Cy*prus* (Holway, 1964). One of the highest recorded levels of DDT in the Herring Gull was found in Cyprus as reported in Pandey et al. (1985).

Because the 1950’s, 1960’s and 1970’s were times of civil strife and political turmoil in Cyprus it is obvious that the environmental problems that arised from the use of DDT and wildlife conservation in general was not on the top of the political or any environmental agenda. It soon became unknown after the last stock of DDT was shipped away in the late ‘70s. The legacy of the spraying survived and is evident in reports in the ‘80s especially concerning unusually patchy distribution and low populations of amphibians, semi-aquatic reptiles and water birds. No mention of fish was ever recorded again in the literature.

Today organochlorine pesticides are not prevalent in Cyprus surface waters. Recently published results have shown that the most commonly encountered organochlorine insecticides were hexachlorobenzene and heptachlor. Hexachlorobenzene was mostly found in Garyllis (1943 675 80) river, while heptachlor was mostly found in Kalavassos Dam (Fatta et al., 2007).

The problem with a DDT induced die-off of aquatic biota is that some vertebrates such as fish can in no way recolonize their former distribution since the isolated river basins are not connected by a water network. So this creates a completely artificial shift in base-lines of natural biota. One native fish, the River Blenny, is hypothesized to have become a victim of the spraying effort and it is unknown whether any other species were affected to that great extent.

The issue of insecticide use on Cyprus must be researched in greater depth because anti-mosquito campaigns continue in almost all stream reaches in Cyprus and there is no knowledge of their affects on aquatic biota.

3.8. Interpretation of the complete sampling campaign

The following tables summarize the sampling results:

Table 3.2. *Number and length of water bodies (WBs) investigated that hold fish populations.*

	Total WBs	Investigated Areas	Percent of all water bodies (number and length)
Number of water bodies	216	58	27%
Length of defined water bodies (km)	2.585	1.198	46%

Out of a total 216 river WBs (total length =2.585 km) designated in Cyprus, 58 WBs have been sampled, covering a length of 1.198 km, or 27% of the country's WBs (46% of the WBs' length).

Table 3.3.*. Number and length of water bodies (WBs) investigated that hold populations of three potentially important indicator species.*

	WBs	Length (km)	Percent of all water bodies number (and length)
Eel *Anguilla anguilla*	6	174	3% (7%)
Brown Trout *Salmo trutta*	4	207	2% (8%)
Rainbow Trout *Oncorhynchus mykiss*	10	252	5% (10%)

More specifically at this stage of research, three species of fish are provisionally chosen to provide key potential bioassessment metrics and the area they cover is expressed above. The Eel is the most important of these, being a native species with specific requirements. Eel was found to be present in 6 designated water bodies (which cover an area of 174 kms); however eel was found in wetland areas and in the occupied territory where no water bodies have been designated. The Brown Trout is especially interesting because it maintains naturalized populations that are self-sustaining for at least 70 years (as shown by a historical review and specific expert interviews); its populations is localized, present in only four waterbodies. Additionally, Rainbow Trout provides evidence of maintaining self-sustaining populations in limited river reaches and it too is treated within this analysis; in contrast to the Brown Trout it is widerpsread in Cyprus.

Table 3.4. *Number and length of water bodies (WBs) investigated in relation to designated type/condition (i.e. River Water bodies, Heavily Modified River Water Bodies and Water Bodies at Risk).*

	count	length (km)	% total length	% investigated length
River WBs	216	2.585		
Investigated WBs	58	1.198	46%	
Fish present WBs(fish)	50	1.069	41%	89%
Fish present WBs (Eel only)	6	174	7%	15%
Heavily Modified River WBs	49	434	17%	
Investigated HM WBs	24	277	11%	
Fish present HM WBs(fish)	23	275	11%	99%
Fish present HM WBs (Eel only)	3	48	2%	17%
River WBs at Risk	43	643	25%	
WBs at Risk investigated	7	170	7%	
Fish present WBs at Risk (fish)	7	170	7%	100%
Fish present WBs at Risk (Eel only)	0	0	0%	0%

In terms of water body type and designated condition, the survey investigated 58 river water bodies (representing a total length of 1.198 km), comprising 46 % of the river water bodies under control of the Republic of Cyprus. Fish are now known to be present in 50 designated water bodies (WBs) which cover 41% of all the country's designated water bodies. It should be noted that sites that were sampled (electro-fished) immediately upstream of many dams are not subscribed to the upstream river body if they are in close proximity with the dam, so in this case many river bodies that are above the dam and partially maintain some fish populations are not included.

Twenty-four (24) investigated water bodies are classified as Heavily Modified Water Bodies (covering a total length of 277 km), and comprising 11% of the river water bodies under control of the Republic of Cyprus were investigated/sampled for fish. Seven (7) river water bodies at Risk were investigated for fish (covering a total length of 170 km), and comprising 7% of the river water bodies at Risk under control of the Republic of Cyprus. The relative distribution of fish in the River Water Bodies, Heavily Modified Water Bodies and the River Water Body at Risk are shown in Table 3.4.

3.9. Generalization pertaining to the confirmed fish species in Cyprus waters

Successful fish-based bioassessment procedures combine knowledge of an area's natural history with straightforward sampling and statistical analyses. Natural history – descriptive knowledge of the living systems- not solely a search for statistical relationships and significance drives the development of effective bioassessment tools (Karr and Chu 1999). Here we present descriptive details pertaining to an account of 18 species that were confirmed during this project in Cyprus' inland waters.

Below the Initial synthesis from the information collected for 19 confirmed fish species in Cyprus' inland waters (Table 3.5). The underlined fish are native; and the asterisk symbol (*) is given to signify species that were found in rivers/lotic waters. Initial unpublished data on species' date of introduction were secured from Dr. Eleftherios Hatzisterikotis during collaboration on alien species research that is in progress. Table 3.5. further refers to the ecological guild and other classification attributes of each species in a comparative manner.

Table 3.5. *Initial synthesis from the information collected for 21 confirmed fish species in Cyprus' inland waters*

Confirmed Fish Species	*Generalizations on the distribution, abundance; initial ecological interpretations*
Alburnus alburnus **(Bleak)**	*Introduced in 1972 (probably from UK stock). Probably widely distributed in several dam reservoirs; not observed and/or captured during electrofishing in any rivers. Observed at Livadi and Kannaviou Dams. This species may not interfere negatively with the stream biota and should keep to lacustrine reservoir conditions (planktonic still-water feeder).*
Anguilla anguilla* **(Eel)**	*The Eel (Anguilla anguilla) was found at 6 river WBs (representing 174 km of length), or 3% of the total WBs (the equivalent of 7% of the total length of designated water bodies on Cyprus). In contrast, in the expert interviews the presence of the Eel is surprisingly widespread. In fact in certain sites the Eel has been photographed recently and collected by locals although electrofishing failed to locate it at these specific sites. In total 68 eels were located in the survey. However Eels were located in several river basins and anecdotal evidence indirectly suggests their presence in many others. We estimate that the top-priority sites of Chrysochou, Diarizos, Ezousa, Pyrgos, Chapotami, and Germasogeia alone probably attract more than 1000 glass eels between February and June (on a wet year). If we include all the minor river basins (or unknown river basins) in the entire republic, certainly another 1000 glass eels enter on wet years. Conservatively speaking, this proves that Cyprus hosts significant population of this Critically Endangered species at the eastern edge of its global distribution.* *A definite decline in populations and distributions is evident but*

	difficult to precisely document or quantitatively measure. Adults collected or presence confirmed in only a few streams, especially where perennial flowing conditions exist in lowlands and where there are few obstructions to longitudinal connectivity and connection to the sea. Observed populations always were very small (1-7 individuals) but varied size-classes were present at areas where habitats were optimal (e.g. Kidasi Diarizos, Goudi Chrysochou). Glass Eels (the anadromous young Eels that enter the rivers from the sea) were collected at 6 small streams in spring 2012 (a very good year in terms of running waters); but during the 2011 expedition they were found only at Pyrgos and Chrysochou river mouths. With respect to the questionnaire responses there is no doubt that before 1980 Eels were widespread throughout nearly all river basins on the island and they were found in many mountain streams also frequently up to 1000 m. in the Troodos Area. There is anecdotal evidence that poisoning for anti-malarial campaigning also created a significant decline; mass deaths of eels have said to occur in the past. *Mention has been made of Eel rearing and stocking in Cyprus in the past (Stephanou, 1988a). In the mid-1980s Glass Eels, imported from the U.K., were used for experimental rearing on an intensive basis. The work centered mainly on weaning techniques. Weaned Eels are distributed to interested individuals in addition to those used for stocking a few selected dams; this rather costly practice no longer exists. There is little evidence that any of the Eels seen/collected in recent times are from this stock. The use of stocked eels in the '80s may have created confusion regarding the existence of native eel stock. Currently, as observations during the 2012 survey, supplemented with the questionnaire responses, show, populations of wild in-coming glass eels in Cyprus are at a minimum of 2000 individuals per wet period season. This is the first study to confirm widespread native eel presence on the island.*
Aphanius fasciatus **(Mediterranean Toothcarp)**	*Relic populations found only in coastal wetland areas of the Akrotiri Peninsula (Zakaki Marshes, Phassouri "Pits"). Not found in any lotic systems or in other marshlands, where suitable habitat conditions exist (allegedly a population also exists in the Ammochostos area near Salamis, near the river mouth of the Pediaios; in the Occupied Territory). This is a protected species (in Annex II of 92/43/EEC) and the populations of Cyprus may be evolutionary significant units (needing further study). The confinement of the species only to the Akrotiri area is unusual and it is considered nearly certain that in the past it existed in other areas (fragmentation and degradation of wetlands can easily cause a population to become extirpated). The population's genetics of the species' collected speciments will be investigated within an independent project led by HCMR.*
Atherina boyeri **(Silver-side Atherina/ Silver-side smelt)**	*Marine transient entering freshwaters only when natural connectivity with inland waters or river-mouth is possible. Collected only from the small coastal ponds at the Phassouri "Pits" from the*

western side of the Akrotiri Peninsula. Very likely to also enter river mouths in other parts of the Island. Potentially a good indicator species of river-mouth connectivity with the sea.

Abramis bjoerkna

(Silver Bream)

Introduced in 1972 (probably of UK stock). A species found only in reservoirs; not collected in any river during the electrofishing sampling. Observed only at Asprokremmos Dam. This species may not interfere negatively with the stream biota and should keep to lacustrine reservoir conditions (but little is known of potential impacts within reservoir waters).

Carassius auratus*

(Goldfish)

This species is frequently spread by amateur fish-breeding hobbyists to small ponds and reservoirs on Cyprus; observed at many such locations. Collected only rarely in rivers (i.e. Xeros (Lefkas) downstream of Kafizides Dam).It is interesting that there is no mention of the notorious Gibel Carp (Carassius gibellio) a highly invasive species that is a close relative of the Goldfish, also originating from East Asia.

Cyprinus carpio*

(Carp)

The species has been captively reared in Cyprus since classical times and several varieties have been introduced in the '1960s from Israeli stock. A species found primarily in reservoirs; widely stocked and sometimes entering the streams adjacent to some reservoirs. Caught only once during the electrofishing campaign, this species is a poor disperser in rivers even where there are very low barriers.

Dicentrarchus labrax*

(Sea Bass)

Native populations in Cyprus have allegedly collapsed; this species seems to require shallow water rearing areas near to and often within river mouths. When river mouths opened during heavy rain-fall periods in spring 2012 several specimens were collected in coastal river sections (10-500 m. from the sea) at rivers in the south and west of the country. These specimens may be escapees from fish farming units or may be relicts of wild populations. The status of native wild populations in Cyprus is poorly-studied.

Gambusia holbrooki*

(Mosquitofish)

This species was allegedly introduced to many reservoirs and lowland still and flowing waters through Cyprus in an effort to combat mosquitoes. It is said that it was first introduced into Cyprus in 1939 from stock of Syrian origin (the species was spread into the Mediterranean countries originally from the Southern USA). It is one of the most widespread and abundant inland fish species in Cyprus. Surprisingly it was collected in relatively few locations during our research in 2010-2012. It is a poor disperser and requires aquatic refuges even during extreme drought events therefore populations may locally become extirpated rather easily in Cyprus. High-density populations where observed in some lowland river sections (e.g. Pediaios) and especially in some wetlands (e.g. Akrotiri marshes at Zakaki, Oroklini wetland). The species can tolerate rather high salinity and pollution. It is considered to be an invasive and detrimental alien in inland waters. In Hawaii, Poeciliids including Mosquitofish have been shown to be the source of parasites that now infest native gobies, causing disease and reducing overall fitness of native fish. Poeciliids have also been shown to impact

	native fish by competing for food resources as well as through direct predation.
Ictalurus punctatus* ***(Channel Catfish)***	*Imported in to Cypriot reservoirs in 1975 from American stock. This highly tolerant to pollution species is likely to be more widespread than the electrofishing sampling reveals. Most observations are from reservoirs (but it was also collected in the Xeros (Pafos) above Asprokremmos Dam and seen at Marathasa and Agia Marina Reservoir as well). At least two other catfish species are said have been imported into Cyprus waters; that is the North African Clarias, a tropical species, imported since classical times; and Silurus glanis imported in 1979. No evidence of these rather cryptic species was collected since they probably are restricted and may thrive in some reservoirs)*
Lepomis gibosus* ***(Sunfish)***	*A recent addition to the alien fauna of Cyprus, the species is now common and even locally abundant in a few reservoirs; its populations do infiltrate nearby rivers but river populations are very small and it is only found in close proximity of the confluences as it is a poor disperser in rivers (it is difficult for Lepomis gibosus to surpass even very low barriers). It was collected in the lower Diarizos immediately below Tzelefou Bridge.*
Micropterus salmoides* ***(Largemouth Bass)***	*Introduced in 1971 (probably of UK stock). A recent addition to the alien fauna of Cyprus, the species is now common and widespread in a several reservoirs; its populations do infiltrate nearby rivers but river populations are very small and restricted to the proximity of the dams. It is a poor disperser in rivers (it surpasses even very low barriers with difficulty). Sometimes populations at river confluences with the reservoirs are high, such as Evretou Reservoir, Dipotama and Kouris.The species is known to be a verocious carnivore consuming insects, amphibians, other fishes and reptiles. For this reason it is considered a potential invasive that will disrupt biotic interactions in streams and reservoirs; it should not be promoted and dispersed beyond its current distribution.*
Mugil cephalus* **(Striped Grey Mullet)**	*This was a common and abundant marine euryhaline visitor to coastal wetlands and river mouths in many parts of Cyprus in the past (as questionnaire responses revealed). During the current sampling survey it was the most widespread of the Mugilids. The species was allegedly introduced to Germasogeia reservoir; an act that has little environmental impact since it cannot reproduce in freshwaters (translocated populations no longer exist in reservoirs).*
Liza aurata [Golden Grey Mullet]	*Similar to Mugil cephalus and Liza ramada this is one of three mugilids found in inland waters in Cyprus. A single specimen was collected from the Xeros river mouth in April 2012 and this represents the first time the species is recorded inland waters in the island.*
Liza ramada ***[Thin-lippted***	*A frequent small mugilid that enters rivers in all mediterreanean Islands. On Cyprus nearly all individuals were found very close to the sea – less than on km from the river mouth outlet usually. In*

Grey Mullet]	*other countries the species is known to travel up-river more than 100 kms. It feeds mainly on algae and will grow fast but must return to the marine environment to spawn.*
Oncorynchus mykiss* **(Rainbow Trout)**	*Introduced from USA stock in 1969. One of the most widely stocked fish in Cyprus, since it is prized for angling and frequently escapes from upstream fish farms. Indications of spawning and self-sustaining populations where found at the upper Kryos (Kalydonia), and perhaps also at the upper Kargotis and upper Xeros (Lefkas). The species was not found where Brown Trout existed and this may show a potential competition between these two salmonids. Remarkably high densities exist in a few upland locations (Kalydonia – Kryos, Upper Kargotis near Spilia) and these may concern sites where there are releases of farmed or stocked fish (as well as potential good spawning habitat).*
Oreochromis aureus* **(Tilapia)**	*Introduced from Israel in 1976 (allegedly along with Oreochromis niloticus a similar-looking species). This fish is now widespread in lowland warm-waters (ponds, canals, some reservoirs). During the electrofishing it was located in the Germasogeia river immediately upstream of the reservoir. This tilapia was also observed in the Asprokremmos and adjacent irrigation canal (at Achelia Village). The species is susceptible to mass die-out during cold winters (observed even at Germasogeia and Achna in cold winters).*
Perca fluviatilis* **(Perch)**	*Introduced to dams in 1971 (from UK stock). Common in dams such as the Kouris Dam. Common in the river-mouth of the Kryos river and immediately upstream of the Kouris Dam.*
Rutilus rutilus* **(Roach)**	*Introduced in 1972 (probably of UK stock). This is now the most widespread cyprinid in Cyprus and it is frequently encountered in streams at many locations (primarily near reservoirs). It has been widely introduced in reservoirs, cisterns, and agricultural ponds as well in the uplands. One would expect it to be even more widespread in streams, longitudinal barriers to movement and severe drought events however, probably deter or extirpate populations. In some populations the fishes were surprisingly long-bodied (i.e. at Germasogeia) or had unusual head disfiguration (i.e. at Marathasa); DNA analysis[9] proved that these fishes where in fact all typical Rutilus rutilus and the structural changes observed may be from malnutrition or poor-conditions in hatcheries. The species is often abundant in streams in Cyprus (e.g. Marathasa; Evretou river-mouth and the adjacent Chrysochou river upstream of the Dam; Germasogeia). A capable disperser, specimens were found downstream or at the spill way below the Dams also (e.g. Germasogeia, Livadi Dam, Ezousa).*
Salmo trutta*	*The species was introduced in 1948 from the UK during a British*

[9]Dr. Radek Sanda, curator of Ichthyology at the Natural History Museum in Prague examined Rutilus rutilus from several Cyprus populations in 2011; all roach populations at Germasoyia, the Western Cypriot reservoirs and at Marathas are of typical central European stock.

(Brown Trout)	*forest conservation initiative. In May and June 2011 our investigations proved that it still maintains self sustaining wild-reproducing populations at the Mesa Potamos (Kouris), Upper Diarizos and Upper Xeros (Pafos).Formerly also known to exist in the Kargotis but not found there by our surveys; usually does not co-occur with the other trout species. Fingerlings (YOY) were found at these locations but in unusually small numbers. Nearlly, all populations showed unusually low densities (the densest populations are on the Fini and Kaminaria tributaries of the Diarizos. The species is a good disperser and may migrate to various parts of the upland river network or may even enter downstream reservoirs in winter. Interviews with DFMR researchers show that although specimens are kept at the Kalopanagiotis Hatchery (Marathasa) the species is not stocked in any rivers or reservoirs by this institution in Cyprus. Genetic research should be promoted to ascertain the species' providence.*

3.10. Fish population structure

In Fig. 3.31 the distribution of lengh-class sizes of the 8 most widespread taxa in Cyprus' rivers are presented. It is interesting to note that most fish are small sized (class-sizes <5 cm, 6-10 cm dominate). Very small sized species (Aphanius fasciatus, Gambusia holbrooki and the rather small Rutilus rutilus) are the most abundant, and nearly always in small size classes at the survey sites. The larger, longer-lived trout (Oncorhynchus mykiss and Salmo trutta) have a distribution of several size-classes, as does the Eel (Anguilla anguilla).

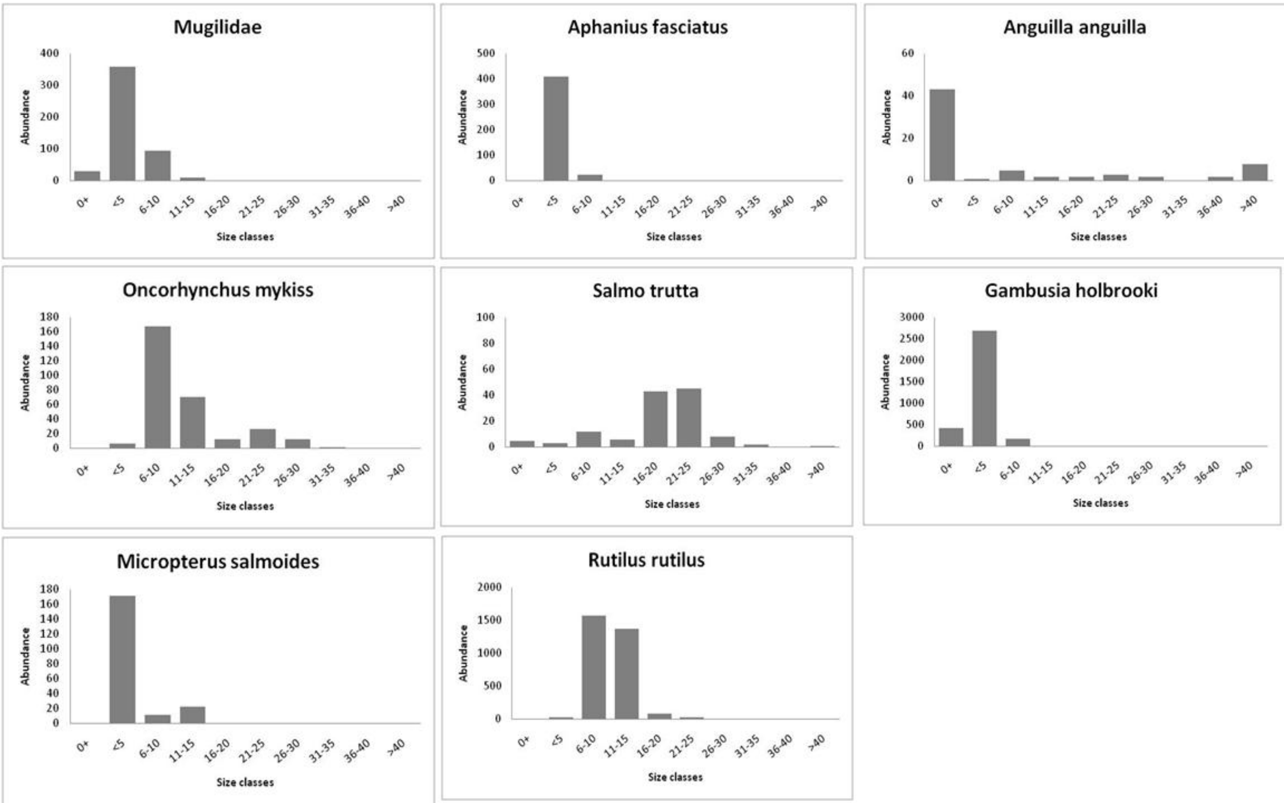


Fig. 3.31. *Distribution of size-class structure within the fish taxi during all collections of the sampling campaign.*

3.11. The Eel in Cyprus: a conservation policy priority

The European Eel (*Anguilla anguilla*) is a catadromous carnivorous species, widely distributed in marine, coastal and freshwater systems in the North Atlantic, Baltic, Mediterranean Seas and the Black Sea. It is a species of ecological and economical importance with significant fisheries and aquaculture value for several coastal European countries (FAO, 2004-2011) yet it is currently assessed as critically endangered in the International Union for Conservation of Nature's Red List of Threatened Species (Freyhof & Kottelat, 2008).

A decline in European eel landings has been observed as early as 1975 and today both the stock and the recruitment levels are at a historical low, while the fisheries are characterised as unsustainable (ICES, 2006; OSPAR, 2010). Although there are uncertainties due to the fragmentary character of the available information on stock abundance, exploitation, anthropogenic pressues, climate change impacts, spawning conditions and early life cycles, many possible causes of the population decline within the European freshwater systems have been identified (OSPAR, 2010). These include overfishing for glass eel and downstream migrating silver eel, pollution, presence of parasites such as the *Anguillicola crassus*, mortality and loss of connectivity associated with the presence of hydropower stations and dams (barriers to in-stream migration), predation and habitat loss (Freyhof & Kottelat, 2010; ICES, 2006).

In 2007, the European Council (EC) published the Regulation 1100/2007/EC establishing measures for the recovery of the stock of European Eel. This legislative document creates the framework for the protection of the Eel in Community waters, coastal lagoons, estuaries, rivers and communicating inland waters and seas within the ICES (International Centre for the Exploration of the Sea) areas III, IV, VI, VIII and IX and in the Mediterranean Sea. Each EU Member state carries the obligation to identify and define within its territory Eel River Basins that constitute eel habitats to regularly monitor and to prepare an Eel Management Plan (EMP) for each basin. The objective of the Eel Management Plans is to achieve escapement to sea of at least 40 % of the silver eel biomass estimated for conditions that would have existed in the absence of anthropogenic impacts. To achieve this objective, Member States may choose an implementation strategy based on a variety of proposed measures including reducing commercial and recreational fishing activity in inland waters, restocking with eel less than 20 cm in length, improving habitats, increasing connectivity, transporting silver eel to areas where escapement to the Sargasso Sea is possible, combating predators, temporary switching off hydroelectric turbines and aquaculture related measures. If fisheries are operating in community waters (marine waters seaward of Eel River Basins), Member States must reduce either the fishing effort or the catches by 50% relatively to the average fishing effort or catches for the period 2004 – 2006. The Eel Regulation permits gradual implementation, however the beginning of implementation of measures, should not delay past the first year following the approval of the EMP by the Commission.

Exemptions from the implementation of the Regulation have been foreseen for Member States where no river basin within their national territory can be identified and defined as constituting a natural habitat for the European Eel. In November 2007, Cyprus requested from the European Commission, derogation from the implementation of the Eel Regulation on the grounds that no rivers exist within its national territory that run throughout the whole year and flow out to the sea and that Eel fisheries are absent in Cyprus. The European Commission responded to this request, along with similar requests by other EU Member States (Austria, Malta, Romania and Slovakia), by soliciting an ICES Advice on the evaluation of possible exemptions from the obligation to submit Eel Management Plans. The ICES Advice Report of 2008 concluded that no fisheries of eel are present in Cyprus and that the winter population of eel in Cyprus amounted to less than 1.000 individuals (ICES, 2008; 2009). Measures for the conservation of Eel were therefore not believed to have a significant contribution on the conservation status of the species. Following the ICES consultation, the exemption from the obligation to submit EMPs for its entire territory was approved for Cyprus by the Commission Decision 2009/310/EC of 2 April 2009.

It is true that there are no fisheries of Eel on Cyprus and only a very small number of amateurs collect Eels for food; however the numbers of Eels in Cyprus' inland waters are not trivial, although comparatively small to other EU states. Currently, as observations during the 2011 and 2012 survey confirm, populations of wild in-coming glass eels in Cyprus are at a minimum of 2000 individuals per wet period season (February-June). This is the first study to confirm widespread native eel presence on the island. Eels survive inland for more than 10 years, before descending to the sea to travel to the Atlantic for spawning. Inland populations of these long-lived fishes were found in several large rivers (Pediaios, Pyrgos, Chrysochou, Ezousas, Diarizos, Pouzis) and there may be many others. The places were Eels survive must obviously sustain long-term surface waters even during the summer drought. Although Eels have the ability to cross remarkable barriers (more than any other fish), they are stopped by high dams, dessicated river-beds, and poors connection or water-flow to the sea. As a species that signals longitudinal connectivity, hydromorphological naturalness during drought and a natural connection to thes sea, it should be considered an important bioindicator of these elements of lotic water ecological integrity on Cyprus. It is important to note that the current study cannot replace a proper study of the Eel in Cyprus since there area specific problems in surveying and measuring stocks. Our initial remarks on this cryptic species show that although current knowledge is very limited, the Eel may be much more widerspread on the island than previously thought.

Fig. 3.32. *Eel at the "Yellow Eel" stage inhabiting the mid section of the Chrysochou river at Goudi Bridge. Although this individual was collected with electrofishing gear it is often difficult to use electricity effectively to catch Eels in waters were the electrical conductivity is higher than 1200 μ/S (Photo: S.Zogaris June 2011).*

Fig. 3.32. *Rutilus rutilus (Roach/Κοκκινοφτέρα) in the Xeros (Pafou) River near Finikas, u/s of the Asprokremmos Dam (Photo: A.Vidalis).*

Fig. 3.33. *Salmo Trutta (Brown Trout/ Καφετιά Πέστροφα) at Mesa Potamos, Kouris River. At this site young fry were found in early May 2011. (Photo: A.Vidalis).*

Fig. 3.34. *Ictalurus punctatus (Channel Catfiish/ Αμερικάνικο Γατόψαρο) at the Xeros (Pafou) upstream of the Asprokremmos Dam. (Photo: A.Vidalis).*

Fig. 3.35. *Underwater photograph of Carassius auratus (Goldfish/Χρυσόψαρο) in the Xeros River (Lefkas), d/s of the Kafizides Dam. Over several generations the "golden" pigment may revert to the wild-type grey-brown color (Photo: S. Zogaris).*

Fig. 3.36. *Salmo trutta (Brown Trout/ Καφετιά Πέστροφα), underwater photograph in the Xeros river at Roudias Bridge. (Photo: S. Zogaris).*

Fig. 3.37. *Salmo trutta (Brown Trout/ Καφετιά Πέστροφα), underwater photograph in the Xeros river at Roudias Bridge (note color pattern variation). (Photo: S. Zogaris).*

Fig. 3.38. *Invasive non-indigenous species infestation at Germasogia stream near Germasogia Dam. The dominant species is Lepomis gibosus (Sunfish/ Ηλιόψαρο) a carnivorous predatory American fish that exerts pressure on native aquatic biota. (Photo: S. Zogaris).*

Fig. 3.39. *Underwater photograph of Oreochromis aureus (Tilapia/Τιλάπια) in the Germasogia River, immediately u/s of the Germasogia Dam. This African species is abundant in several reservoirs and water transfer canals at low elevations. (Photo: S. Zogaris)*

Fig. 3.40. *"Glass Eel" (Anguilla anguilla) with Grey Mullet (Mugil cephalus) fry at the Chrysochou river mouth in early May 2011. (Photo: S. Zogaris).*

Fig. 3.41. *Detail of the same nearly-translucent "Glass Eel" caught at Chrysochou River mouth. Total length 73 mm. (Photo: A. Vidalis)*

Fig. 3.40. *Underwater photograph of wild-living Rainbow Trout in Marathasa, near Moutoulas (Photo: S. Zogaris/N.Chartosia).*

Fig. 3.40. *Healthy large-sized Rainbow Trout in Marathasa, near Moutoulas (Photo: N. Chartosia).*

SECTION 4

METRICS CALCULATION AND APPLICATION

4.1. Fish as bio-indicators of environmental conditions in lotic waters in Cyprus

Although fish as a biological quality element for river bioassessments is widely used in Europe, difficulties in its use exist in several Mediterranean countries; in Cyprus it is not included among the standard methods of bioassessment. Essentially, the challenge in Cyprus is to understand the underlying patterns in a high-variability stream system, to identify and to validate fish-based metrics in order to build a consistent and practical index for the island. The rivers of Cyprus have unique qualities, due to their insular biogeography, the effects of a seasonally semi-arid climate, climatic changes on a depauperate fauna, and especially the widespread and complex anthropogenic alterations to natural ecosystems. Today the number of native fish species is very low; fish populations and their distributions are severely fragmented and in low densities. However, there are fish in the island's rivers and there were fish before modern anthropogenic degradation of the rivers as well. The main problem here is the understanding of the natural history, the intricate ecological patterns and the history of anthropogenic environmental change, so as to be able to utilize the information the fish community attributes give to assess river ecosystem integrity. There is no tradition in river ecosystem studies in Cyprus and as a result existing knowledge is severely limited.

One would expect that certain fish attributes would react to different anthropogenic disturbances, giving some sense of a river biotically-driven ecological status. This is a classic pattern and it has been utilized throughout the world (Fig. 4.1). However, this is especially difficult currently in Cyprus since reference conditions are extremely difficult to construct because natural and near-natural conditions are nearly non-existent in the majority of streams on the island and there is much variability of the populations and distributions of present fish assemblages (dominated by recently naturalized non-indigenous species). In this context the present work with fish-based approaches can only be called exploratory; it has helped establish an initial reference framework for further research and development.

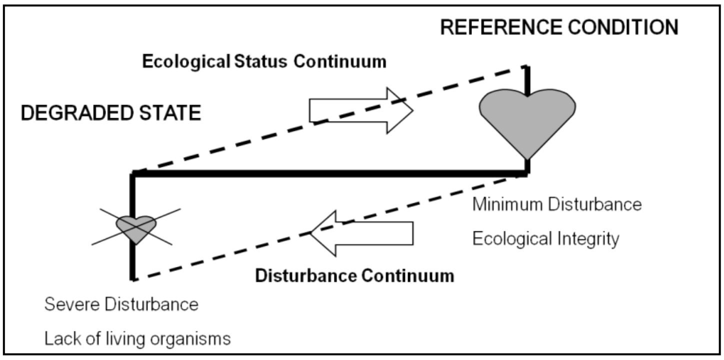


Fig. 4.1. *Continuum of anthropogenic disturbance on an attribute's biological condition (symbolized by the heart; i.e. the metric). At one end of the continuum severe disturbance eliminates the attribute (no living organisms). At the other end we have minimally disturbed conditions and high ecological integrity with the attribute in*

reference conditions. Reference conditions would in this case be classed as the "high" ecological status and the end of the degraded state would be classed as "bad" ecological status following the WFD five-tiered classification terminology.

Collecting and interpreting information to explore whether fish attributes may act as indicators of biological quality is a hierarchical process. It begins with describing and defining the regional fish assemblage to be studied, organizing a river-type classification and building an appropriate study design to research how specific fish attributes react to anthropogenic pressures in order to construct and later to validate a bioassessment index. This classical reference conditions based process is illustrated in Fig. 4.2. Many varying applications of this bioassessment development procedure using fish have been successfully attempted throughout the world, but few have been developed on islands or areas with very low species pools.

In Europe, a standardized procedure for testing-evaluating and organizing the framework for support of the BQE fish in rivers, is comprised by the following steps (FAME, 2005):

- Definition of a fish-based typology
- Linking biotic and abiotic typology by identifying abiotic factors and thresholds structuring fish assemblages
- Screening of potential metrics for each river type (= metrics supposed to respond to human pressures)
- Selection of candidate metrics for each river type (= metrics proved to respond to human pressures)
- Selection of the final metrics for each river type (tests of sensitivity to human pressures)
- Potential application of a type-specific metrics or existing multi-metric index
- Potential assignment of 5 classes for the ecological status based on the Biotic Integrity of the system as shown by the fish-based metrics.

Appropriate development of a sound multimetric index requires experience and training in this specific study design, appropriate fish assemblage sampling, organized pressure analysis, monitoring to check and interpret natural variations, and a deep, ichthyological, ichthyogeographic and ecological understanding of the particular systems.

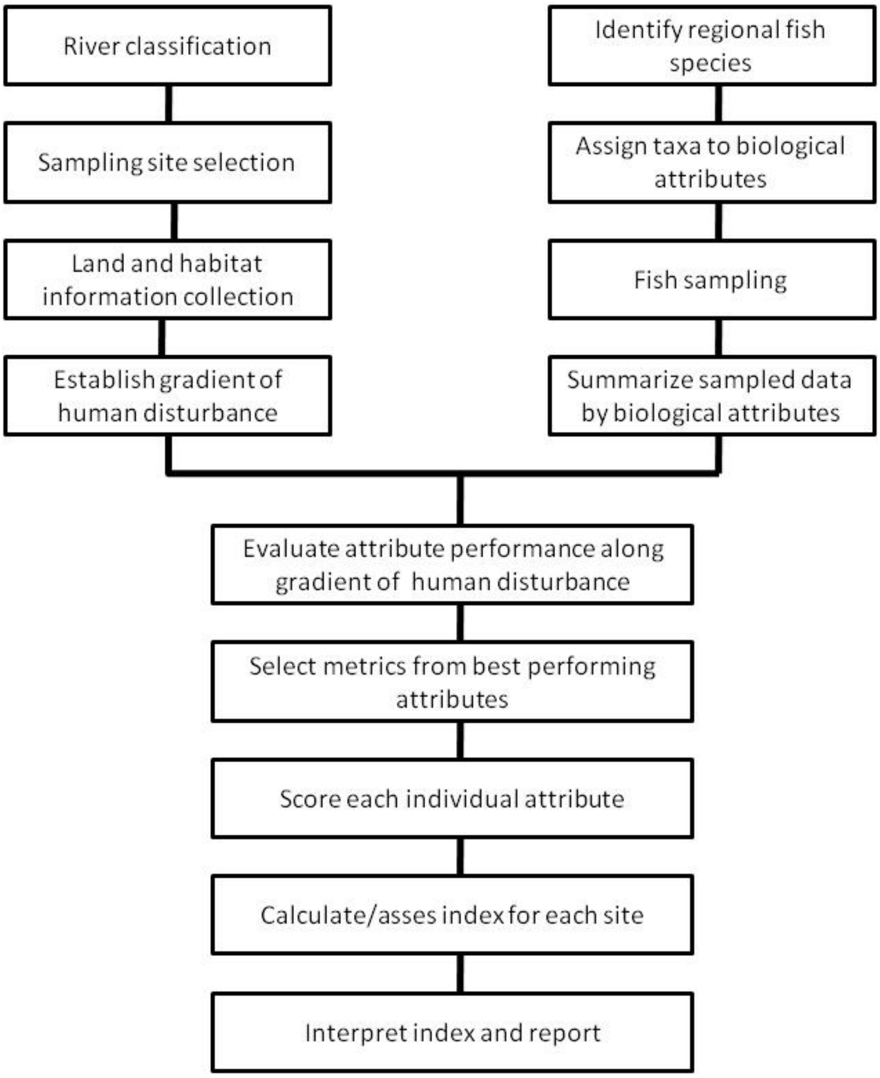


Fig. 4.2. *Conceptual diagram for developing a fish-based biological index with respect for the fish-based index of biological integrity concept. Note that river classification and fish species assemblage research are integrated to explore metrics analysis (the last column). In order to evaluate fish community attribute performance along a gradient of human disturbance reference conditions need to be constructed. (Adaptation from US EPA 2002)*

The remarkable knowledge gaps in Cyprus do not allow the investigation to reach the level of development of a specific index based on the BQE for river fish in this study. An initial reason for this is the inherent variability of fish attributes in Cyprus' streams. Fish are surprisingly scarce in Cyprus streams and their survival is often influenced (positively and negatively) by anthropogenic water management structures, such as the dams, river diversion, and water abstraction and by human actions such as unchecked introductions and stocking. Empirical evidence suggests that fish are scarce in Cyprus streams primarily because of recent anthropogenic pressures (i.e. artificial desiccation of rivers due to water abstraction etc); biogeographical effects at several spatio-temporal scales have also obviously affected the low species numbers. It is currently not possible to isolate biogeographic effects from centuries-old anthropogenic pressures on the waters and fishes of Cyprus. Very recent anthropogenic pressures such as the widespread and intensive use of DDT certainly have had significant impacts on native and established non-indigenous species, and the poisoning-extermination impacts have never been assessed properly. We reiterate the problem of a lack of background natural history research, any kind of ichthyological monitoring and historical ecology investigations; this does not allow easily applied analysis for reference condition building (e.g. Leitbilt approaches, *sensu* Skoulikidis et al., 2011). Within this framework, what ichthyological resource and conditions can be constructed will be based the specific set of quantitative samples and on expert opinion gained from the recent one-off wide-ranging surveys. The surveys document that the variation among sites is remarkable in Cyprus. It seems today that certain alien species are filling-up vacant niches in the reservoirs and in perennially flowing streams as well; fish assemblages are not yet in an equilibrium – there seems to be a dynamic flux and sites that had no-fish may have some populations just because of species expansion during "good" or wet years. This variability in fish spatial and population attributes, the inherent uncertainties and poor understanding of fundamental natural history baselines makes the use of fish for bioassessment as BQEs a challenging research initiative, and difficult to develop in practice.

We cannot adequately describe the spatio-temporal variability without monitoring fish populations over at least a few annual cycles. Since the ichthyologic conditions seem to be poorly predictable, it is probable that there will be a mix of "natural" and anthropogenic variation concerning the quantitative aspects of fish community attributes. These need to be researched.

Despite these caveats, fish were proved to be sensitive indicators of the quality of certain stream habitat conditions and certain resource states (often at broader scales than macroinvertebrates or plants) because they integrate multiple effects of degraded longitudinal channel environments while acting as long-lived continuous "monitors" – providing information especially concerning the hydromophology, flow regime and connectivity of rivers. Also, a growing interest in non-indigenous species is showing that they can be used as effective environmental indicators as well (several resource-use stakeholders are also interested in non-indigenous species). A major quest during a fish-based bioassessment development on a large Mediterranean island such as Cyprus is to explore how these potential indicators (specific fish-based metrics) can be used consistently and predictably with minimal uncertainties and be integrated in an ongoing and adaptive approach to water management.

In the present research exercise developments in terms of a generic biotically-relevant river typology is introduced, anthropogenic pressure analysis and a basic Site Quality Index (SQI *sensu* Angermeier & Davideanu, 2004*)* are developed. Specific fish attributes are analyzed to show relationships to environmental parameters and pressures; remarks on the use of potential metrics are made where some metric attributes are correlated with anthropogenic pressures. Finally specific proposals for further development are proposed including specific delineation of priority areas.

This section involves the following attributes:

- **Work package 1**: Fish as a BQE in Cyprus. RESULTS: Initial treatment of the typological data developed. Specialized pressure analysis. Initial exploration and feasibility of identifying, verifying fish-based metrics. Response of metrics to anthropogenic pressures.
- **Work package 2:** Evaluation and proposals: RESULTS: Interpretation of initial treatment and unmet needs expressed.

4.2. Development of a typology

There are many paths towards a typology development for bioassessment and here an attempt for a generic segregation of sites at the broadest scale is made, in order to help define more homogenous types and discern the major natural break-point boundaries that affect the streams fish populations. This will help in exploring fish biotic groups, their constituent attributes and their responses to environmental parameters and anthropogenic pressures.

The hierarchical framework towards a biocoenotic typology involves two major steps: (a) the establishment of an initial spatial framework (i.e. biogeographic regional units), focusing on zoogeographic patterns, and (b) the identification of biologically relevant abiotic variables (and class boundaries within them) that determine relatively homogeneous biotic communities. Worldwide fishes are important indicators of biotic components of rivers and especially in Mainland Europe, many models have been developed to show the progressive “zonation” of fish as they are related to specific river types, river zones and river environmental parameters (Fig. 4.3). These zonation patters are extremely important in bioassessment regionalization and definition of water body units to be accurately assessed using the fish BQE (Economou et al., 2003; 2007).

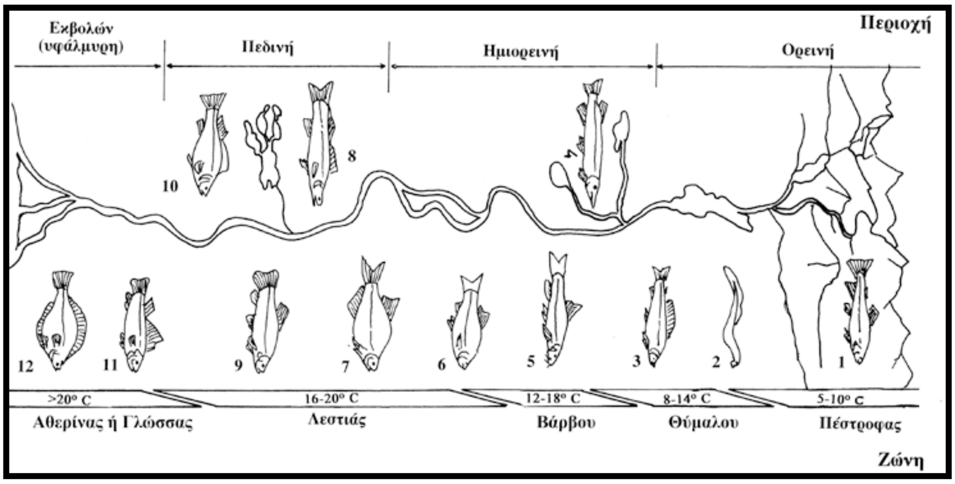


Fig. 4.3. *Example of a classic European fish-based river zonation by Muus and Dahlstroem 1971 modified by Kousouris 1998. Distinct river zones, from mountain areas (right) to the river mouth (left) are identified based on dominant fish species. Numbers next to the each fish give species name that dominates in each river zone (Greek fish names identify each temperature-class and fish-based zone, at bottom): 1=Salmo trutta (πέστροφα), 2= Lampetra fluviatilis, 3 =Thymallus thymallus (θύμαλος) 4= Esox lucius, 5= Barbus barbus (βάρβος), 6= Scardinius erythopthalmous, 7= Abramis brama (λεστιά), 8= Sander lucioperca, 9=Tinca tinca, 10= Perca fluviatilis, 11=Dicentrarchus labrax, 12= Atherina or Platicthys sp. (αθερινά ή γλώσσα). Some of these fish species are present as alien or naturalized aliens in Cyprus streams and reservoirs.*

To classify rivers into biotically-relevant types, it is suggested that a combination of System A (ecoregions) and System B be applied; this specifies obligatory physical and chemical descriptors (altitude, latitude, longitude, geology and size) coupled with a characterization of the flow regime. Initially effort must be devoted to develop a typology scheme for a segment using the top-down approach (using expert judgment to select biologically-relevant abiotic variables provided by the WFD).

Using available environmental data at the sampled sites (and GIS extracted broader-scale attributes) we attempt a generic top-down typology. This must be necessarily broad-based and holistic so as not to create artificial boundaries or highly heterogeneous groupings.

4.3. Abiotic generic typology development

In the context of the development of ecological quality/ bioassessment indices, a desirable property of a river typology scheme (river ecological classification), apart from adequately translating the expected structure of species assemblages, is to be based on straightforward abiotic environmental variables, in order to allow to allocate easily non-sampled sites into a given generic river type. A “pre-classification” of sites into three generic river types is proposed - mountain, middle course and coastal. This was carried out based on expert judgment. Intuitively the mountain-middle course boundary should be based on the dominance of salmonids in coldwater mountain streams and their absence in warmer lower-elevation non-salmonid streams (this property of salmonid as indicators of temperature is world-wide (Mathews 1998)). Finally a third type should intuitively be associated with river mouths – and this is evident in Cyprus both during the wet year when the river-mouths are connected to the sea and during the times the river-mouths create pools were fish of marine origin assemble. The rationale behind this classification was that different fish communities should exist in such contrary abiotically-driven types, (i.e. based on the major geographical, physical and chemical conditions that prevail there). The consistency of this classification in terms of the fish assemblages was tested using a nonparametric analysis of similarity (ANOSIM, Clarke & Warwick 1994).

In order to assess the consistency of this classification in terms of the environmental descriptors, two independent approaches were used. First, a discriminate function analysis (DFA; Legendre and Legendre 1998) using a forward selection procedure was performed in order to identify which environmental variables best discriminated each river type. The advantage of using DFA is that it allows allocating new sites into the classification scheme. A cluster analysis based on k-means non-hierarchical clustering procedure was used in order to check whether the groups formed with this technique were consistent with the pre-classification based on expert judgment of sites. K-means clustering (Legendre and Legendre 1998) was performed considering 3 clusters, and resulting groups were compared with the pre-classification river typology.

4.4. Confirmation of the general abiotic types

Concerning the analysis shown in the figures pertaining to the typology, the following data were used and only 91 sites were electrofishing and/or fry net collection was applied were utilized in the analysis. For the biotic comparison/clustering, 43 sites (with fish present) were used.

For the abiotic environmental characteristics the following variables were used:

- Distance from source (km)
- Distance from mouth (km)
- Altitude (m.a.s.l)
- Height of source (m.a.s.l)
- Ratio of altitude/height of source
- Watershed area (km^2)
- Temperature_annual average
- Precipitation_annual_mean
- Precipitation_annual_sum
- IOS4_mean
- IOS4_sum
- Channel slope
- Upstream watershed % of permeable substrate

According to the results of the DFA, there is a good consistency between the pre-classification of mountain sites (84.38% of sites correctly classified) and middle course sites (86.27% of sites correctly classified) and the set of environmental descriptors. However, there is a poor discrimination between coastal and middle course sites (62.5% of sites correctly classified). Five out of 32 mountain sites were allocated to the middle course type. Three and four out of 51 middle course sites were allocated, respectively, to the mountain and coastal types. Three out of eight coastal sites were allocated to the middle course type. Selected variables in the discriminant functions were: distance to mouth, distance to source, altitude, mean annual precipitation in the upstream watershed and mean ombrothermic index in the upstream watershed. These results were considered sufficiently consistent to be accepted as the basic river types (Table 4.1).

In terms of the environmental variables that best discriminate the three river types, the mountain type is characterized by low distance to source, high distance to mouth, high altitude, high precipitation and low IOS4 (Fig. 4.4). Coastal type is characterized by high distance to source, low distance to mouth, low altitude, low precipitation and high IOS4. Middle course type is characterized by intermediate values for these variables.

Table 4.1. *Confusion matrix between the pre-classification based on expert judgment and the predicted classification based on the discriminant function analysis.*

		Predicted			
		Mountain	**Middle course**	**Coastal**	**% correct**
Observed	**Mountain**	27	5	0	84.38
	Middle course	3	44	4	86.27
	Coastal	0	3	5	62.50
	Total	30	52	9	83.52

ANOSIM results also suggest that the pre-classified river types are significantly different to each other in terms of fish community structure (Table 4.2). However, the resulting R statistics are relatively low. This may be due to the effect of anthropogenic pressures, which were not taken into account in this analysis. In other words, data included both disturbed and less disturbed sites, affecting the fish composition. Further analyses concerning fish types will have to include only less disturbed sites or to use species or metric variables instead of fish communities. This needs to be continued when more sites with fish are collected in the near future.

Table 4.2. *Results of one-way analysis of similarity (ANOSIM) with 999 permutations.*

Groups	*R Statistic*	*Significance Level %*
Middle course, Mountain	*0.192*	*0.1*
Middle course, Coastal	*0.378*	*1.6*
Mountain, Coastal	*0.404*	*0.3*
Overall	*0.240*	*0.1*

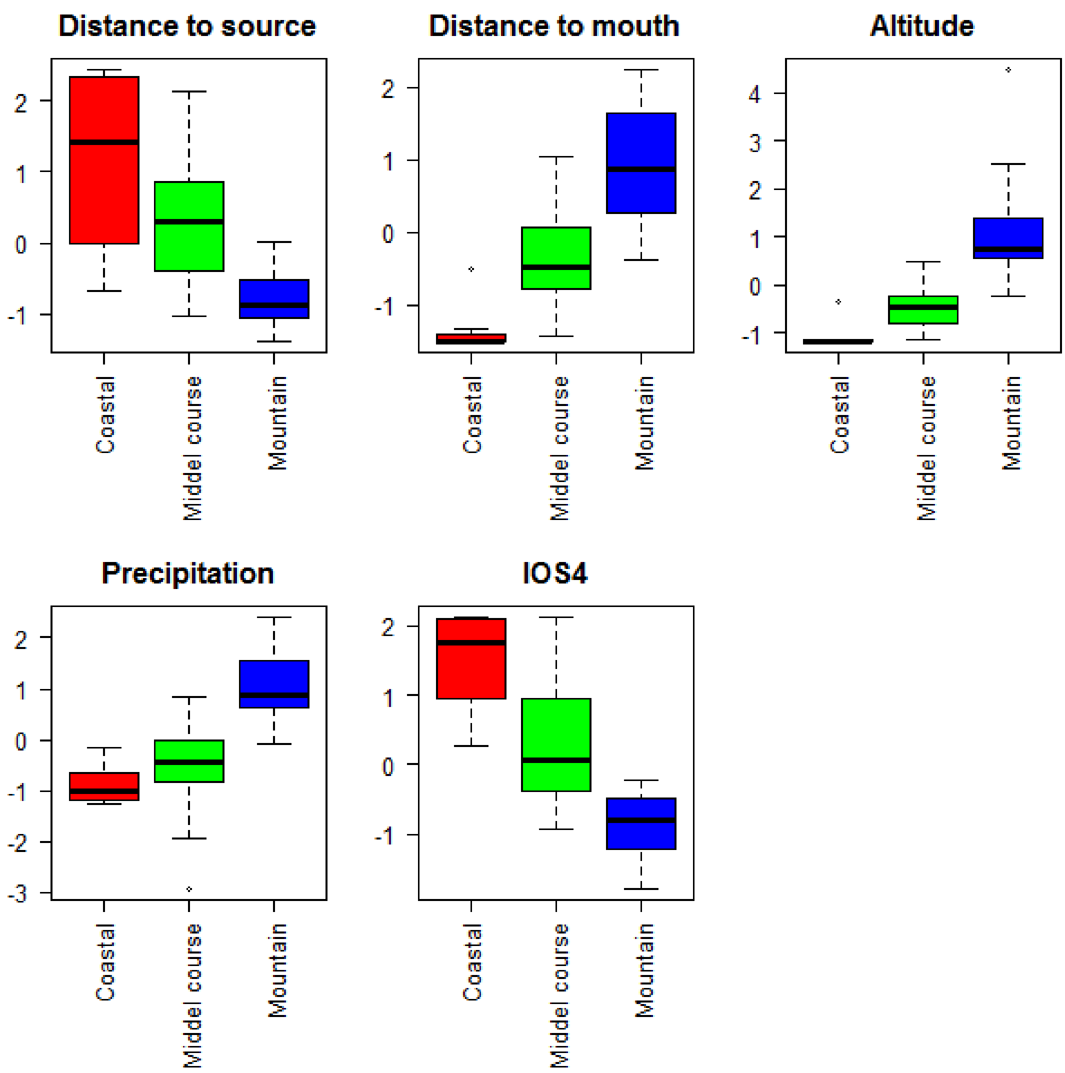


Fig. 4.4. *Box plots representing the variation around the median value of each variable selected in the DFA for each pre-classified river type.*

Results of the K-means clustering of sites also show that there is a good match between the pre-classified mountain sites and the resulting group 1, with a % of concordance equal to that obtained with DFA (84.38% of concordance). Most pre-classified middle course sites were classified in group 3, although with a poorer % of concordance compared to DFA results (70.59% of concordance), since many of these sites were classified in group 2. The match between pre-classified coastal sites and group 2 was the same as in the case of DFA (62.50% of concordance) (Table 4.3, Fig. 4.5).

Table 4.3. *Confusion matrix between the pre-classification based on expert judgment and the K-means clustering. * - percentages based on concordances between mountain group and k-means group 1, middle course group and k-means group 3 and coastal group and k-means group 2.*

		K-means groups			
		1	**2**	**3**	**% Concordance***
Observed	**Mountain**	*27*	*0*	*5*	*84.38*
	Middle course	*2*	*13*	*36*	*70.59*
	Coastal	*0*	*5*	*3*	*62.50*
	Total	*30*	*52*	*9*	*83.52*

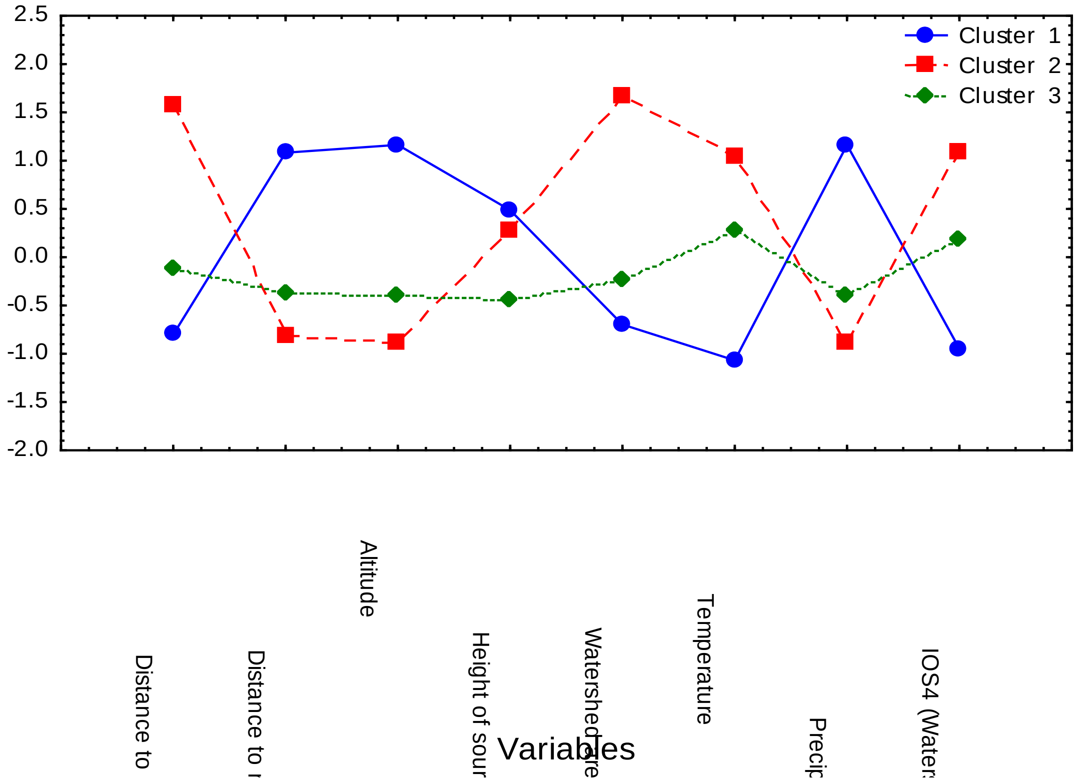


Fig. 4.5. *Profile of each group resulting from the k-means clustering representing mean values for each considered environmental variable. Cluster 1 (Coastal-Rivermouth), Cluster 3 (Mountain – Salmonid); Cluster 3 (Middle Course –Nonsalmonid).*

Fig. 4.6. *Coastal section of the Pyrgos stream, 100 m upstream of the river mouth. This is one of very few streams flowing frequently into the sea. The lower section is spring-fed clear, cool water; but during parts of the year there may be no flow. May 2011.*

Fig. 4.7. *Middle course section of the Xeros (Pafos) immediately downstream of the Asprokremmos Dam. Rivers such as this probably had areas of emergent vegetation before damming (observed also at the Ezousa, Chrysochou and lower Diarizos valleys). May 2011.*

Fig. 4.8. *Mountain course section of the Kargotis stream upstream of the Agios Nikolaos fish farm. Although this is a perennial cold-water cascading stream that would otherwise host trout high metal content and other natural toxics render it fishless. May 2011. (All photos by A. Vidalis).*

4.5. Fish biotic group attributes per type

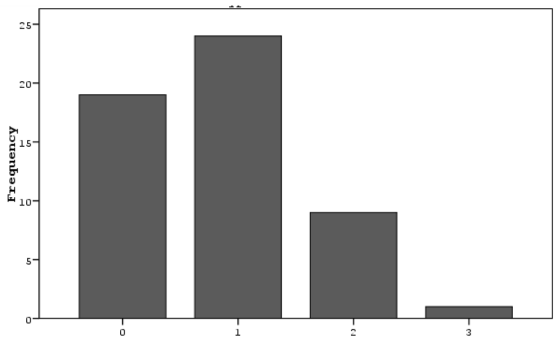
So far our work has shown that three abiotic types may exist in Cyprus, in terms of bringing forth a framework for type-specific baselines in bioassessment. Our investigation has shown that within these, assemblages of fishes can be grouped and classified. Seven rather distinctive and widespread fish biotic groups are apparent. Table 4.4 refers to these sites and the number catalogued after the statistical analyses (Classification, NMDS using Primer).

Table 4.4.

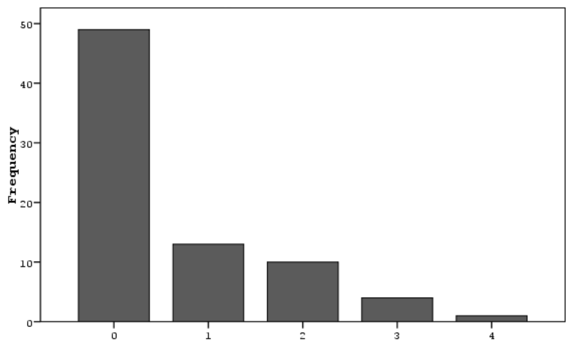
Biotic Group[10]	Generic Abiotic Stream Typology	Number of sites in Group	Characteristics
Brown Trout	*Mountain*	*14*	*Restricted to Mountain, usually Trout-only*
Rainbow Trout	*Mountain*	*11*	*Restricted to Mountain, usually Trout-only*
Lacustrine (Reservoir Fishes)	*Middle-course, Mountain*	*22*	*Widespread; often mono-species group (Rutilus); this changes very close to reservoirs Lake-fish type. Near reservoirs, usually in warmer middle-course segments more than one species present.*
Eel dominated	*Middle-course, Coastal*	*9*	*Few sites but characteristic –often inland in Middle-course sections.*
Mosquitofish dominated	*Mountain, Middle-course,*	*13*	*Often inland in Middle-course sections but also near-and in reservoirs in mountain areas. Usually mono-species.*
Non-eel dominated coastal sites (Aphanius dominated)	*Coastal*	*4*	*Rare. Aphanius often in high densities.*
Non-eel dominated coastal sites (Mugilid dominated)	*Coastal*	*6*	*Common; but probably only during wet years; mugilids in varying densities.*

[10] Biotic group is treated here analogous to fish community or ichthyocenoesis. The term biotic group is better than fish community since in this case limited proof of consistency or interrelations among abiotic and biotic parameters has been researched (see Zogaris 2009).

Mountain (=Salmonid)



Middle Course (=Non-salmonid)



Coastal (=Rivermouth)

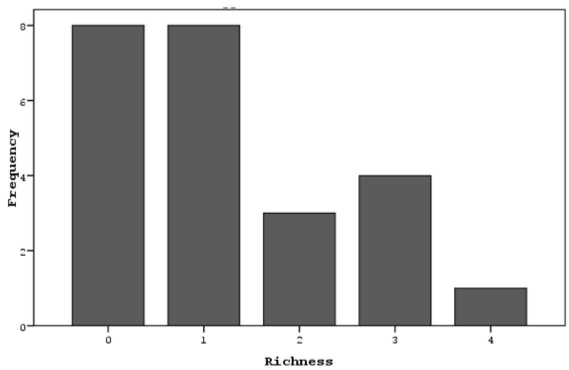


Fig. 4.9. *The number of sites (Y-axis) with regards to species richness per generic river type. Note that all three abiotic stream types had a very high frequency of sites with no fish. Especially the middle course type had very few sites with fish.*

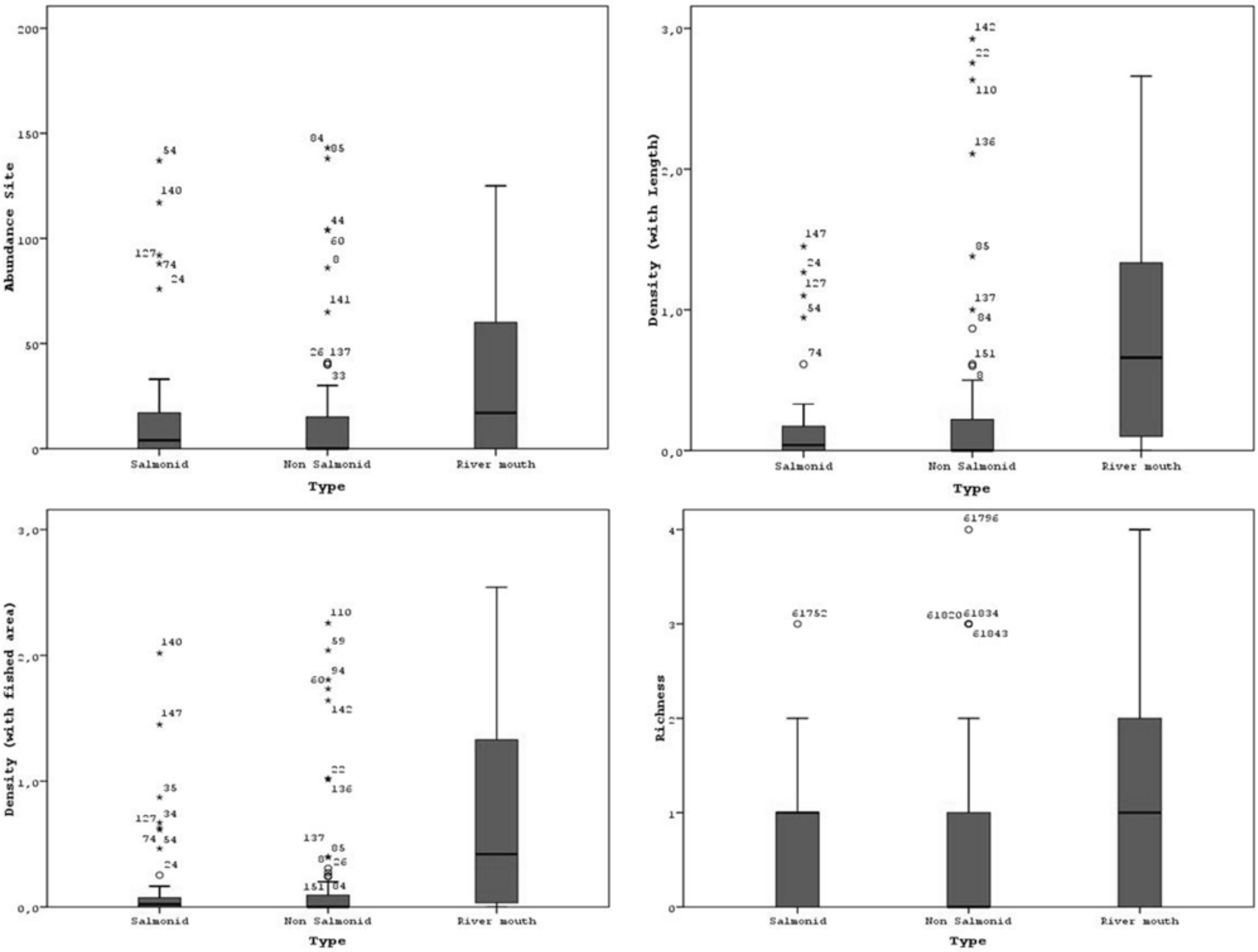


Fig. 4.10. *Abundance, Density (per stream length), Density (per fished area), and species richness in the three abiotic types (Mountain=Salmonid; Middle Course= Non-salmonid; Coastal = River mouth).Note again that the river mouth type is characteristically the richest for fish because of its connection to the sea creating a distinct biotic relationship with incoming euryhaline species.*

4.6. Analysis of pressures that effect fish attributes in Cyprus streams

Sixteen (16) pressure elements were collected for each site. Several of these pressures or anthropogenic stresses may affect fish in various ways. We developed a simple Site Quality Index to classify the degradation of these sites (for method see Angermeier & Davideanu, 2004).

Only 8 of these anthropogenic pressures where used to build our Site Quality Index that we judge is immediately appropriate for fish-based degradation procedure. These elements that we defined should be responsive to fish attribute in the Cyprus stream are categorized as:

- Morphological degradation,
- Hydrological degradation,
- Longitudinal discontinuity.

Chemistry and land-use data, although collected, were not included as there was a danger of confounding the summed index with the incorporation of more elements (pressure indicators).

Based on artificial substrate, embanked riverbank area, riparian degradation, and channelization a morphological factor assessment was created (Each of the four elements was scored from 1 to 3 – slight, moderate, severe condition; 3 applied to sites where degradation was above 50% while score 1 was below 10%). The four elements were summed to create one factor condition. The factor for each site ranged from 4 (highest quality) to 12 (lowest quality).

The hydrological factor was assessed with respect to two elements (flow pattern deviation and flow quantity deviation). Each element was scored from 1 to 3 – slight, moderate, severe condition; 3 applied to sites where degradation was above 80% while score 1 was below 50%). The scores of the two elements were summed to create one factor condition for each site. The factor for each site ranged from 2 (highest quality) to 6 (lowest quality).

Longitudinal discontinuity was assessed with respect to two elements (discontinuity upstream and discontinuity downstream). Each element was scored from 1 to 3 – slight, moderate, severe condition; 3 applied where a dam was present at a distance shorter than 5 km upstream while score 1 where a dam was present more than 10 upstream). The scores of the two elements were summed to create one factor condition for each site. The factor for each site ranged from 2 (highest quality) to 6 (lowest quality).

The SQI summed the final scores of the three factors (8=highest quality; 22 lowest quality). This gradient of degradation is to be useful when correlating or searching to find response of fish attributes to specific degradation categories (see below). Also the SQI helps define sites which may give best available references.

Type		N	Range	Minimum	Maximum	Mean	Std. Devia	Variance
SALMONID	Abundance Site	51	436,0	0,0	436,0	23,9	66,4	4409,7
	Density (with Length)	51	4,4	0,0	4,4	0,3	0,9	0,7
	Density (with fished area)	51	2,0	0,0	2,0	0,1	0,4	0,1
	Richness	51	3,0	0,0	3,0	0,9	0,8	0,6
	Abundance of alien species	51	436,0	0,0	436,0	23,8	66,4	4407,0
	Abundance of salmonids	51	92,0	0,0	92,0	7,8	18,2	330,1
	Abundance Salmo trutta	51	21,0	0,0	21,0	2,5	4,9	24,5
	Abundance eels	51	1,0	0,0	1,0	0,0	0,1	0,0
	Abundance of Salmonid below 10cm	51	87,0	0,0	87,0	3,6	14,4	207,2
	Morphological SQI	52	4,0	4,0	8,0	4,8	0,9	0,9
	Hydrological SQI	52	4,0	2,0	6,0	2,8	1,1	1,3
	Hydrological SQI DAMS	52	4,0	2,0	6,0	3,4	1,0	0,9
	TOTAL SQI SCORE	52	9,0	8,0	17,0	11,0	1,9	3,8
	Valid N (listwise)	51						
NON SALMONID	Abundance Site	75	1590,0	0,0	1590,0	90,8	283,2	80185,0
	Density (with Length)	74	15,1	0,0	15,1	0,8	2,5	6,5
	Density (with fished area)	72	13,3	0,0	13,3	0,5	1,7	3,0
	Richness	75	4,0	0,0	4,0	0,6	1,0	0,9
	Abundance of alien species	75	1506,0	0,0	1506,0	69,6	222,4	49477,2
	Abundance of salmonids	75	14,0	0,0	14,0	0,3	2,0	3,9
	Abundance Salmo trutta	75	0,0	0,0	0,0	0,0	0,0	0,0
	Abundance eels	75	15,0	0,0	15,0	0,3	1,9	3,5
	Abundance of Salmonid below 10cm	75	3,0	0,0	3,0	0,1	0,4	0,2
	Morphological SQI	77	8,0	4,0	12,0	6,1	1,8	3,1
	Hydrological SQI	77	4,0	2,0	6,0	3,6	1,5	2,2
	Hydrological SQI DAMS	77	4,0	2,0	6,0	3,7	1,0	1,1
	TOTAL SQI SCORE	77	14,0	8,0	22,0	13,4	3,0	9,3
	Valid N (listwise)	72						
RIVER MOUTH	Abundance Site	23	267,0	0,0	267,0	36,3	60,1	3608,5
	Density (with Length)	17	5,6	0,0	5,6	1,0	1,4	2,1
	Density (with fished area)	18	2,3	0,0	2,3	0,6	0,8	0,6
	Richness	23	4,0	0,0	4,0	1,1	1,4	1,9
	Abundance of alien species	23	30,0	0,0	30,0	1,6	6,3	40,0
	Abundance of salmonids	23	0,0	0,0	0,0	0,0	0,0	0,0
	Abundance Salmo trutta	23	0,0	0,0	0,0	0,0	0,0	0,0
	Abundance eels	23	7,0	0,0	7,0	0,8	1,8	3,1
	Abundance of Salmonid below 10cm	23	0,0	0,0	0,0	0,0	0,0	0,0
	Morphological SQI	23	7,0	5,0	12,0	7,2	1,7	2,8
	Hydrological SQI	23	4,0	2,0	6,0	4,4	1,6	2,4
	Hydrological SQI DAMS	23	2,0	2,0	4,0	2,7	0,8	0,6
	TOTAL SQI SCORE	23	10,0	10,0	20,0	14,3	2,7	7,4

Fig. 4.11. *Descriptive statistics in the three abiotic types (Mountain=Salmonid; Middle Course= Non-salmonid; Coastal = River mouth). The SQI elements of Morphological, Hydrological and Discontinuity (SQI DAMS) are given for each type.*

In Fig 4.11. the values of variance are very high especially for such characteristic attributes such as abundance. Variance in this table is shown as a measure of dispersion around the mean, equal to the sum of squared deviations from the mean divided by one less than the number of cases. The variance is measured in units that are the square of those of the variable itself.

4.7. Multi-dimensional statistics of relationships among parameters, sites and fish are analyzed using the programme CANOCO.

Detrended Correspondence Analysis, DCA on the biological data gave values of the length of gradients in the first axes of the ordination = 6.099 >3 showing a normal distribution therefore Canonical Correspondence Analysis (CCA) was chosen. CCA was applied independently using environmental parameters and anthropogenic pressure parameters. Utilizing the Monte Carlo permutation and the inflation factor specific environmental parameters and anthropogenic pressure parameters were chosen for the analyses.

Environmental parameters

From the available environmental parameters, distance to source, distance from mouth, height of source and upstream watershed % permeable substrate were utilized since all these parameters had p-values of <0,05 and an inflation factor of < 20. Table 4.5 provides coordinates of the environmental parameters in the two axes (the first axis being the most significant - distance from mouth- and the second the next most significant - distance from source).

Table 4.5. *Relations between the parameters and the axes through the CCA analysis*

	AX1	***AX2***
Distance to source	*0,501*	*0,253*
Distance to mouth	*-0,758*	*0,163*
Height of source	*-0,300*	*-0,090*
Upstream watershed % permeable substrate	*0,410*	*0,182*

The first two axes that were chosen for the plot in sum interpret the 11,7% of the biological data and 70,1% of the relationship between the biological data and the environmental parameters (Table 4.6)

*Table **4.6**. Results of the CCA analysis*

Axes	*I*	*II*	*III*	*IV*
Eigenvalues	*0,620*	*0.411*	*0.354*	*0*
Species-environment correlations	*0,845*	*0,705*	*0,703*	*0,363*
Cumulative percentage variance				
A) of species data	*7,0*	*11,7*	*15,7*	*16,6*
B) of species-environment relation	*42,1*	*70,1*	*94,1*	*100.0*
Test of significance of first canonical axis, P- value	*0,012*			
Test of significance of all canonical axes, P-value				*0,002*

The plot in Fig. 4.12 gives a graphical representation of the correspondence of the sites with the environmental parameters.

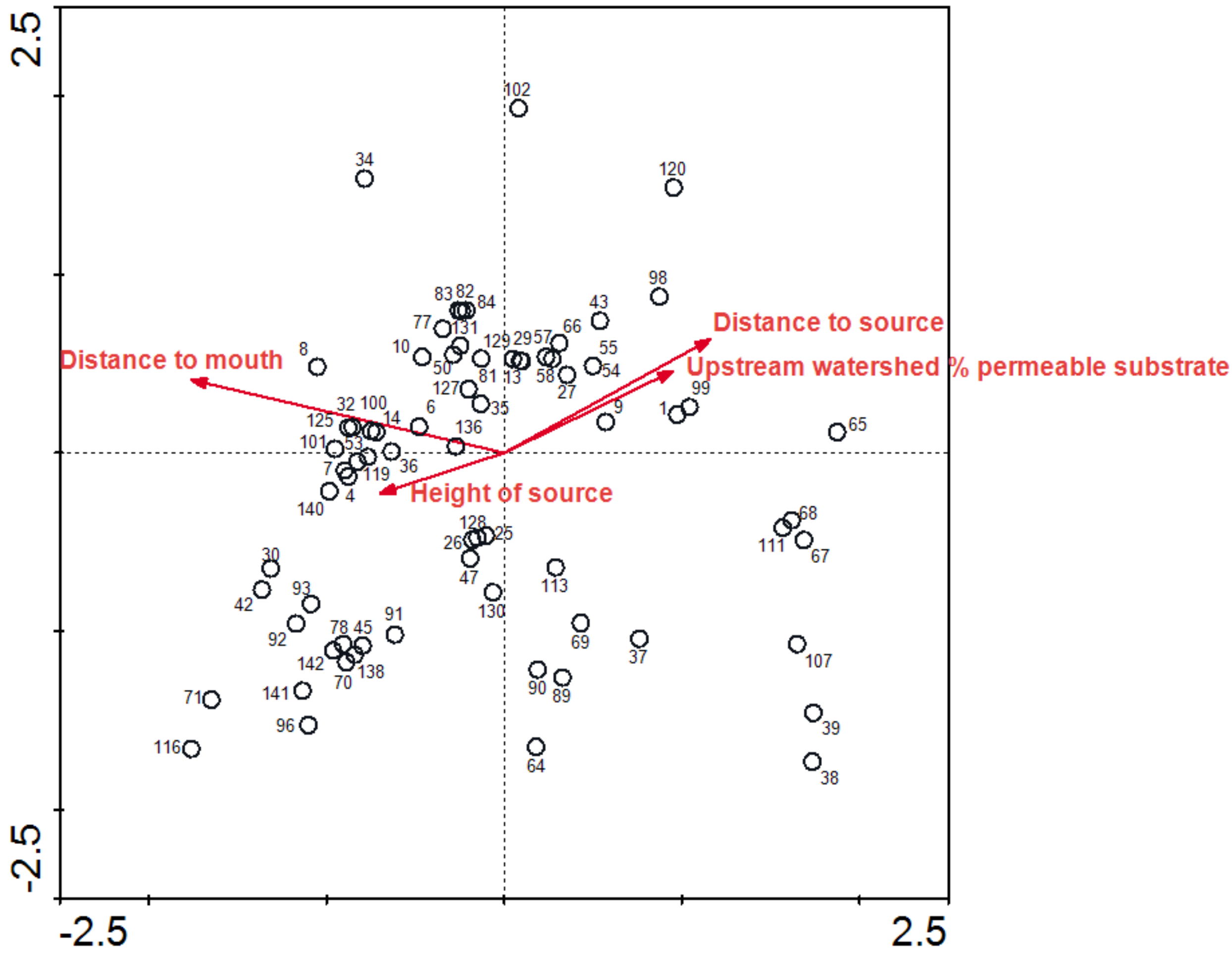


Fig 4.12. *Correlation plot of the sampling stations with the environmental parameters according to their influence in the biological data. The diagram shows that the river size parameters are important as are geological substrate and elevation of the source of the river. The sites are numbered and are available in the Appendix, Table A.3 (p. 200).*

The plot in Fig. 4.13 gives a graphical representation of the correspondence of the sites with the biological parameters (fish species populations and presence).

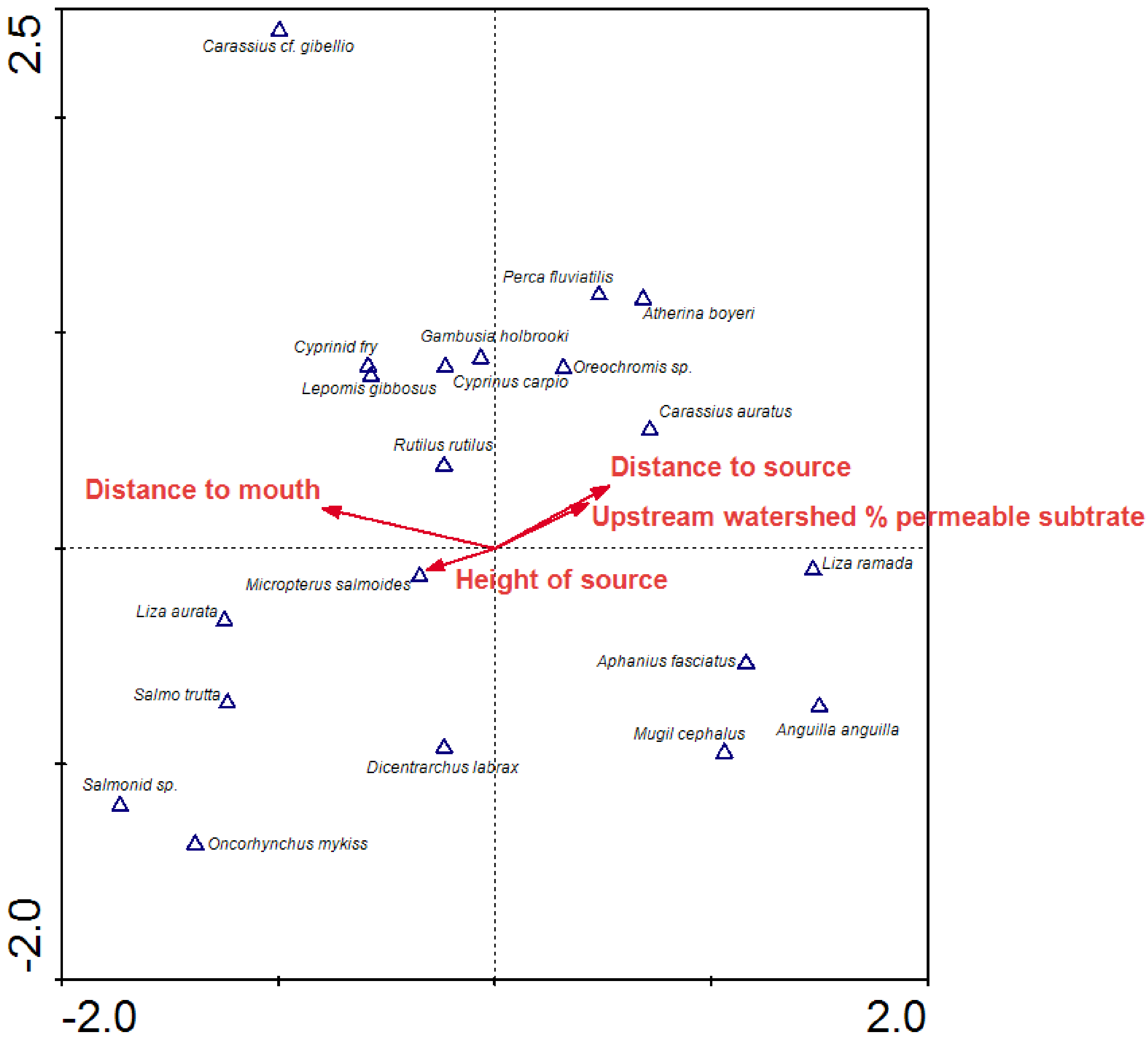


Fig. 4.13. *Diagram showing correlation graph of the biological data with the environmental parameters. Note that the "distance to mouth" helps define the species that are at low elevation (lower right part of plot); while "distance to source" and "upstream % permeable" - the geological substrate- separates the upland species (lower left) and lowland species (upper right).*

Anthropogenic pressures

With regard to the available anthropogenic pressures no parameter had p< 0,05 and therefore the ones that were chosen ware the ones with the lowest p values, and specifically "riparian degradation", "flow pattern deviation" και το "canalization". It should be said here that riparian degradation given as the % degradation of the riparian zone as assessed through the QBR index is a key indicator of riparian degradation and is easily and consistently defined for each site (and for the surrounding river segment at a broader scale as well). Flow pattern deviation (using the expert-based method devised by the

FAME group) is open to subjective inconsistency. Finally the canalization pertaining to channelized state of the river channel is also given in values of degradation based on optical assessment at each site and is a fairly consistent assessment.

Table 4.7 gives coordinates of the pressures in the two plotted axes. The first and most significant axis is “flow pattern deviation” the second, next most significant is “riparian degradation”. No p-values were significant but three parameters were retained.

Table 4.7. *Relations between the parameters and the axes*

Anthropogenic Parameter	***AX1***	***AX2***
Riparian degradation	*-0,183*	*0,324*
Canalization	*-0,151*	*-0,106*
Flow pattern deviation	*0,390*	*0,057*

The first two chosen axes for the CCA plot in sum account for 5.0% of the variation in the biological parameters and 82,9% of the relation of the biological data with the pressure parameters.

Table 4.8. .*Results of CCA analyses*

Axes	*I*	*II*	*III*	*IV*
Eigenvalues	*0,256*	*0,184*	*0,091*	*0,949*
Species-environment correlations	*0,620*	*0,512*	*0,420*	*0,000*
Cumulative percentage variance				
A) species data	*2,9*	*5,0*	*6,0*	*16,7*
B) species-environment relation	*48,2*	*82,9*	*100,0*	*0,0*
Test of significance of first canonical axis, P- value	*0,122*			
Test of significance of all canonical axes, P-value				*0,042*

Fig. 4.14. gives a graphical correspondence of the sites with the anthropogenic pressures.

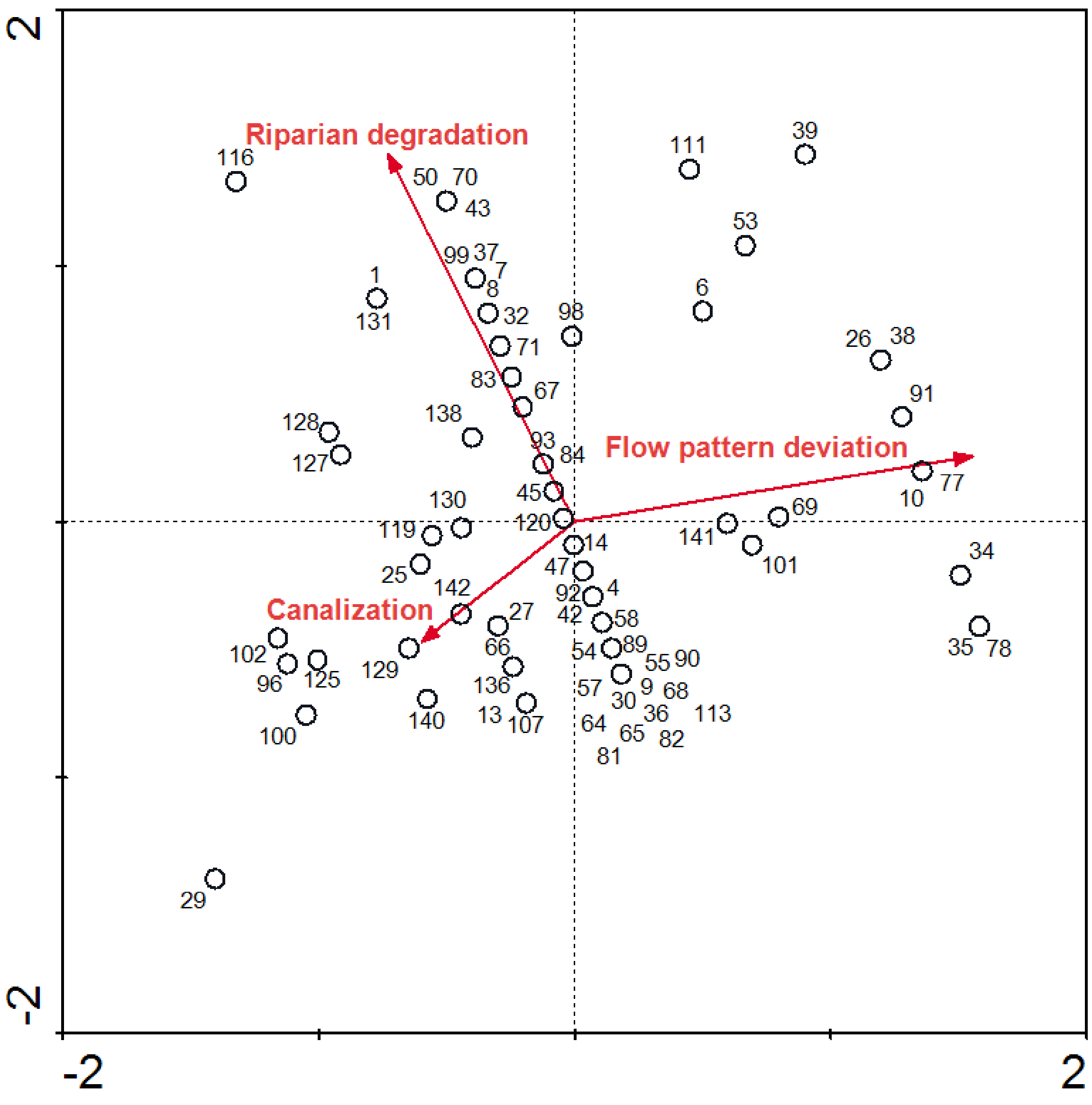


Fig.4.14. *Correlation graph of the sites with the anthropogenic pressures according to their influence in the biological data. Riparian degradation is shown to be an important measure. The points' numbers refer to the sites and are presented in the Appendix Table A.4 CANOCO (p. 201).*

In the Fig. 4.15 the biological parameters are given in relation to their distribution as influenced by the anthropogenic parameters.

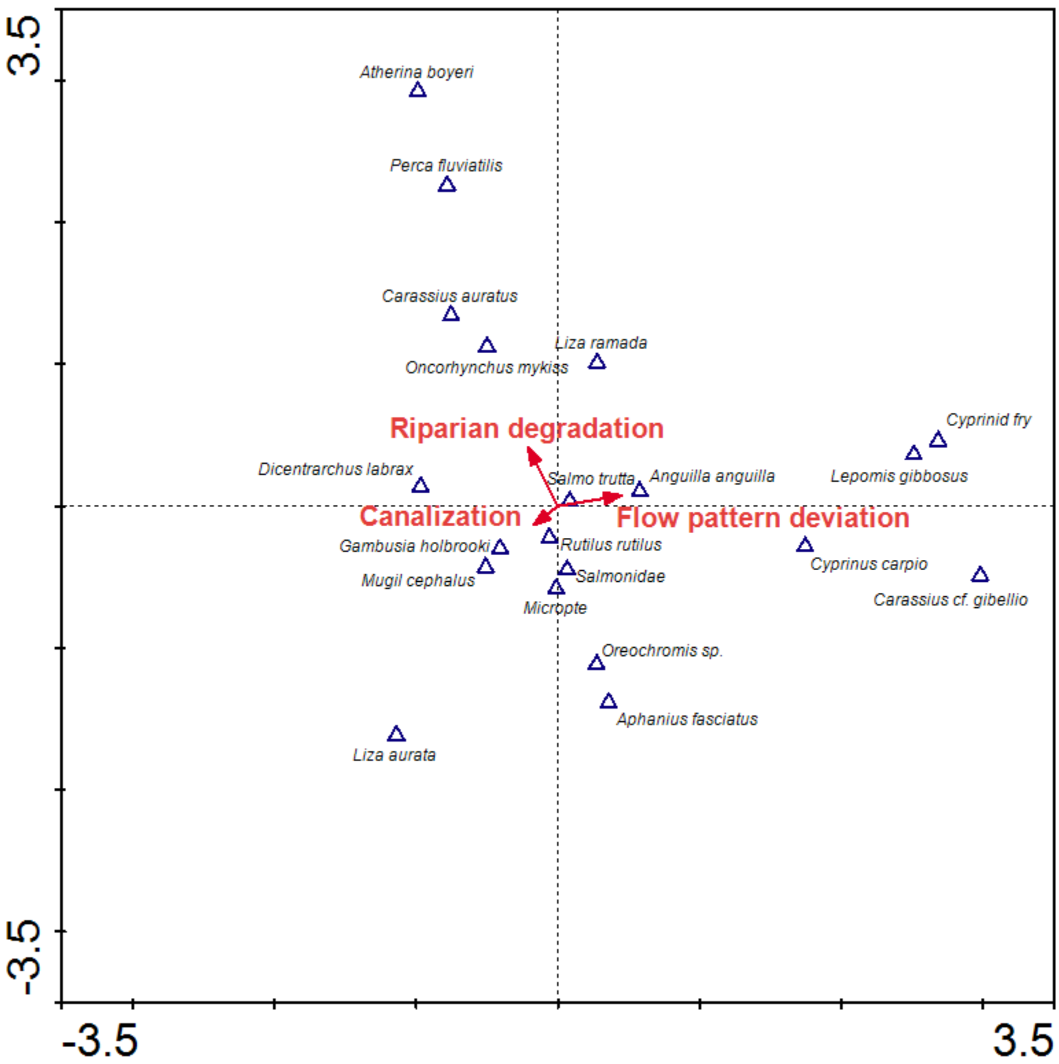


Fig. 4.15. *Correlation plot of the biological data with the anthropogenic pressures. No specific anthropogenic parameters seem to be to have a significant response to fish attributes. Perhaps minor aspects may be apparent (e.g. roach Rutilus rutilus with canalization). It must be noted that some sites had extremely few fish (e.g. one Liza aurata in only one site) therefore these discrepancies may distort the overall depictions.*

4.8. Exploring conditions in best available reference sites

If the SQI and the other pressures are summed giving a specific degradation measure for each site, the sites with the best scores can be clustered as best-available sites to explore patterns for reference conditions. Theoretically this can be done, however in Cyprus fish species are missing, very possible due to human impacts in the past, so this is difficult to apply correctly. Fig. 4.16 shows 25 sites which have a high degree of naturalness relative to the SQI scores and the other pressures as well (other pressures were exceedingly low in the sites that are shaded grey).

Site	Impoundment	Artificial sbstr	Embankment	Riparian degradation	Canalization	Road density	Flow pattern deviation	Flow quantity deviation	Discontinuity upstream	Discontinuity downstream	Impervious area %	Chemical classification	Irrigation UPSTRarea %	BOD	TN	TP	Type	TOTAL SQI SCORE	5-SCALE	
Agiasma	0,0%	0,0%	0,0%	20,0%	0,0%	1,9%	50,0%	50,0%	3	1	2,65%	GOOD	39,73%	37300,14	75412,85	2708,91	Salmonid	9	1	HIGH
Agios Avvakoum	100,0%	0,0%	30,0%	75,0%	0,0%	2,2%	90,0%	50,0%	3	4	0,00%	GOOD	18,87%	28679,03	18211,98	867,41	Non salmonid	9	1	HIGH
Ag Mamas Limnatis	0,0%	10,0%	30,0%	80,0%	50,0%	1,9%	90,0%	90,0%	4	0	0,00%	GOOD	20,45%	26457,31	16805,57	800,25	Non salmonid	13	3	MODERATE
Ag Maura	100,0%	0,0%	30,0%	65,0%	0,0%	3,0%	50,0%	50,0%	1	3	1,71%	GOOD	26,36%	90266,27	114949,60	4816,33	Non salmonid	14	3	MODERATE
Alonoui	0,0%	0,0%	30,0%	25,0%	0,0%	1,8%	50,0%	15,0%	0	0	3,52%	UNCLASSIFIED	5,59%	45027,67	22536,15	1169,15	Non salmonid	9	1	HIGH
d/sCedrus	0,0%	0,0%	0,0%	0,0%	0,0%	0,9%	50,0%	15,0%	0	0	0,00%	GOOD	0,00%	1039,30	12871,32	382,13	Non salmonid	9	1	HIGH
DiarMid	0,0%	0,0%	0,0%	60,0%	0,0%	1,9%	50,0%	15,0%	0	3	0,78%	GOOD	10,49%	417608,03	137685,31	6510,36	Non salmonid	10	2	GOOD
finifisheries	100,0%	10,0%	80,0%	20,0%	0,0%	1,5%	50,0%	15,0%	0	3	0,47%	GOOD	16,67%	110556,91	79673,28	3523,92	Non salmonid	11	2	GOOD
Garillis confluence	0,0%	0,0%	30,0%	30,0%	0,0%	0,9%	50,0%	15,0%	0	0	0,00%	GOOD	0,20%	2083,22	8521,66	264,30	Non salmonid	10	2	GOOD
Gef Roudias	0,0%	10,0%	0,0%	80,0%	0,0%	4,1%	50,0%	15,0%	0	0	0,91%	GOOD	3,35%	531,89	22485,59	632,00	Salmonid	10	2	GOOD
Gefelias	100,0%	0,0%	0,0%	80,0%	30,0%	3,8%	90,0%	90,0%	0	0	7,83%	GOOD	4,83%	18133,74	4463,23	194,94	River mouth	10	2	GOOD
Gerfyrka	0,0%	0,0%	0,0%	0,0%	0,0%	2,6%	50,0%	50,0%	1	2	1,30%	GOOD	12,42%	163773,27	153372,49	6003,98	Non salmonid	9	1	HIGH
Kakopetria Garillis	0,0%	0,0%	30,0%	80,0%	0,0%	4,6%	50,0%	50,0%	1	0	1,85%	GOOD	18,78%	401451,12	246651,83	9244,60	Non salmonid	10	2	GOOD
Kalidonia trailhead	0,0%	0,0%	0,0%	55,0%	0,0%	4,8%	50,0%	50,0%	1	0	1,95%	GOOD	18,95%	416530,85	252925,23	9429,29	River mouth	9	1	HIGH
Katgerakies	0,0%	0,0%	0,0%	0,0%	0,0%	1,9%	90,0%	50,0%	0	1	0,00%	GOOD	0,00%	1620,28	2395,30	63,35	Salmonid	10	2	GOOD
Mesa potamos Kouri	0,0%	0,0%	0,0%	10,0%	0,0%		0,0%	20,0%	0	0	2,49%	GOOD	0,00%	11450,72	9944,17	396,79	Non salmonid	10	2	GOOD
Mesopot_katgef	0,0%	0,0%	50,0%	60,0%	0,0%		60,0%	70,0%	3	0	0,05%	GOOD	2,67%	22529,23	31062,29	904,45	River mouth	10	2	GOOD
Moutoulas	0,0%	0,0%	100,0%	85,0%	100,0%		100,0%	95,0%	5	2	0,00%	GOOD	23,26%	26969,46	14968,82	545,16	Non salmonid	12	2	GOOD
Panagia Diakou Agia	0,0%	0,0%	0,0%	65,0%	0,0%		40,0%	40,0%	0	0	3,69%	GOOD	23,42%	909208,69	112246,05	6422,88	River mouth	12	2	GOOD
Pareklissoudi	0,0%	0,0%	0,0%	80,0%	0,0%		100,0%	100,0%	1	0	0,00%	GOOD	0,00%	0,00	0,00	0,00	River mouth	9	1	HIGH
Spilia	100,0%	10,0%	0,0%	30,0%	0,0%	3,5%	50,0%	50,0%	1	3	1,47%	GOOD	19,02%	123618,28	57177,78	3274,44	Non salmonid	9	1	HIGH
Stenoi	0,0%	0,0%	0,0%	0,0%	0,0%		5,0%	5,0%	0	3	0,00%	GOOD	0,00%	0,00	0,00	0,00	Salmonid	9	1	HIGH
Two bridges	0,0%	0,0%	0,0%	10,0%	0,0%		20,0%	30,0%	2	2	4,71%	GOOD	44,45%	11647,23	20967,02	748,39	Salmonid	10	2	GOOD
Vrachos	100,0%	0,0%	0,0%	15,0%	0,0%		30,0%	30,0%									Salmonid	9	1	HIGH
Xeros_up	0,0%	0,0%	0,0%	65,0%	0,0%	4,4%	90,0%	90,0%	3	0	0,93%	GOOD	13,22%	738737,98	190628,87	8538,28	River mouth	10	2	GOOD

Fig. 4.16. *Pressure characteristics of anthropogenic pressures of the least impacted sites in the data set. SQI elements and other pressure elements such as chemical pollution are utilized. The shaded site names are the ones that are least impacted without the SQI scores.*

SITES WITH ALL SALMONIDS							
Descriptive Statistics							
	N	Range	Minimum	Maximum	Mean	Std. Devia	Variance
Abundance Site	25	138,0	0,0	138,0	21,2	33,9	1151,3
Density (with Length)	25	1,1	0,0	1,1	0,2	0,3	0,1
Density (with fished area)	25	0,6	0,0	0,6	0,1	0,2	0,0
Richness	25	3,0	0,0	3,0	1,2	0,6	0,4
Abundance of salmonids	25	92,0	0,0	92,0	15,7	23,7	561,1
Abundance of non salmonids	25	130,0	0,0	130,0	5,5	26,0	674,0
Abundance Salmo trutta	25	21,0	0,0	21,0	5,0	6,1	37,7
Abundance of Salmonid below 10cm	25	87,0	0,0	87,0	7,2	20,1	404,7
Abundance eels	25	1,0	0,0	1,0	0,0	0,2	0,0

SITES WITH SALMO TRUTTA							
Descriptive Statistics							
	N	Range	Minimum	Maximum	Mean	Std. Devia	Variance
Abundance Site	15	137,0	1,0	138,0	17,7	33,9	1150,1
Density (with Length)	15	0,9	0,0	1,0	0,1	0,2	0,1
Density (with fished area)	15	0,5	0,0	0,5	0,1	0,1	0,0
Richness	15	2,0	1,0	3,0	1,3	0,7	0,5
Abundance of salmonids	15	20,0	1,0	21,0	8,9	6,5	42,1
Abundance of non salmonids	15	130,0	0,0	130,0	8,8	33,5	1124,3
Abundance Salmo trutta	15	20,0	1,0	21,0	8,3	5,9	34,8
Abundance of Salmonid below 10cm	15	8,0	0,0	8,0	1,4	2,8	7,8
Abundance eels	15	1,0	0,0	1,0	0,1	0,3	0,1

Fig. 4.17. *The conditions of the fish attributes with the least impacted sites after the scoring process to identify sites for developing reference conditions.*

Note in Fig 4.17 that selected best-available reference sites with Brown (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) show some important differences. Variance values are higher in the Brown Trout biotic group; abundance is significantly lower in Brown Trout as well. Perhaps these differences reflect the fact that in certain sampling stations with Rainbow Trout, stocking (or releases from trout farms) have created much anthropogenic variability.

4.9. Exploring correlations among fish attributes (potential metrics) and anthropogenic pressures

When graphed, responses of biotic elements to anthropogenic pressures are a good way to screen for biological responses to environmental degradation. Graphs of correlations may reveal the biological responses important for evaluating metrics. However, statistical correlation can miss an important relationship if the x-variable (i.e. showing gradient of degradation) is measured with low precision or if additional factors beyond those plotted on the x-axis influence the biotic attribute (or metric) values but are not included in the statistical analysis (Karr and Chu 1999). Graphs highlight idiosyncrasies in data distributions; when these are examined closely they may provide insight into the causes of particular biological pattern. Even the spread of the data points can offer insights and illustrate variation. However it is important to remember the correlation measures association and not causation. Obviously not all aspects of human influence (degradation) can be easily captured in a single graph or statistical test.

Here all attributes that were conceived as potential metrics to the pressures impacting the sampled sites were screened. In this case, bivariate observations of our biotic variables and our anthropogenic degradation (measured in ordinal or interval scales) are displayed as scattergrams. This simple dot-diagram gives an immediate and useful indication of whether a sample of observations is roughly symmetrically distributed about a mean and the extent of variability. When an increase in one variable is accompanied by the other the correlation is said to be positive (and vice versa). In this case we present the correlation coefficient of (r) as an index of the degree to which two variables are related. The numerical value of the correlation coefficient, (r), falls between +1 and -1; a correlation of 0 or near 0, indicates a lack of correlation.

The following 10 fish-based attributes from the sampling are used to assess the relationship to anthropogenic pressures through their response to degraded site state:

- Abundance of alien species
- Abundance of Salmonids
- Abundance of Non-Salmonids
- Abundance of *Salmo trutta*
- Proportion of lacustrine species
- Abundance of Salmonid YOY
- Abundance of Eels
- Presence of Eel
- Abundance of native species of marine origin
- Age structure of native fish and naturalized brown trout populations

We have arbitrarily chosen to show graphs with a correlation coefficient that is larger than 0.005 in the following graphs; all others below this very weak correlation value are not shown. Generally anything below 0.19 is considered a very weak correlation in ecological studies (Fowler & Cohen 2000). We present these correlations in scatter plots and the fish attributes (potential metrics) with the anthropogenic gradient of degradation (on x-axis, the more degradation scale varies from high on left to bad at right).

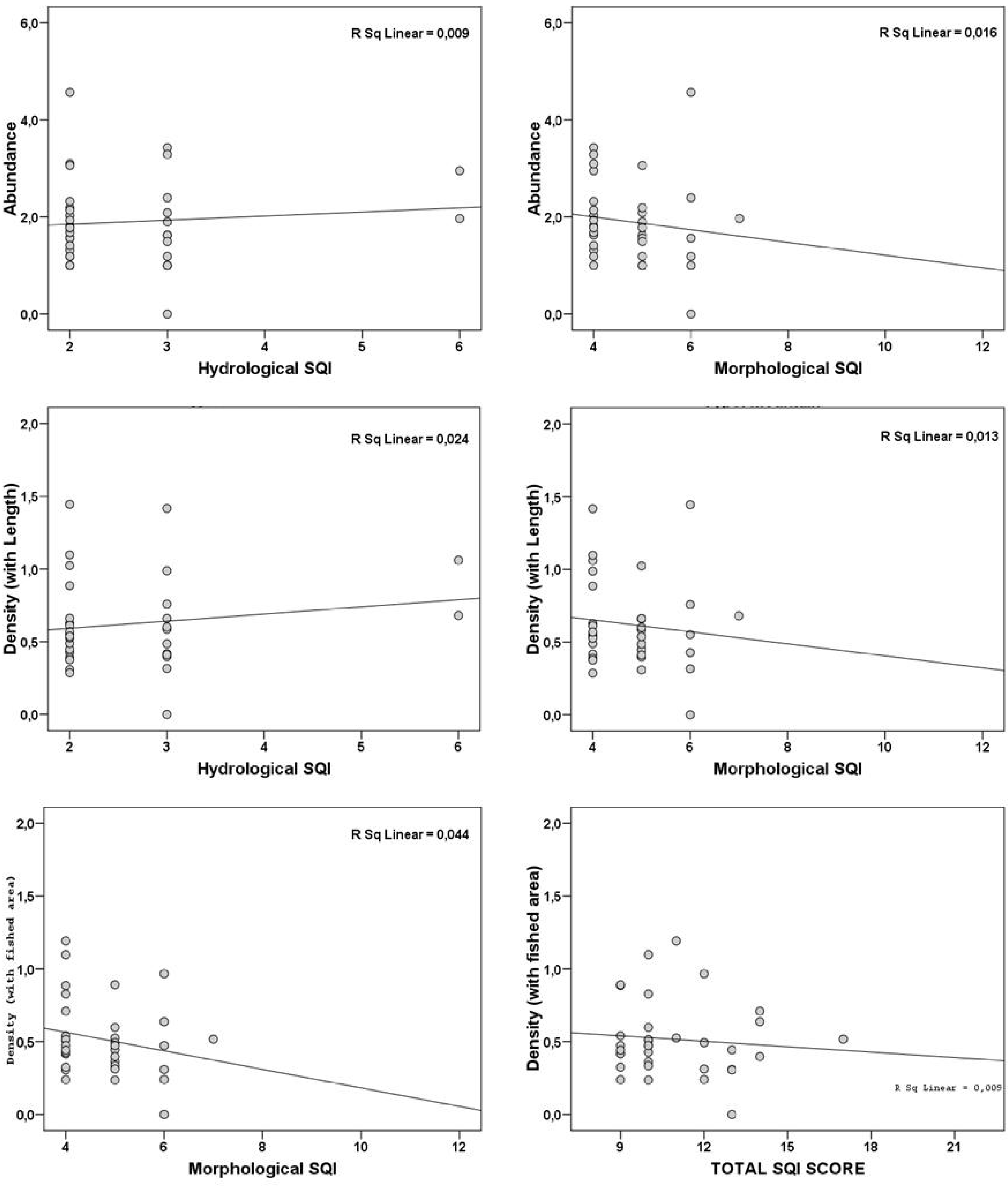


Fig. 4.18. *The abundance attribute of fish in* ***mountain river type*** *(Site Quality Index gradient shown on x-axis). A very weak negative correlation is shown by density and morphological degradation (bottom left) also slightly apparent when abundance is used (top right).*

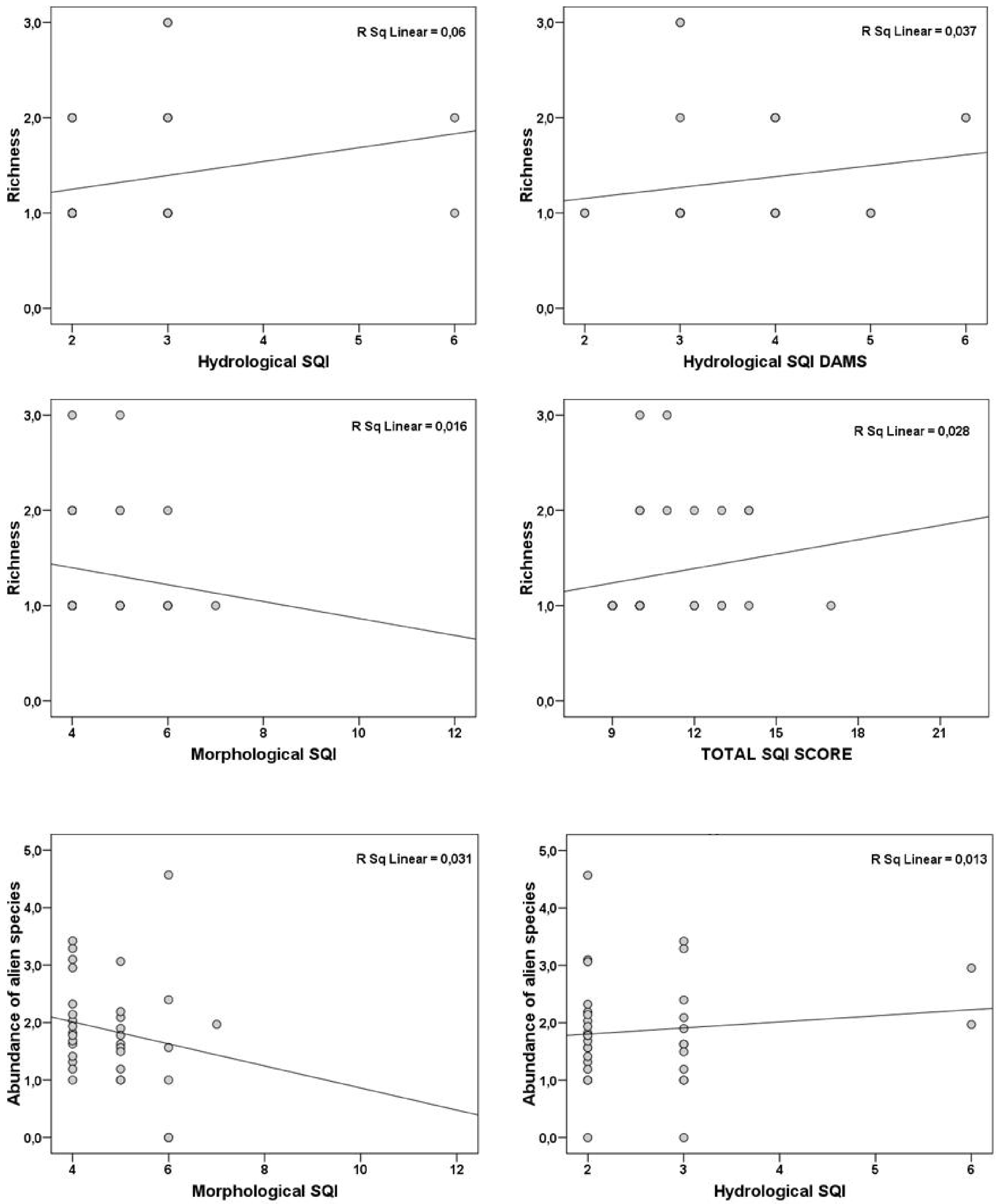


***Fig. 4.19** The species richness and abundance of alien fish in **mountain river type**. A very weak positive correlation is shown in relation to hydrological condition, dam presence (top) and total (middle right). A very weak negative correlation is apparent in relation to both richness and abundance of alien species with regards to morphological degradation (middle left; bottom left).*

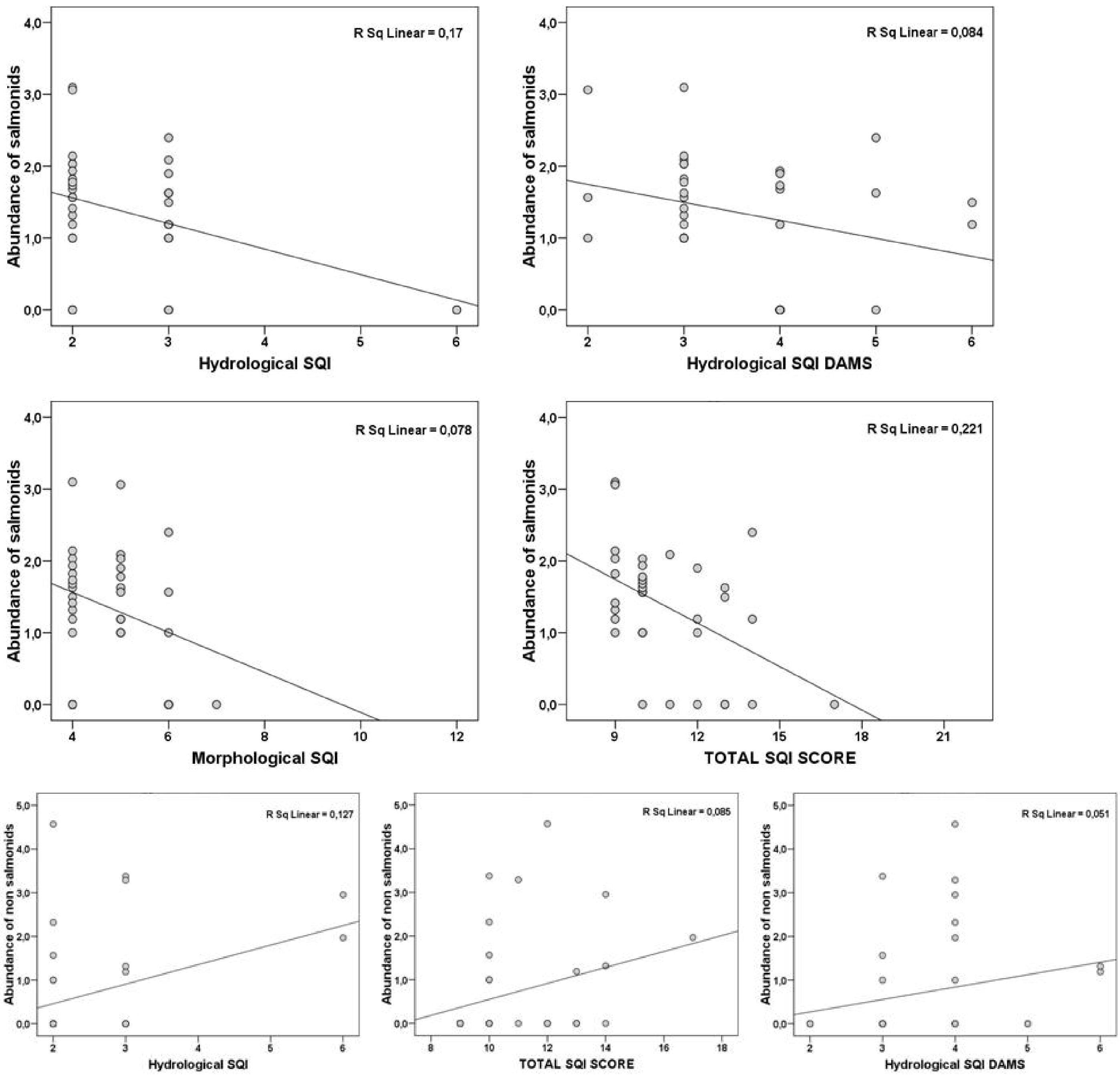


***Fig. 4.20** The abundance salmonids were considered one of the most favourable potential metrics in the **mountain river type**. A very weak negative correlation is shown in relation to total SQI score and this is supported by the constituent elements of the index (graphs in middle-left and top). A very weak positive correlation is apparent when abundance of non-salmonids is provided as intuitively expected (bottom graphs).*

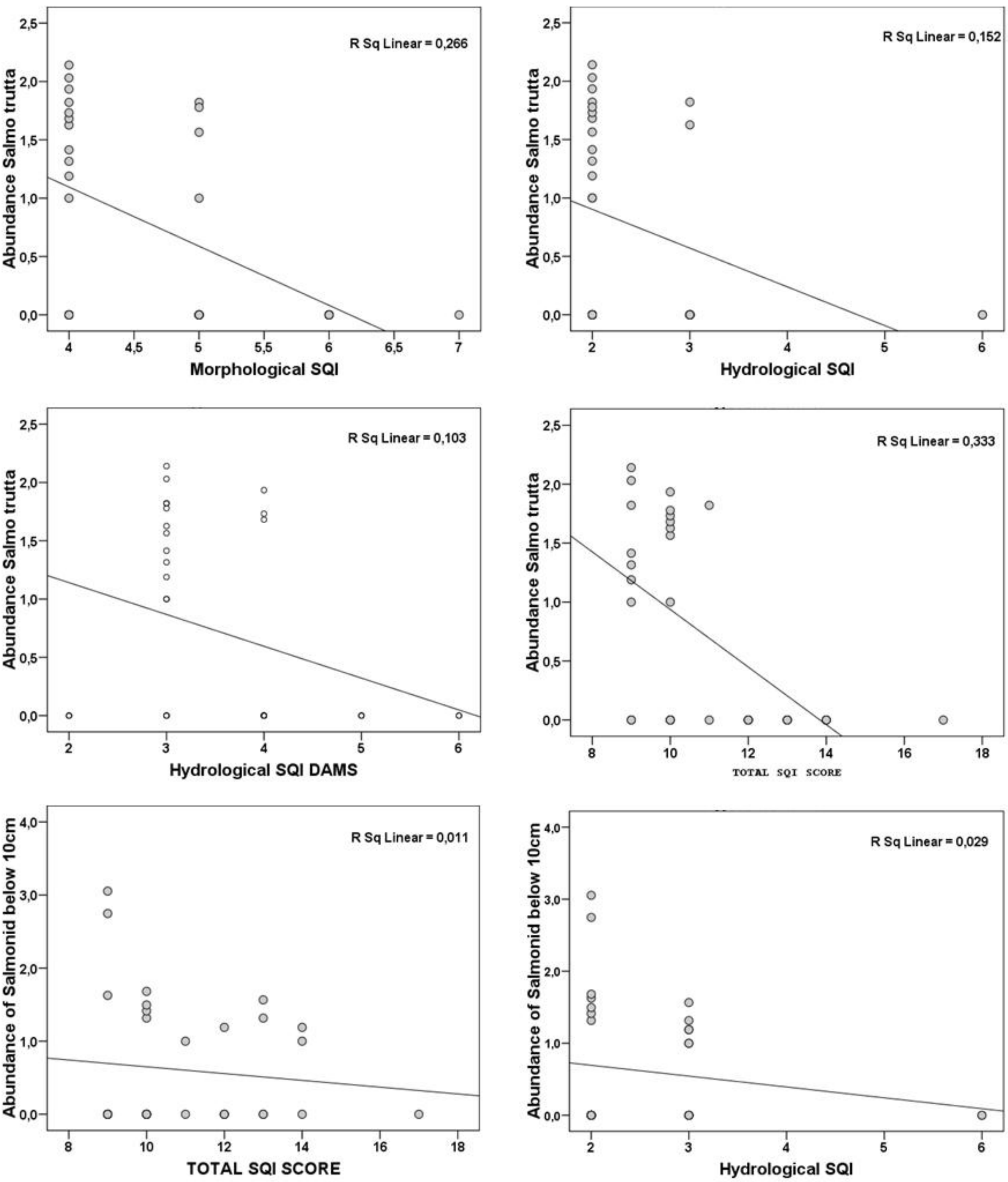


Fig. 4.21. *Salmo trutta was also considered one of the most favourable potential metrics in the* ***mountain river type****. The only modest negative correlation in these tests is seen in the middle-right graph were the abundance of Salmo trutta given against the total SQI (and this is corroborated by the constituent index elements). The abundance of YOY or very young salmonids gives a very week correlation but is negative as to be expected (bottom graphs).*

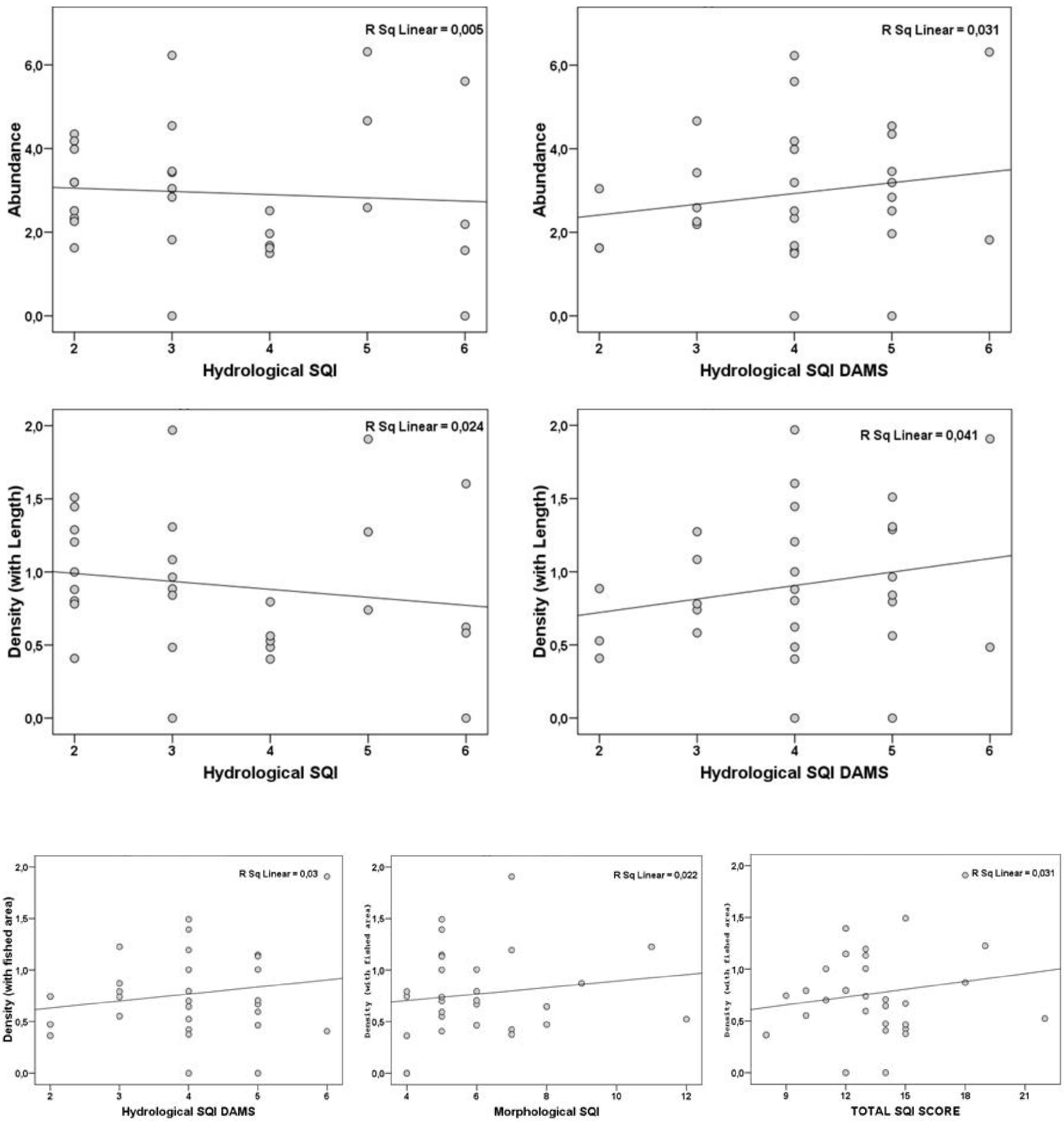


***Fig. 4.22. Middle course river type** showed very poor responses to fish attributes and this is expected due to the great variation values the sampling gave here. We expected that the density of the fish would be correlated positively with increasing dams (this is shown in the middle right graph but the correlation is very weak). This "pressure" (i.e. the dams as refuges for fish) is countered by the degraded surface water conditions (middle right graph).*

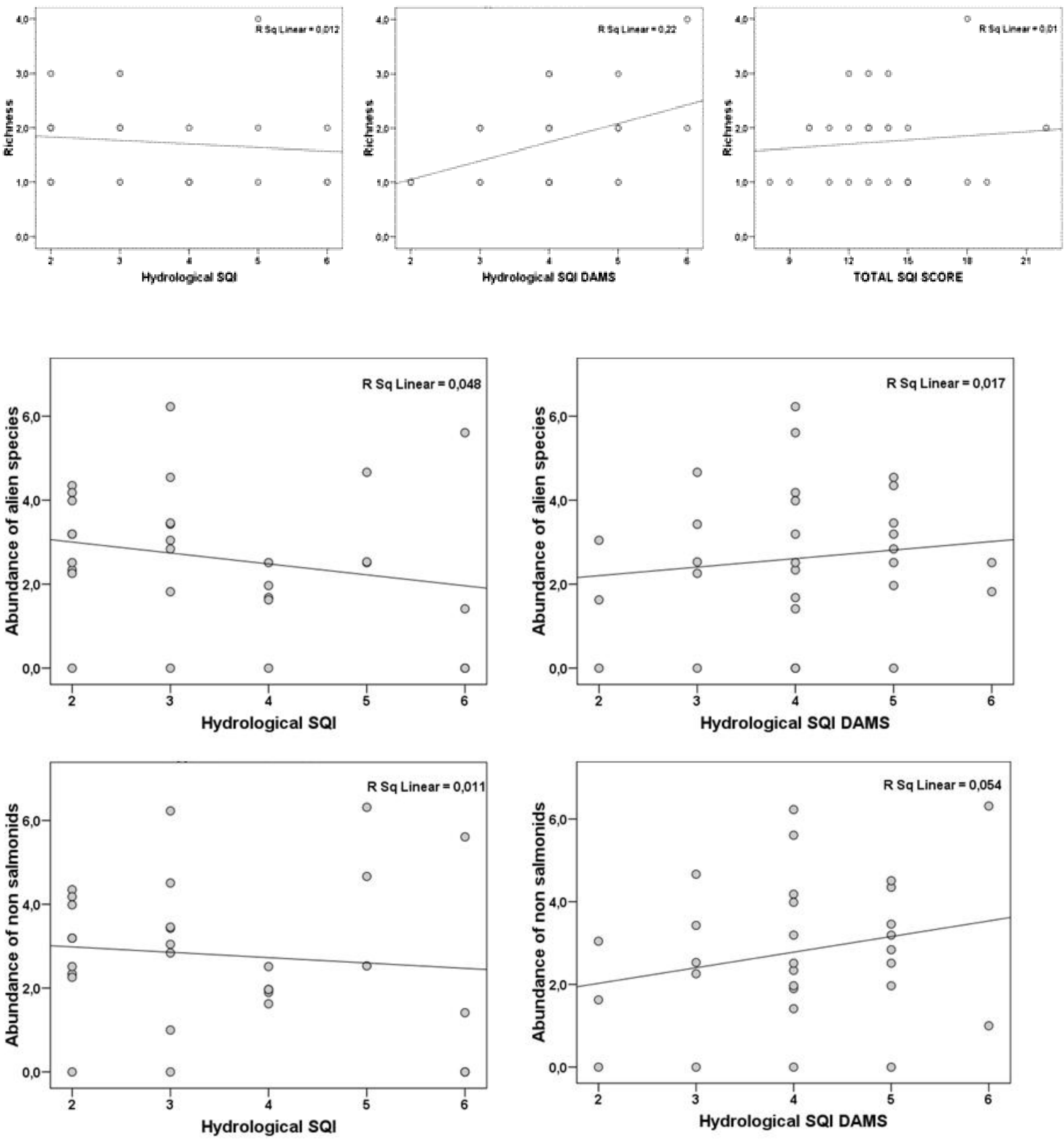


Fig. 4.23. *Fish attributes reacted with positive and negative responses to hydromorphological pressures in the* ***Middle course river type.*** *One of the most expectant attributes pertains to the species richness with increasing dam degradation, and this gives a very week positive correlation in the upper middle graph. In comparison with the mountain river type, depicted correlations are fewer and values are weaker.*

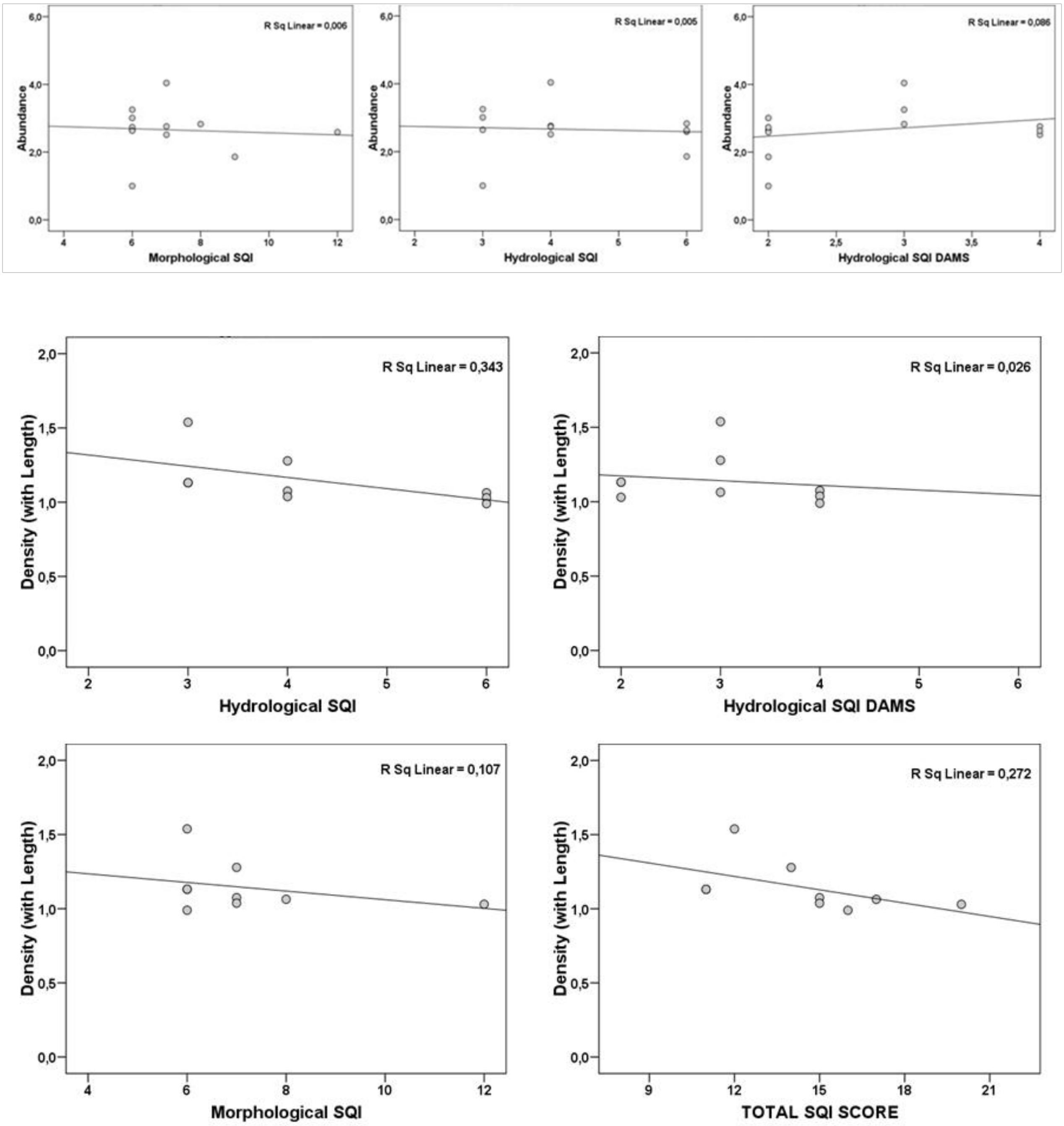


***Fig. 4.24. River mouth type** showed very poor responses to fish attributes and this are expected due to the difficulty of depicting pressures at these very degraded sites. Great variation of values in the sampling of the fish also existed here. We expected that the density of the fish would be correlated negatively with increasing degradation (this is shown in most graph but the correlation is very weak). This “pressure” of dams upstream (i.e. the dams as refuges for fish) should give a positive correlation as depicted in the top right graph. It should be mentioned that relative to the other types, river mouth had a much smaller number of sites as well; this increases the likelihood of a spurious correlation arising by chance.*

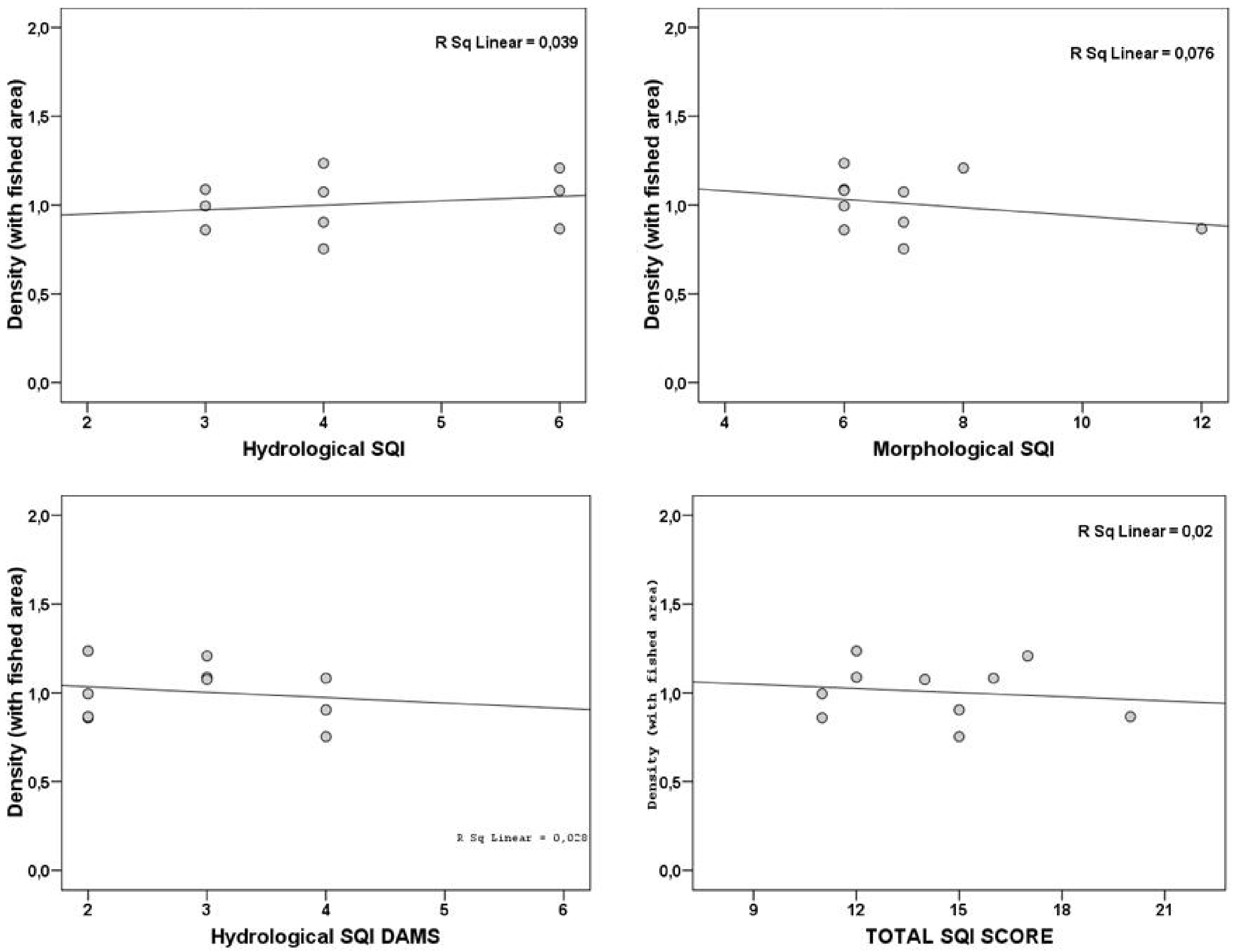


Fig. 4.25. *Fish attributes reacted with positive and negative responses to hydromorphological pressures in the* ***River mouth type,*** *correlation were extremely weak.*

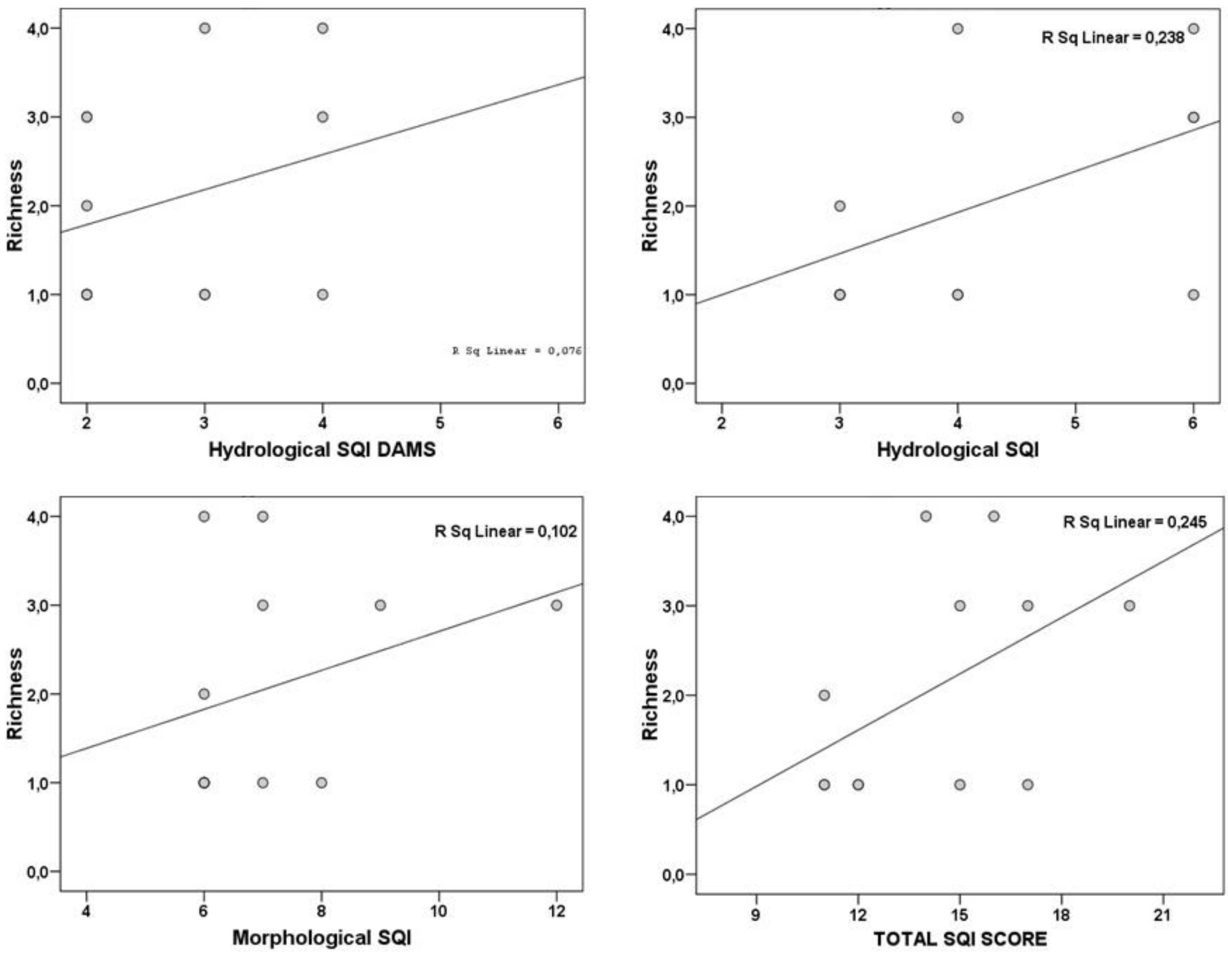


Fig. 4.26. *Fish attributes such as species richness reacted with positive very week response to hydrology and morphology; this trend would be expected in* ***River mouth type.***

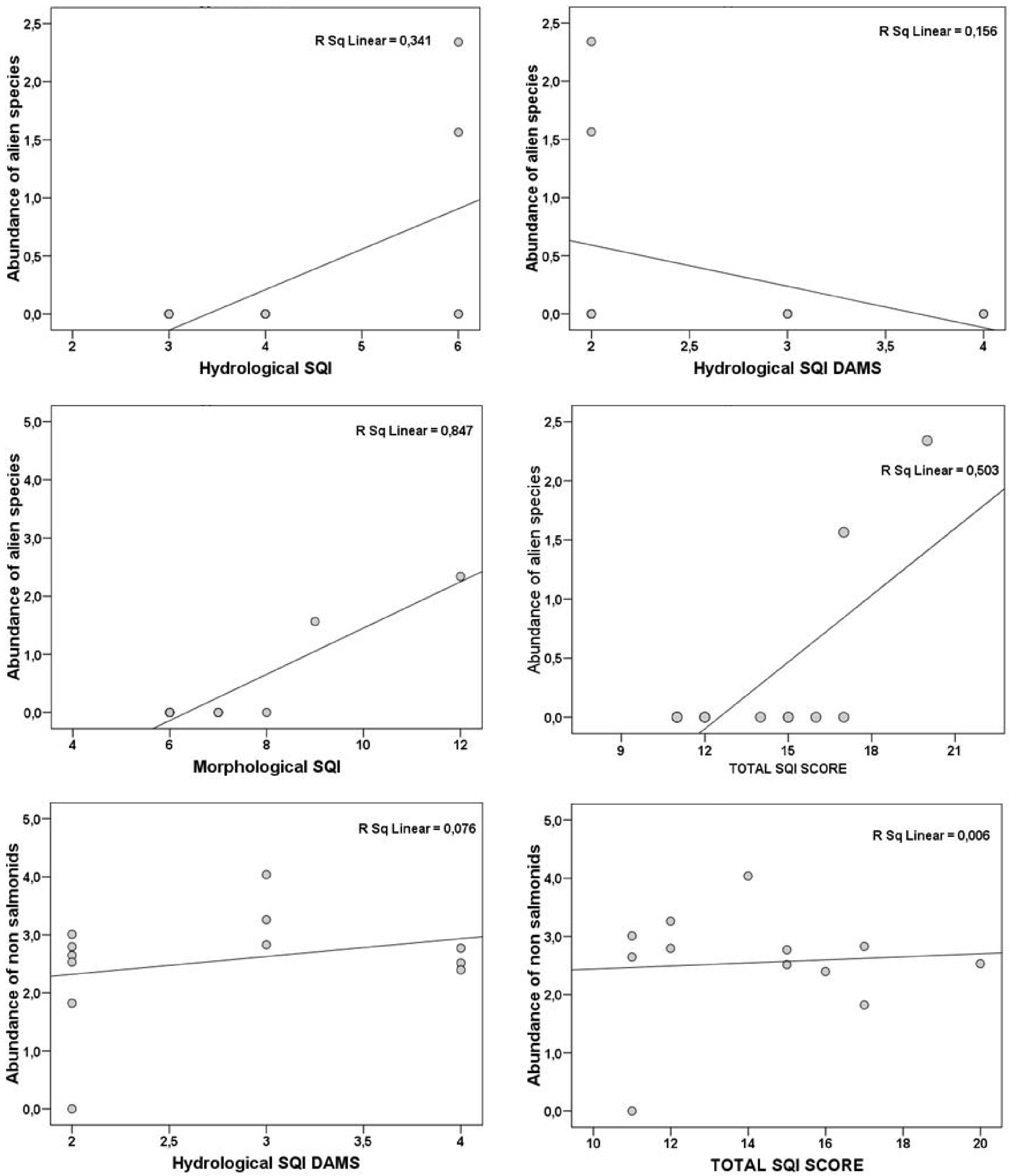


Fig. 4.27. *Some attributes cannot be useful but they were all graphed and inspected. Interestingly very few alien species were located in the **river mouth type**. As expected alien numbers should increase with degraded hydrology (graph top left) and this shows well when full SQI gradient is provided (Middle right graph). However, in this case the low number of sites and variability of values may still create spurious correlations.*

The correlation analysis above illustrates the following points:

- The mountain type river environment had more potential metrics that responded to environmental degradation
- Salmonids may react very weakly but the expected trend in their reaction to degradation holds.
- Brown trout was found in rather good-quality sites and this incidentally shows a response to degradation; however this is expressed weakly.
- The Eel metrics (presence, abundance, size-classes) did not produce any significant correlation. This is because the lowland areas where the species was found are all heavily impacted and the degradation measure of pressures does not precisely give micro-habitat conditions that may affect Eel distribution at a finer scale. Eels were also located at very few sites during sampling (14).
- The Eel is scarce; and lives very cryptically (sampling problems confound the results since many high-conductivity sites which are known to have Eel could not be effectively eleectrofished). Eels are survivors – they can persist in polluted water but need the adequate habitats, rich foodwebs, summer refugia, and connectivity to the sea. The existence of eel may not give a holistic sense of stream integrity but it does give a signal of functioning hydrological, morphological conditions in perennial streams. This alone makes the eel a potential bioindicator of natural in-stream morphology and longitudinal connectivity.
- The specific precision assessed by the degradation of each site is difficult to estimate; in some types of pressure this is more objectively estimate than in others.
- Many of the pressure elements may conflict in terms of eclipsing the effect of degradation. For example, dams firstly may provide refuge for alien species, or may provide water downstream for aliens but conversely they may block fish movement and may starve streams of water downstream during droughts. The connectivity degradation given by the specific measure (i.e. distance from site) does not express these complexities.
- Generally, and as expected, variation among the examined fish-based variables and their distribution among different degraded sites is extremely high in Cyprus. The river environments of the coastal and middle course types are much degraded and it is difficult to assess relative degradation with precision especially with respect to so few fish species.

4.10. The geography of fish acting as potential bio-indicators

The work we have done so far has shown that naturalized salmonids, the Eel and perhaps some marine fishes of the coastal river mouths may act as bioindicators in streams. Bioindicators are elements or attributes of the ecosystem that can be directly measured to give signals or act as surrogates describing the broader conditions and/or resources of the ecosystem. Using the term bioindicator loosely would mean that these species tend to react well to environmental and anthropogenic parameters that influence the aquatic-river corridor environment. A list of the specific attributes of each fish species is given in Table 4.8.

Table 4.8. *Ecological guild categorization of extant confirmed fish species.*

Confirmed Fish Species	*Ecological guild categorization of extant confirmed fish species.*
Alburnus alburnus	*Wide-temperature tolerance; lacustrine; water column feeder; planktonic/omnivorous feeder; phytolithophilic reproduction; short-distance migrant; short-lived.*
Anguilla anguilla	*Wide-temperature tolerance, eurytopic; piscivorous/omnivorous; benthic feeder; Marine reproduction; Long-distance migrant; Long-lived.Migratory sexual segregation; females longer lived travel further upstream and are larger-bodeid than the males.* ***[Requires river-to-sea longitudinal connectivity; summer refugia in intermittent streams].***
Aphanius fasciatus	*Warm-water species; slow flowing/no flow and euryhaline; Planktonic/ insectivore; surface and water column feeder; short-distance migrant, short-lived. [****Sensitive to competition by Gambusia holbrooki, tolerant of very high water temperatures; high salinity****]*
Atherina boyeri	*Wide-temperature tolerance, marine and transient euryhaline; water column feeder; planktonic/omnivorous feeder; marine reproduction; short-distance migrant; short-lived. Frequently enters freshwaters in Mediterranean islands and is known to reproduce in isolated freshwaters/brackish waters also.*
Abramis bjoerkna	*Wide-temperature tolerance, eurytopic, benthic feeding habitat; benthivore; lithophilous reproduction; medium-distance migrant; long-lived. Not as adaptive and wide-niche ability as Roach (Rutilus rutilus).*
Carassius auratus	*Wide-temperature tolerance, eurytopic, benthic feeding habitat; benthivore; phytophilous reproduction; medium-distance migrant; long-lived. [****Pollution tollerant; highly invasive in stagnant and lacustrine conditoins****].*
Cyprinus carpio	*Wide-temperature tolerance, eurytopic, benthic feeding habitat; benthivore; phytophilous reproduction; medium-distance migrant; long-lived. [****Pollution tollerant****].*
Dicentrarchus labrax	*Wide-temperature tolerance, eurytopic, benthic and water column feeding habitat; marine reproduction; medium-distance migrant; long-lived.* ***[Most fish in Cyprus are alegedly escapees from fish farming operations].***
Gambusia holbrooki	*Warm-water species; eurytopic but not rheophilous; insectivore/invertivore; viviporous reproduction;short-lived.* ***[Highly invasive; detrimental to other small-sized fish and invertebrates; pollution tolerant; poor disperser].***

Ictalurus punctatus	*Warm-water tolerance; eurytopic, benthic feeder; piscivorous/omnivorous short-distance migrant; long-lived.*
Lepomis gibosus	*Warm-water/wide temperature range tollerance; eurytopic but not rheophilous; insectivore/invertivore/piscivorous; wide reproduction conditions ;short-lived.* ***[Highly invasive; detrimental to other small-sized fish and invertebrates; perhaps poor disperser due to lacustrine habitat].***
Micropterus salmoides	*Warm-water/wide temperature range tollerance; eurytopic; insectivore/invertivore/piscivorous; wide reproduction conditions ;long-lived.* ***[Highly invasive; detrimental to other small-sized fish, invertebrates, aquatic vertebrates].***
Mugil cephalus	*Wide-temperature tolerance, marine and transient euryhaline; water column and benthic feeder; planktonic/omnivorous and phytophagous feeder; marine reproduction; medium-distance migrant; long-lived.*
Oncorhynchus mykiss	*Cold-water tolerance; rheophilous; water-column feeder; long-distance potamodromous migrant; insectivore/invertivore/piscivorous; lithophilous reproduction; long-lived.* ***[May compete with naturalized Brown Trout and may feed on other fish etc; intolerant of severe water pollution]****.*
Oreochromis aureus	*Warm-water tolerance only; lacustrine and in canals; water column and benthic feeder; insectivorous/invertivorous;omnivorous; short-distance migrant; long-lived.* ***[Intollerant of cold-water conditions].***
Perca fluviatilis	*Wide-temperature tolerance, eurytopic, benthic and water column feeding habitat; Phyto-lithophilous reproduction, short-distance migrant; long-lived.*
Rutilus rutilus	*Wide-temperature tolerance, eurytopic, benthic and water column feeding habitat; phyto-lithophilous reproduction, short-distance migrant.* ***[Mildly tollerant of eutrophic conditions].***
Salmo trutta	*Cold-water tolerance; rheophilous; water-column feeder; long-distance potamodromous migrant; insectivore/invertivore/piscivorous; lithophilous reproduction; long-lived.[****Intolerant of severe water pollution****].*

The table above (Table 4.8) shows that some fish species have rather narrow and specific tolerances to pollution (i.e. *Salmo trutta*), water temperature (Salmonids, *Oreochromis aureus*) and river continuity (connectivity) and particular habitat preferences (i.e. pertaining to reproductive habitat, feeding habitat, and migratory requirements). This is important evidence that it is possible to employ specific fish species, with particular biological attributes to research signals of river degradation. More specifically, Brown Trout, Eel, and the diadromous euryhaline species are potentially good indicators that provide measurable signals depicting high ecological integrity. Eel is particularly interesting since it is allegedly very widespread species in the past. Finally several lacustrine and invasive species may potentially be used as negative signals, showing decreased ecological integrity (i.e. due to their influence on biotic interactions, the proximity of dams and artificial impoundment of surface waters).

Based solely on the work of this preliminary survey (i.e. with no monitoring or complete surveillance of the river systems of Cyprus), 11 river systems can be isolated, with widespread presence, persistence and potential use of fish-based bioindicators.

Especially concerning the Eel, there are other areas (such as small river mouths etc) but we will not refer to all at this early stage of the fish-based assesssment development. The priority river segments that we feel are important for pursuing the use of specific species of fish as bioindicators are outlined below.

The Eel

Rationale: As explained earlier in this report the Eel is considered an important, but not a typical and easily surveyed freshwater fish. It has undergone a global decline and collecting adult eels during sampling with electricity in Cyprus streams was shown to be difficult. The very low numbers and very few sites where Eels were collected made it difficult to see if the eels had a correlation with specific anthropogenic pressures. Eels are non-the-less extremely important as bioindicators because their presence does connote a definite longitudinal connectivity down to the sea, the presence and habitat quality of refugia during drought, the longitudinal integrity of river continuity upstream and the persistence of aquatic environments inland for many years (since Eels are long-lived species). In this sense, just the presence, abundance of adults and/or the occurance of in-comming juvenile Eels are significant elements for assessing the ecological integrity of aquatic systems. The total distribution of the species in Cyprus streams is approximately 120 km at a minimum (including several other river sites not included here – most notably many areas in the Pediaios catchment of the Occupied Territory).

Pyrgos.

Distributed in approximately 2,3 km of river length (however formerly distributed for many more kilometres inland)

Lower section: the habitats in this very small river-mouth need to be protected and maintained so eels can survive and disperse upstream. Evidence of eels upstream is virtually unknown and may be erratic. One priority monitoring site is labled in Fig 4.28 (#1: "Ek_Platys_Pyrgou" at the river mouth of the Pyrgos river).

Chrysochou.

Distributed in approximately 33,4 Km of river length

The lowland section as well as the upland tributaries all hold eel and it is very possible the most important and most extensive eel habitat on the island. Habitat and connectivity need to be managed. Two priority monitoring sites are labled in Fig 4.28 (#2: "Polis Mouth" immediately above the river mouth, and #3: "Goudi Bridge").

Ezousas.

Distributed in approximately 27,5 Km of river length

The river has high electrical conductivity making electrofishing sampling nearly impossible.

However, the river's physical character with low-sloping poorly drained riparia and springs (e.g. Amati) makes this a very important habitat area for a large section of its flow downstream of the new Kannaviou Dam. Eels could show the ecological potential in parts of the river and this means that specific habitats (spring, in-stream wetlands) and anthropogenic connectivity barriers need to be managed. One priority monitoring site is labled in Fig 4.28 (#4:"Ek_Ezousa").

Diarizos.

Distributed in approximately 20 Km of river length (formerly much more, and this included areas upstream of the Arminou dam)

The Diarizos is one of the most well known rivers harbouring Eel, perhaps because it was flowing perennially for most years; it has good eel refugia and wetland fringe habitats at some parts in its lower section. Today the river has eels at both its river mouth, the Kidasi Alder woodland and perhaps very few eels upstream of the Arminou dam as well. The most important areas for the eel here are the river mouth which must be managed to support eels and have enough summer water pools for them to survive. Eels at Kidasi should be monitored (this is the largest density of adult eels recorded on Cyprus by this study). No knowledge of weather it is possible for eels to scale Arminou Dam is available, but the presence of a rather young eel in 2012 upstream of Kelefos in the main Platys tributary signals that somehow this specimen has passed the dam. Two priority monitoring sites are ladled in Fig 4.28 (#5: "Ek_Diarizos" at the river mouth, #6: "Kidasi" at the characteristic rock outcrop in the Oriental Alder wood).

Chapotami.

Distributed in approximately 1,7 Km at minimum of river length (upstream reaches not explored)

The lower portion of the river is important for eels and a large number of incoming glass eels was observed in the spring of 2012. Some of the riparian areas are on private land and golf course developments with artificial barriers (small dams) may exist. The status of eel should be surveyed here and the importance of both free movement and habitat structure is paramount. One priority monitoring site is labled in Fig 4.28 (#9: "Ha_ek"; this site could also be combined with a site 200 m. upstream in order to have two nearby sites).

Germasogeia.

Distributed in approximately 5.4 Km of river length

The lower section is famous for Eels; the inhabitants of Lemessos traditionally sought Eels in the river and formerly in the river mouth as well. Today the lower part is paved and canalized and not Eel habitat exists, but glass eels to enter in wet years. Between the dam and this lower coastal urban reach there is habitat for eels. The number of glass-eels swimming upstream was rather high in 2012 (and they did manage to cross an artificial waterfall barrier that was two meters high. So this section is important for eels. Riparian habitat and instream habitat as well as barriers have to be managed appropriately. One priority monitoring site is labled in Fig 4.28 (#12:"Germ_b_wier" below the Germasogeia Dam and specifically below the characteristic wier on the river).

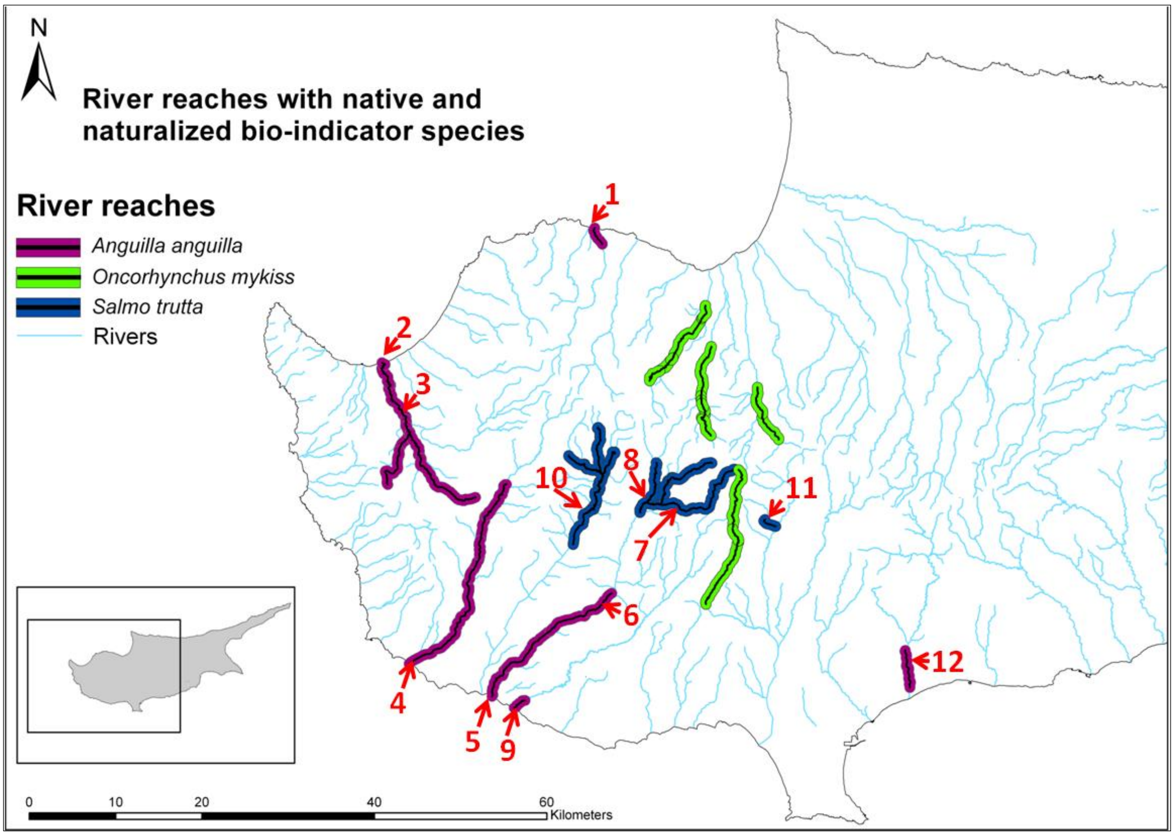


Fig. 4.28. *River reaches with the presence of three fish taxa that may potentially provide metrics for the implementation of fish-based indicators in Cyprus (as recorded from electrofishing and interviews in 2011 and 2012). The most extensive Eel Anguilla Anguilla populations within the free territory of the Republic are in Diarizos, Chrysochou (=Stavros Psokas), Pyrgos, Germasogeia, Hapotami and Ezousa. Although Eels have been documented by scientists in several other locations in recent times these are not shown here, however there numbers at other sites are probably not trivial (i.e. Pediaios, Oroklini etc.). The six river segments with eels are the priority areas as current knowledge shows. Reproducing populations of Salmonids include three areas with Brown Trout Salmo trutta (Xeros Pafou, Diarizos, Mesa Potamos Kouris) are shown. Limited areas of suspected reproduction/self sustaining populations of Rainbow Trout Oncorhynchus mykiss are also located in four areas (Xeros (Lefkas), Garyllis Kakopetrias, Kalidonia Kryos, Upper Marathasa), although this species is widely stocked within the upland reservoirs. The numbers sites on this map correspond with 12 "priority" monitoring sites are provided in red (see text).*

The Brown Trout

Rationale: Brown trout in contrast to Rainbow Trout is definitely a “naturalized” non-indigenous species in Cyprus. Although considered non-indigenous the presence of a native salmonid in the past cannot be disproved. The genetic stock of the present fish populations has not been researched so the question of their specific provenance is unknown. So the species is potentially a useful cold-water fish bioindicator. In contrast to the Rainbow Trout this species may not be considered an invasive in the sense that it is not widely stocked or transplanted by humans. In fact, there may be evidence of a decline in the species range (extirpation was alleged from the Kargotis). The species was located co-existing with Rainbow Trout only in one locality immediately under a Rainbow Trout farm (Fini); there may be competitive exclusion taking place. The total distribution of the species in Cyprus streams is approximately 54 km at minimum.

Mesa Potamos, Kouris

Distributed in approximately 4 Km of river length

A remarkable small, isolated and unusual population. It survives in a river stretch that is not much longer than 4 kms; copying with very little water during the summer and it reproduces in the small stream. The main course of the Kouris river is uninhabited by fish because of toxins leaching from the upstream unused mine. The Mesa Potamos population has been known for many years and may certainly be naturalized for many decades. This is the case for all Brown Trout population in Cyprus since the species was introduced decades before the Rainbow Trout and today the Rainbow Trout clones are preferred to Brown Trout in fish hatcheries. If we are to accept Brown Trout as a naturalized species that is worthy of study and monitoring as a bioindicator, then the population of Mesa Potamos should be safeguarded (this is straightforward, as it is in a steep ravine and only illegal fishing is the problem). One priority monitoring site is ladled in Fig 4.28 (#11: “Mesa Potamos Kouris” on the Mesa Potamos Tributary).

Diarizos

Distributed in approximately 30 Km of river length

The species is widespread in Diarizos and in fact, the upper part of the system has the most extensive and most dense populations. The Platys has trout along most of its course but in summer they were not found near the Kelefos Bridge where Roach dominates. Upstream of the confluence of the Fini-Kaminaria segment there are no Roach and Trout dominates (perhaps some poaching is responsible for low numbers and the lack of large fish; but this has not been researched). The Kaminaria reach has large numbers of trout and the highest densities are found there. The Fini reach has trout all the way from the Chandara Falls past Fini down to the Tries Elies Bridge. The populations in the Fini are of relatively high density also (and many parts of this river are poorly accessible so poaching is probably restricted). A study of the trout is useful because the species again has a rather unusual age-class distribution with certain years being prevalent and very few young fish. Perhaps this signals severe drought effects on the population. Two priority monitoring sites are ladled in Fig 4.28 (#8: “Two Bridges” on the Platys Tributary, #7: “Agiasma” on the Fini Tributary).

Xeros (Pafos)

Distributed in approximately 20 Km of river length

Upstream of Roudia Bridge there are trout populations but in rather low densities. Again this is unusual for such good habitat in such an extensive system of cold waters. In some areas near bridges (Gefyrka Bridge) numbers are lower than in wilderness reaches away from the road – this could be an indication of poaching but this is uncertain. Surprsingly very little recruitment of young trout is apparent –similar as in many other reaches in Cyprus. One priority monitoring site is labled in Fig 4.28 (#10, Roudias_Bridge; although other sites upstream could also be important places for monitoring, i.e. Gefyrka Bridge).

The Rainbow Trout

Rationale: This is a very controversial invasive species in terms of labelling it a “naturalized” fish or giving it any kind of distinction as a positive bioindicator for environmental quality. Obviously the presence of a cold-water species that is broadly intolerant to human-induced habitat degradation is important for bioassessment but in Cyprus some populations are definitely influence heavily by reservoir stocking, un-official stocking in river sites and escapes from fish farming. The species is therefore better appreciated as an “invasive alien” that may signal positively for some attributes (longitudinal connectivity, low-temperature conditions, adequate cover/habitat when reproducing and refugia during drought) or negatively for some other (presence of downstream dams, competition with other fish species, carnivorous bio-interactions etc. The question of how to assess the species for biodiversity conservation and water management needs further study. We do not recommend priority monitoring locations for this species but this can easily be done at many locations both within the delineated cold-water reaches and elsewhere in the uplands above dams. The total distribution of the species in Cyprus streams is approximately 60 km at minimum (including sites other than the ones described here, i.e. above dams).

Kryos, Kouris

Distributed in approximately 18 Km of river length

The populations upstream (near Platres) are the densest on the island and there is evidence of YOY that seem to have reproduced in the wild. It is unknown if the river is illegally stocked because the DFMR does not stock the river (only reservoirs are stocked). The population exists down to Agia Mavra but some sites that have good habitat did not have any fish (Pera Pedi – in the village). It is highly unlikely that the species reproduces downstream of the Pera Pedi Dam.

Kargotis

Distributed in approximately 7.5 Km of river length

The populations upstream of Kakopetria (on the Spilia road) are some of the densest on the island and there is evidence of YOY. However most are escaped from a nearby trout farm. It is unknown if the river is illegally stocked. The fish are heavily poached and populations inside Kakopetria are very low-density. A fish was collected while sampling as far down as Evrychou Bridge but this is unknown to be regular. Generally Rainbow Trout is not a good indicator for anything in such as degraded stream (with the exception of indicating poaching levels).

<u>Marathasa</u>

Distributed in approximately 12.3 Km of river length

Very large parts of the stream valley flow perennially down to the Lefkas Dam. Fishes abound in many parts of the stream. Generally Rainbow Trout is perhaps not a good indicator for bioassessment in such a degraded stream were the Kalopanayotis Hatchery certainly does introduce large quantities of stocked fish in both Lefkas and Kalopanayotis dam. The upstream areas near Moutoulas do have good habitats for Rainbow Trout reproduction. Fish are very much a part of the system (naturalized Roach, Mosquitofish; perhaps other escapees from the hatchery) but the biology and ecology of these fish species in the particular stream is little known. Interestingly their populations are usually of high density in several parts of the stream. The migratory species, and their survival do indicate a level of connectivity and they are part of the river foodweb.

<u>Xeros</u> *(Lefkas)*

Distributed in approximately 13 Km of river length

The population of Rainbow Trout in Xeros are remarkable because they are rather dense in numbers and are found in a rather extensive section of the river (the river has two small reservoirs which are stocked). This fish may reproduce and utilize the reservoirs as refugia but the population does not lend its self for bioassessment.

4.11. Steps towards developing metrics for a fish-based assessment approach for Cyprus rivers

In Europe, already enough experience exists about which selected fish-based metrics respond consistently to different levels of human effect, and not all attributes need to be tested to begin using a fish-based index. Consistently reliable metrics include the total number of taxa present in a sample (total taxa richness), the number of particular taxa or ecological groups (e.g. taxa richness of salmonids), the number of intolerant taxa, and the percentage of all sampled individuals (relative abundance of certain taxa) belonging to stress-tolerant taxa (i.e. invasive aliens that survive in polluted conditions). However in Cyprus and other areas with unique assemblages and conditions, metric responses need to be tested in particular locales to see whether the patterns observed elsewhere can be generalized.

In surveying the available data set we can explore the potential for constructing reference conditions based on the current field observation and utilizing natural history generalizations. The following attributes of the fish community were repeatedly registered as existing in sites with near natural conditions (or best-available semi-natural conditions). The generalizations below are based on a conceptual extrapolation of our results to all rivers of Cyprus and are obviously based on the currently available information; future research may better define this framework.

Coastal Sections (river mouth)

Where streams enter the sea during winter, spring and even early summer period (in wet years) large numbers of small-sized mugilids should abound. The numbers and even the presence may vary, but the most common species are the so-called grey-mullets *Mugil cephalus and Liza ramada*. Little is known about what may influence the seasonal intrusion of these marine species into small streams; however, they are herbivores and omnivores and benefit from the high productivity in brackish and shallow freshwaters (e.g. abundance of filamentous algae). Grey-mullets may be abundant in such coastal stream situations throughout the Mediterranean and will enter to feed on algae and retreat to the sea to spawn.

Glass Eels enter the streams primarily in spring, between February and July. During periods when the river mouth is open – and this is a naturally occurring phenomenon that varies with respective precipitation- a dozen or more glass Eels are easily observed with the use of electrofishing equipment in most river mouths on Cyprus. After about early June the migration of Glass Eels was not observed in Cyprus streams (however, our research was localized and incidental during only two summer seasons). Adult Eels are often found in lower sections of the rivers, especially where pools and reedbeds survive.

Other fish species of marine origin that forage or enter freshwaters to find shelter and grow as juveniles also are found in river-mouths and up to a few hundred meters inland. These euryhaline species may include up to 5 species. The sea bass may seek refuge and feed on small fish here also, however it needs an open corridor to the sea (it is postulated that even escaped farmed sea bass will enter inland waters). Lastly, where lagoons exist other species may enter or may have entered estuaries in the past (e.g. *Aphanius fasciatus*).

Provisional Ichthyological Reference Conditions are hypothesized as such:

Typical River Mouth Conditions

- High diversity of fish (4-6 species)
- Glass-eel entry from February to July
- Presence of large number of Grey-mullets (Mugilids)

Atypical salt marsh-lagoonal-coastal pond conditions

- Abundance of Aphanius fasciatus
- Presence of some other fish species also depending on habitat conditions (Grey-mullet, Eel, Atherina)

Middle Course sections (non-salmonid)

These sections are currently typically very poor in terms of fish presence. Eels are the only native fish species that exist here. In the past *Salaria fluviatilis* certainly existed in several small stream at least in the Lemessos District- as has been proven by specimens collected before 1907. We consider based on the bathygraphy of the island south and west coast that the species was almost certainly present in other larger catchment in the west; most probably at Diarizos. Although there is no evidence, it is very likely that the species was widespread on the island (it is widespread on Crete and Corsica, for example). The chances of other species of fish existing up until the 20th century in these waters are very slim. However, it is not unlikely that a cyprinid fish was once found there and when extinct at some point (e.g. due to drought, human water abuse and pesticide poisoning). Today in several locations in mid-course sections the Roach (*Rutilus rutilus*) is rather widespread.

Provisional Ichthyological Reference Conditions are hypothesized as such:

- Glass-eel entry from February to July
- Presence of high numbers of eels
- Presence of more than three size classes of eel
- Presence of *Salaria fluviatilis*

Mountain sections (salmonid)

Cyprus does not to our knowledge have any native trout; and there is no evidence at this point of our research that it had trout in recent times (i.e after the late 19th Century). This fish was an element the British hoped to introduce, since the island does have rather extensive cold-water perennial streams. Brown Trout, having been successfully introduced since the late 1940s, may now be considered naturalized. Biogeographically the island may have had an ancestor of Mediterranean trout in the past (as salmonid species are found in small coastal catchments in Asia Minor, Peloponnese, Sicily, Corsica and Sardinia), but there is nothing to prove the existence of the species here in Cyprus. Extinction is very possible on islands – perhaps due to climatic changes and human persecution. During glacial period salmonids could transverse the sea and reach larger islands such as Corsica, Crete and Cyprus; on Crete there is indirect evidence of a recent extinction. The existence of trout on Crete is postulated from several early references by visitors up until the 19th century (Rackham and Moody 2000); however there are no native populations there now. If the lack of trout is the product of extinction, even an introduced population may fill a "vacant niche" and could be accepted as a naturalized replacement of an extinct species.

Provisional Ichthyological Reference Conditions are hypothesized as such:

Without Cold-water species

- Presence of eels
- Presence of large-sized eels in appropriate habitats
- Localized presence of Salaria fluviatilis

<u>With Cold-water species</u>

- One salmonid species
- Reproduction of salmonid (YOY, fry, fingerlings, smolts)
- Several size-classes of salmonid
- Moderate abundance of salmonid in appropriate habitats
- Co-occurrence with Eel
- Presence of large-sized eels in appropriate habitats

Based on the experience gained in Cyprus; on the hypothesized references stated above and the biological attributes and ecological requirements of the specific species a provisional list of fish-based metrics was constructed (Table 4.9).

Table 4.9. *List of potential metrics that may be tested for Cyprus streams.*

1	2	3	4
Potential Metric	**Applicable River Type**	**Potential use in Cyprus rivers**	**Subjective utility in Cyprus**
1. Abundance of Alien Species	Mountain, Middle Course, Coastal	Increased alien species presence should signal a **decline** in ecological integrity.	** ⇩
2. Abundance of Salmonids	Mountain	Increased salmonid species presence should signal an **increase** in ecological integrity.	*** ⇧
3. Abundance of Non-Salmonids	Mountain	Increased non-salmonid species presence should signal a **decrease** in ecological integrity in cold-water mountain rivers where salmonids and/or Eels should dominate.	* ⇩
4. Alien: Native Ratio	Mountain, Middle Course	Increased alien: native ration species presence should signal a **decrease** in ecological integrity.	* ⇩
5. Abundance of *Salmo trutta*	Mountain	Increased number of *Salmo trutta* signals an **increase** in ecological integrity. These are naturalized populations, existing on the island for about 70 years.	*** ⇧
6. Proportion of Lacustrine species	Mountain, Middle Course	Increased lacustrine species presence should signal a **decrease** in ecological integrity.	* ⇩
7. Abundance of Salmonid YOY	Mountain	Increased number of very small (potentially naturally spawned) young-of-the-year salmonids signals an **increase** in ecological integrity.	** ⇧
8. Abundance of Eels	Mountain, Middle Course, Coastal	Increased number of Eels signals an **increase** in ecological integrity since their presence relates to connectivity with the sea and the presence of special habitats (summer refuges, rich food web, etc).	** ⇧
9. Presence of Eel	Mountain, Middle Course, Coastal	Sometimes simply the presence of a single Eel may mean something important- this is proof of connectivity – even to a degree and therefore it signals an **increase** in ecological integrity.	** ⇧
10. Abundance of native species of Marine origin	Coastal	Increased number of native species signals an **increase** in ecological integrity.	** ⇧
11. Age structure of native fish and naturalized brown trout populations	Mountain, Middle Course, Coastal	Increased number of native species size/age classes signals an **increase** in ecological integrity.	** ⇧

LEGEND: Column 1: specific metric proposed based on a review of catch statistics.
Column 2: pertains to the river typology developed in this project.
Column 3: comments on potential use in Cyprus rivers; emphasis is given on signals (increase or decrease attributes)

Column 4: symbols show attribute of metric (signal that shows an increase or decrease in biotic integrity); and asterisk: * = minor use on Cyprus; ** probable use in Cyprus; *** highly probably use on Cyprus.

It must be noted that these potential fish-based metrics are each predicted to respond negatively or positively to anthropogenic pressures; for example: an increase in the number/amount of a given metric shows a positive relationship when there is an increase in the river water body's ecological integrity (shown by the arrows in Table 4.9). Some potential metrics can be applied only within particular types of streams.

4.12. Practical application of specific metrics within present data set

Sampling surveys have not yet been completed to a level where satisfactory analyses to test the attributes and metrics can take place based on the available data set. Research of this kind must necessarily have a very good distribution of sites with representative fish populations. Specifically the metric calculation aspects of this work are not developed or completed in this report since a project extension was granted in order to collect more field data during the summer of 2012.

The following weaknesses in the present data set are evident after a review of the catch statistics and the attributes of the species involved:

- Many sites had very few or no fish; native species are remarkably scarce and irregularly distributed.
- Recently a remarkable European decline in the Eel has taken place and this is probably not only affected by local host river basin characteristics or anthropogenic pressures but other global factors (climatic changes, disease etc). This is an active area of research; however this once common and widespread catadromous fish is now critically endangered. Although formerly this was not the case- the rare species is currently difficult monitor due to its much-reduced population densities.
- Several sites with Eel in lowland habitats had very high conductivity conditions and could not be electrofished successfully; this may give a skewed impression of local presence-absence and abundance since these sites often had optimal habitat for Eels (reedbeds, silt substrate, still-waters, backwaters, marshy fringes). Due to the electrical conductivity condition no or few eels were caught in such sites.
- Some native euryhaline species may enter inland waters only during years of normal rain-level and their time of entry and residency in river-mouths may vary greatly temporally and spatially.
- Remarkable variability exists among sites relative to the densities of fish present – this being influenced by the proximity of dams – and how fish are artificially transferred upstream or downstream of the dams;

- Conspicuous fish assemblage patterns were often poorly associated with environmental and anthropogenic parameters with the exception of the influence of dams, the cold-water parameters, and river-mouth conditions.
- The ecological requirements of many alien species in Cyprus are poorly understood; increased alien species may not signal a decline in ecological integrity if the alien species have occupied 'vacant niches' thus replacing species that may have existed in the distant past (or occupying niches that fish occupy within similar Mediterranean stream ecoregions).
- Many lowland, river mouth and middle course sites are so degraded by anthropogenic pressures (river diversions etc) that fish are not able to survive, even otherwise hardy species that are rather frequently stocked (i.e. Mosquitofish). One desiccation period in the past may cause an all-out catastrophic extirpation of fishes in a large area of river segments – and this is apparent in the questionnaire responses where in several locations local experts where certain that fishes existed, yet current sampling proved no fishes existed. Flooding events may frequently be responsible for washing-out fish populations or their young; but this has never been studied in Cyprus.

Obviously, the investigation into metric analysis was not pointless since this has guided fish sampling design (distributing sampling sites among sites showing a gradient of anthropogenic disturbance, for example). Furthermore, many sites had no fish; something balanced by the rather interesting distribution patterns seen in some non-indigenous species near dams and in different river types (e.g. cold-water versus warm-water communities and the importance of river-mouth connectivity to the sea). Lastly, it is important to note that most of the specific fish species on the island confound the complexity and heterogeneity of sample results (i.e. Eels show very irregular patters in age-class, presence-absence and habitat conditions).

4.13. Theoretical background metric and index development

Human actions affect biological resources in multiple ways and at multiple scales (Karr and Chu, 1999); a rather large number of metrics (e.g. 8 to 12) from broad categories are usually selected and then scored using standardized scoring criteria; these metrics are the building blocks of routine surface water bioassessment for management and restoration.

Building and testing metrics is the beginning of any effort to build a bioassessment tool such as a multimetric index. Initially metric data must be converted into a common scoring base. For example, metrics are quantified with different units and have different absolute numerical values (for example, number of taxa may range from 0 to 15; Relative abundances may be expended from 0% to 100%). Some metrics increase in response to human disturbance (e.g. percentage of alien invasive species), while other decrease (e.g. overall taxa richness). To resolve such differences, each metric is assigned a score based on expectations for that metric at minimally disturbed sites(s) within the same type of stream. For example, the initial IBI assigned a score of 5 to metrics that approximately reach minimally disturbed conditions (reference conditions); those that deviate somewhat from such conditions receive a score of 3; those that deviate strongly are scored 1. The final index is the sum of all the metrics scores (Karr et al., 1986; Aparicio et al., 2011).

The basis for assigning scores is «reference conditions» or the natural type-specific baseline. This broadly refers to the condition at sites able to support and maintain a balanced, integrated, and adaptive biological system having a full range of elements and process expected for a specific biogeographic region. Most indexes explicitly incorporate biogeographic variation into their assessment of biological condition. The WFD also follows a reference condition approach in forging baselines.

In Cyprus there are important barriers to defining type specific reference conditions for river fish communities: 1) the biogeographically isolated character of the island and intensive anthropogenic degradation may have changed local biological systems to such a degree that they are no longer recognizable as parts of the wider biogeographical ecoregion; 2) Constructing reference conditions may be extremely difficult, even if it can be inferred based on the knowledge of the evolutionary and biogeographic processes operating at the wider region. We simply don’t know what the natural conditions in many of the rivers were like a few centuries ago; many local extinctions may have taken place; and climatic conditions may also be responsible – added to periods of extreme and intensive human pressure on water resources.

Based, on Abell et al. (2008), Cyprus is located within the Southern Anatolian Freshwater Ecoregion and this may help to find analogous river types (i.e. in Southern Turkey). However, the Southern Anatolian region is very poorly known ichthyologically and there is evidence that the freshwater biota of species on Cyprus has notable distinctions. Extinction is prevalent on islands, and the relatively depauperate biocommunities of Cyprus Rivers represent a contrasting species-poor composition, seen on all large Mediterranean islands. Mainland Asia Minor is comparatively rich in freshwater fish species. Also the historical data for Cyprus waters is very poor – human activity was already widespread on the island in the several hundred years ago and water resources where heavily utilized – so we do not know if missing fish species are part of the natural standard or precipitated primarily by human pressures.

Further to this, typical Mediterranean streams have strong variation in flow/hydro-period, a species-poor and pollution-tolerant fish fauna, and low ecological specialization of the fish species. These features make it difficult to employ metrics based on species richness, trophic specialization, and reproductive strategy, which are typical of IBIs and similar indices. Overall, these problems suggest that while a fish-based index can be a useful tool for evaluating stream conditions, each sub-region needs to have a customized index. Each index has to take into account not only local conditions and history but the rationale of the assessment tool concept. Theoretically, Cyprus river biota will be responsive to human-caused degradation.

Human activities degrade water resources by altering one or more of five principal groups of attributes: 1) water quality, 2) habitat structure, 3) flow regime, 4) energy source, and 5) biotic interactions. Human activities such as agriculture, road-making, and urbanization affect water quality by introducing sediment and raising water temperatures.

Habitat structure changes when large woody debris is removed or when special habitats (e.g. deep pools and marshes) are lost due to straightening of channels; dams impede longitudinal connectivity. Flow regime is altered by dams. Logging riparian areas alters the energy sources in a stream; organic material entering a stream will decline with logging, and light reaching the water will increase thus increasing algal growth. Biotic interactions are altered by introduction alien species or stocking of species from hatcheries since the alter relationships among predators and prey or competitors. As these changes stress the natural or assumed normal assemblage of stream organisms, they degrade the stream.

Fish-based indexes should be sensitive to these five factors; to help quantify the biological effect of a broad variety of anthropogenic activities that affect stream conditions. Indexes may be able to detect many anthropogenic influences in both time and space, reflecting changes in resident biological assemblages.

Although it may not seem practical at first, monitoring fish can provide insights into both the assessment procedure and into the structure and functioning of living rivers. Utilizing metrics may only become useful after monitoring a system for several years.

Aquatic ecosystems in Cyprus have been severely degraded since at least the beginning of the 20th century (before dam building, larger water transfers, borehole and mechanized pumping). Degradation has accelerated, especially during the last 50 years, and fish populations in streams and rivers of Cyprus have been reduced or have significantly changed in structure and composition. Overexploitation of waters, water development projects and environmental pollution of rivers are the main reasons that fish assemblages have declined and changed.

4.14. The way forward with respect to BQE river fish: Pitfalls and potential

It has been shown that specific research activities and monitoring are central to construction fish-based bioassessment tools that may be effective and evolve into practicable and routine survey/monitoring procedures. it is evident that sampling methodologies need further refinement (i.e. the incorporation of drag nets and eel traps in high conductivity waters), that data sets need to be expanded, and that a meaningful interpretation of ‘reference condition’ for fish in Cyprus has to be decided in order to facilitate completion of the classification/ bioassessment tools.

The following aspects summarize some of the unmet research needs in Cyprus.

a) Classifying river environments to define homogenous sets within the wider study area such as a biogeographically defined units or river types (i.e. building a biologically relevant typology).

b) Selecting measurable fish attributes that provide reliable and relevant information on the biological effects of human activities on river ecosystems.

c) Developing refined sampling protocols and designs that ensure that those biological attributes are measured accurately and precisely.

d) Devising analytical procedures to extract interpret and understand relevant patterns in collected data.

e) Communicating the results to policymakers, citizens and other stakeholders so that all concerned communities can contribute to water management policy applications (Karr and Chu 1999).

A robust measurement tool, such as a rigorously constructed set of metrics or a multi-metric index based on fish (or that may include fish) is difficult in a highly variable water-stressed insular environment. The many uncertainties associated with the use of fish in assessment should not force decision makers to overlook their values as bioindicators. Difficulties and failure usually come about from conceptual approaches, sampling problems and analytical pitfalls.The following pitfalls should be avoided in future steps foward (Karr and Chu, 1999):

<u>Conceptual Problems</u>

- Excessive dependence on theory or policy-driven concepts
- Narrow conceptual framework
- Failure to account for a gradient of human influence on river ecosystems
- Expectation of simple chemical, pressure (or other) correlations
- Poor definition or misuse of reference conditions

<u>Sampling problems</u>

- Inadequate design
- Too few or too many data
- Misunderstanding the sources of variability
- Failure to sample across a gradient of human influence within each river type
- Inappropriate use of probability-based sampling (i.e. random sampling designs etc).

<u>Analytical procedure problems</u>

- Use of poor and inaccurate environmental datasets
- Use of incompatible data sets
- Failure to organize and be aware of sources of variability
- Failure to understand cumulative ecological does-response curves
- Inattention to important signals (i.e. ignoring important yet scarce species)
- Failure to test, validate and adapt metrics to local situations/conditions.

In terms of the need to use fish in water management the following criteria are important for consideration:

Scientific relevance:

In Cyprus, fish are shown that they are not easily used as an unambiguous, scientifically sound measurement of pressures, degradation states or sources of anthropogenic stress. Although fish may not respond exclusively to specific pressures they are a policy-driven scientifically relevant element that can be used in a supplementary way to explore difficult issues of river ecosystem integrity not apparent in other BQE. Fishes are known to reflect important ecological conditions, resources and functioning and threats to these (i.e. connectivity, summer wetness/refugia/habitat, natural hydromophology (states of perennial flow) and relation to longitudinal connection to the sea). However, the methods used to build a database of site-based samples does provide a scientifically defensible baseline for investigating the signals provided by fishes with respect to environmental conditions.

Sensitivity

Some species of fish, native or non-native, are obviously sensitive to environmental change and they may respond abruptly (i.e. mass deaths, individual health, emigration etc). However, as indicators they may not be sensitive to specific pressures and their use may integrate many pressures and the history of the specific river. This confounding aspect in fish sensitivity provides both added information and complexity in their use in Cyprus. In many other instances many fish species and specific attributes of fish communities respond predictably to environmental degradation caused by humans.

Timeliness

Fish may respond promptly and abruptly to environmental changes (fish may easily move, and they die-off also). It is not known whether they can be leading indicators of specific stresses but this is open to more research. Fishes relate to appropriate scales of time and space in river environments that other biological quality elements cannot effectively show (i.e. relative to the use of the zoobenthos, plants and plankton). In this way fish may relate well to management goals for specific river systems at the river segment scale were most restoration actions take place.

Measurability

The use of electrofishing and fry-net sampling provides a consistently measurable, practical and repeatable method. However, there are limitations and biases in the method; for example in high-conductivity rivers in Cyprus, notably in very important priority river areas there are shortcomings with electricity (Ezousa, Lower Chrysochou, Pediaios, and Alikos). Fry net sampling is good in river mouth conditions in Cyprus but it is more difficult to standardize and quantify. So in this sense the question of precision, accuracy and comparable consistency in measurability is challenging for certain water bodies in Cyprus' rivers.

Community Relevance

Other stake-holders see fish as immediately relevant in terms of protecting and managing key ecological factors, pressures and sources of pressures. Fish are extremely important in communicating freshwater conservation issues. They are indicators that the general public and other stakeholders readily recognize and understand (this includes: Forest Management, Game Management, Water Management, Recreation & Tourism development). In this respect the communication value of fish is outstanding relative to other BQEs.

Cost-effectiveness

The easy measurement of sampled fish-based attributes using the method applied in this study means that the measurability in fishes is highly cost-effective. It has been roughly estimated that each electrofishing/fry-net sampling may cost less than 200 Euros in Cyprus (this pricing would include costs of equipment, supplies, field staff time, transportation, data management and expertise to analyze or interpret data). Compared to the FAME investigation (FAME 2005), this is a good cost-effectiveness level since no laboratory time, or specimen collection is usually required on Cyprus. Also the sampling can be done rapidly and quite effectively.

If the following criteria are considered, it becomes clear that there it is desirable to monitor and be informed about the fish BQE in Cyprus rivers.

SECTION 5 CONCLUSIONS AND RECOMMENDATIONS

5.1. Fish for bioassessment of lotic waters in Cyprus

Other than the present survey, there are no completed baseline studies dealing with the inland fish species or their specific distributions or populations on the island. In terms of the EU Water Framework Directive (WFD), the Republic of Cyprus considered that it is not possible to base any type of ecological quality assessment solely on fish species due to several unique island conditions, including the dominance of an non-indigenous fauna and very scarce native fish populations. Consequently, “fish” as a WFD Biological Quality Element (BQE) are not monitored; and Cyprus did not participate in the River-Fish Intercalibration Exercise (although our work did provide the IC process with a report on the Cyprus situation and the results of progress within this present study). In this project (along with the data from previous projects by teh same team members), most significant Cyprus rivers that feature at least some perennial flowing reaches have been investigated in the spring-summer periods of 2010, 2011 and 2012. It is hoped that through this pioneering survey, insights into the practical use of fishes for assessment, conservation, and sustainable management of lotic waters will be promoted.

The scarcity of fishes in Cyprus’s streams is not wholly natural and in many cases this is directly caused by anthropogenic pressures that may degrade the permanence of surface waters or the natural longitudinal connectivity of the river systems. Many fishes on Cyprus are susceptible to exterpation and anthropogenic pressures have caused the decline of both native and non-native fish populations. Evidence to fully support this statement needs careful historical ecology study and this was only researched superficially during this project. Nonetheless we have found evidence that perennial flowing waters have been altered beyond recognition due to many large and small scale human pressures that cause extensive river bed desiccation, water abstractions, and habitats degradation over long stretches of many rivers on Cyprus. Cyprus has on of the highest concentrations of dam reservoirs in the EU; and it is obvious they have impacted river fish communities. Cyprus also had a period of intense and widespread DDT spraying for a very long period (1946-1978) and this targeted and effectively poisoned nearly wall water courses during island’s prolonged summer drought. It is hypothesized that many aquatic and semi-aquatic animals declinded and were extirpated from many river courses; evidence of this is provided in this report. One of the island’s only native freshwater fishes (River Blenny) is threatened with extinction, if it still exists anywhere on the island. This species was documented and reported from small torrent-like streams near Lemessos in the early part of the 20th Century; today it is was found nowhere in the Lemessos District despite a substantial effort during this project. Fishes could survive in many of the currently “fish-less” stretches of rivers in Cyprus, but it is very difficult if not impossible for them to re-colonize rivers due to their restricted ability to disperse. In some respects, the naturalized populations of non-indigenous fishes may stand as “ecological replacements” for species that may have gone extinct in the past; in some river areas non-indigenous species are thriving.

There are several fish communities on Cyprus and most are dominated by non-aliens species (this report described seven such biotic groups). Although stream fish of mostly non-indigenous assemblages were confirmed in several isolated parts of some rivers, it is not yet known how predictable and self-enduring their populations are; and if or how they react predicably to specific anthropogenic pressures. Without site-based ichthyologicl monitoring the stability and in-depth structure of fish assemblages in Cyprus' streams cannot be adequately assessed.

However, the potential to use fish in a supplementary way within biological assessment, restoration and conservation programmes and for WFD-relevant water management certainly exists on Cyprus. In fact it has until now been sadly overlooked. We have shown that some fish species, especially the Eel and naturalized Brown Trout populations may be considered bio-indicators. Naturalized trout of the two species present (*Salmo trutta* and *Oncorhynchus mykiss*) are cold-water fish requiring particular natural habitats and stream connectivity in order to survive and reproduce so even these non-indigenous species give signals about a rivers condition and habitat resources. The presence of these fishes presents interesting theoretical problems in bioassessment, and further research is needed to explore these fishes' interrelationships with the natural biota. Paradoxically, because it is widely stocked or released from fish farms, the Rainbow Trout (*Oncorhynchus mykiss)* may potentially be degrading natural stream biota. These theoretical problems create confounding factors and conceptual confusion when it comes to conciliating biotically-based assessment tools with biodiversity conservation practice.

Potentially, in the near future, fish-based assessment and monitoring could be developed in Cyprus, at least in certain types or limited stretches of rivers and in reservoirs. For example, in stretches were the Eel is known to exist the conservation of surface water habitat conditions and connectivity with the sea is an obvious requirement for maintaining river ecosystem integrity. Eel populations and specific attributes could be used as specific indicators of river integrity (i.e. Eel presence, their age-structure, the influx of glass-eels etc.). However, despite these important aspects of this and other bioindicators, it is not possible to conclusively and practically define the use of fish for assessment and monitoring in Cyprus at this time, the unique insular and environmental conditions on the island create serious obstacles to the development and practical application of the fish BQE for Cyprus' rivers.

With respect to interpretations made thus far and an analysis of the collected data, specific conclusions follow:

a) The fish fauna of Cyprus Rivers is depauperate and often exhibits unusually low population densities and high inter-site variation. Much of this variation remains unexplained by environmental and known anthropogenic pressures. Eight native species are confirmed to inhabit (or have inhabited) the inland waters of Cyprus: a) Eel (*Anguilla anguilla*); b) River Blenny *(Salaria fluviatilis*) and c) six euryhaline fish of marine origin that are only found in the lower reaches of rivers or in coastal wetlands (*Mugil cephalus, Liza ramada, Liza aurata, Dicentrarchus labrax, Atherina boyeri;* and the unique wetland cyprinodont *Aphanius fasciatus*). The River Blenny is in danger of extinction since its lowland habitats are highly degraded by anthropogenic alteration and pressures (or it may already be extinct). In addition to the above species, a large number of alien species were recorded in the inland stream waters of Cyprus, although most of these inhabited short river sections in the immediate vicinity of artificial reservoirs. A few more alien species are confined exclusively to the reservoirs. The total freshwater species list of Cyprus lotic waters is documented to hold 8 native species and at least 12 regularly occurring non-indigenous species.

b) Alien warm-water fish are widespread primarily in dams and in several stream reaches particularly in the immediate vicinity of dams. Obviously, fish populations in rivers that are connected to dams originate from stocking or indiscriminate introductions that take place in the dam reservoirs. The commonest aliens within lotic systems are: *Rutilus rutilus, Gambusia holbrooki, and Oncorhynchus mykiss*, and in some areas *Micropterus salmoides*. Generally predictable patterns in the distributions of these species are not obvious. For example, *Gambusia* is absent from many water bodies although it is said to have been formerly introduced more widely; we assume that populations could frequently be exterminated by periodic all-out drying of rivers and wetlands.

c) Building validated indicators or indices that help assess the river condition in a WFD policy-relevant prespective must be based on an in-depth understanding of river-biota natural history. Through specific research and monitoring specific fish-based attributes may be shown to be reliable, predictable and relevant signals about the biological affects of human pressures on aquatic ecosystems. These attributes are chosen as metrics when they are shown to reflect specific, predictable responses to changes in river health, or river status. These metrics should be easy to measure and interpret haveing strong signals that surpass natural variation. Most indexes of river health explicitly comprise specific metrics (or bio-indicator elements) such as species richness, indicator groups, specific species representation, reproduction, fish health etc. In Cyprus the current understanding of fish-based attributes and their relation to environmental and anthropogenic stresses is still poor and strong spatio-temporal variation creates difficulty in using fishes as bio-indicators.

d) There are preliminary indications that some fish-based metrics can possibly be developed, tested and applied on Cyprus despite the high variability of fish-based biotic attributes at the sampled sites. For example, naturalized Brown Trout was confirmed as spawning in three separate river basins on this survey: the headwater catchments of Xeros (Paphos) and Diarizos rivers and one small headwater tributary of the Kouris River. The populations are of low density, but the fish have allegedly been surviving in the Troodos for at least six decades (Thirgood, 1987). Obviously, if a metric based on naturalized Brown Trout proves to be applicable in the future, any application will not be possible without careful monitoring and, above all, without due metric validation.

e) The native Eel is currently confirmed through our investigation to be distributed in several river catchments on the island. All evidence shows that the species was definitely formerly widespread, as was confirmed by a dedicated questionnaire survey, personal interviews during spring-summer 2011 and 2012, and the discovery of many glass Eel juveniles when the river mouths were open in the spring of 2012. Nonetheless Eel populations are relatively low in Cyprus and the reasons for the low-density populations need to be specifically researched. We hypothesize that the low abundance and localized presence of Eels reflects environmental degradation – most often caused by direct anthropogenic stresses. Many anthropogenic pressures can negatively affect Eel survival (i.e. river-stretch desiccation; barriers to movment; poor connectivity with the sea; unpredictable and erratic water flows; severe flooding; riparian zone degradation, severe pollution etc).

f) Many parts of rivers and their stream tributaries in Cyprus are naturally intermittent and the long-term connection to the sea of most rivers is a rare situation. In addition, many rivers in the lowlands are currently "artificially intermittent" due to the presence of dams and widespread water abstractions; so reference conditions cannot easily be constructed in the lowlands. Only two streams with flowing water at their river mouths were located on this survey during June 2011; the number was surprisingly higher in June 2012 (but that year was said to be exceptional). Therefore, the use of the lower portions of the river segments by marine and euryhaline species is limited and this is definitely negatively influenced by anthropogenic pressures.

5.2. Proposals for further developments concerning the application of BQE fish in rivers in Cyprus

The following anotated statements are made with regards to providing a background base-line for future efforts towards appropriate research, survey, and monitoring actions in Cyprus' rivers with specific regard for the use of fishes in bioassesement. These proposals reflect knowledge gained during this study and refer primarily to policy-relevant unmet needs or opportunities for conservation and sound water management applications. Some of these proposals also include reference to biodiversity conservation which is obviously closely tied to water management on Cyprus since many river valleys are within protected areas. It is important to re-iterate that there is a severe lack of understanding of river ecological systems on Cyprus, especially concerning their biological components so research and monitoring approaches need to become established in a way that will also provide useful knowledge for management and ecological restoration.

The following 8 recomondations are summarized in the following conceptual diagram:

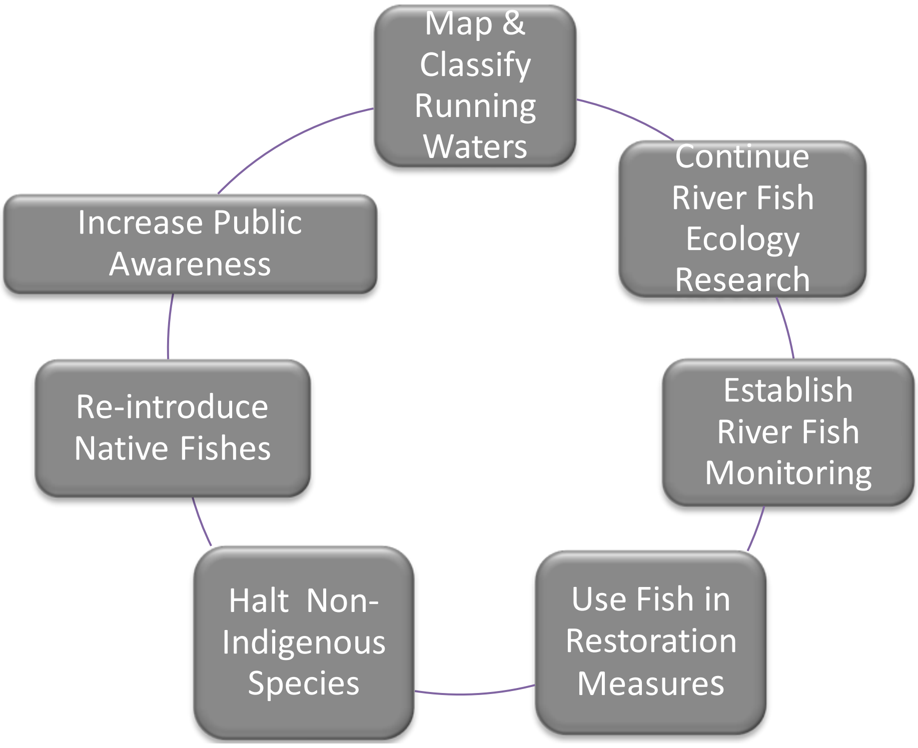


Fig. 5.1. *Eight recommendation categories organized from the first (at top) in a clock-wise fashion.*

Recommendation 1

Map, re-classify and organize data on surface water features in Cyprus

The surface water flow conditions of the rivers of Cyprus are poorly mapped (i.e there is poor geographical delineation of stream flow – showing where areas are flowing perennially for example). One of the fundamental biological aspects of Mediterranean river condition is its surface water hydrological regime especially premenant versus temporary flow. Successful biological monitoring of lotic waters depends on judicious classification of river sites, stretches and segments (and appropriate water body delineations). Yet inappropriate river classification can impede development of cost-effective and sensible monitoring schemes. The challange in a biotically-relevant river classification is to create a system with only as many classes as are needed to represent the range of relevant biological variation in a region and the level appropriate to detection and describe the biological affects of human activity (pressures on the type-specific biota). In terms of using fish biota for classification, it is important to remember that the reason lotic water classification is primarily useful, is to group places where the biology is similar in the absence of human disturbance and where the responses are similar after human disturbance. Classifications will vary according to specific policy-relevant goals, but the basic hydrogical regime attributes must be mapped for any accurate and consistent sheme.

The following priority action relevant to the above river mapping and classification issue is detailed here:

- Perennial reaches that have special interest for conservation and water management must be demarcated and particular restoration base-lines must be developed for them. Fish can be used to monitor bioassessment in these water bodies. Especially lotic reaches with Eel and Naturalized salmonids must be monitored.
- Water tempearture is an important geophysical determinant of river biology, especially in a xero-thermic Mediterranean bioclimatic area such as on Cyprus. Cool water streams could be distinguished from warm water streams during this summer and these should correspond well to salmonid versus non-salmonid sections.
- A method and manual (with accompanying field forms) to identify and score geomorphic, hydrological, physical and biological stream features that distinguish between ephemeral, intermittent and perennial streams must be developed and applied for a baseline cartographic application in Cyprus.

Recommendation 2

Continue ecological research on fishes within an ecosystemic approach and as bioassessment indicators in inland waters in Cyprus

Fish as biological quality elements in rivers, may be of particular interest in Cyprus, yet the specific incentives to promote this at this stage of understanding is primarily of a scientific research nature. Applying fish-based tools for bioassessment in a routine procedure may not be easily possible or practicable however it is wrong to forfeit attention to fishes (i.e. monitoring, research work; use as restoration indicators etc). Fishes are important for policy-relevant research, monitoring, restoration and water management in Cyprus for the following reasons:

a) Native species (Eel, marine euryhaline species and a specialist coastal wetland fish) are present in several rivers, reservoirs and wetlands throughout the island although their current distributions are very localized. The Eel, Mediterranean Tooth carp, and River Blenny are of particular biodiversity conservation interest also and allow the WFD to couple and complement management actions prescribed by the 'Habitats Directive' (92/43/EC) also.

b) Brown trout may now be considered naturalized having been present on the island in cold-water conditions for over 70 years; it is potentially a good indicator of river ecological status. Other EU states (e.g. Ireland) use naturalized species as indicators. The premise, that they may fill a "vacant niche" although it cannot be substantiated by specific evidence at this point, needs further research. Other Mediterranean islands do have trout in their cold-waters and this may mean that they may have existed on Cyprus during glacial periods when trout are believed to hed entered sea-waters to disperse. So the presence of non-indigenous trout in Cyprus may fill a niche of an extinct fish and this may justify the use of the fish as a bio-indicator.

c) The total number of non-indigenous species on Cyprus is large. Non-indigenous species are used as indicators of river and heavily modified water body conditions by many EU states and especially in other jurisdictions beyond Europe (i.e. Australia). In Europe recent work has shown that a supplementary biopollution index could be used to account for the influence of index even within the WFD assesmenet context. A separate biopollution index would uncouple alien species and anthropogenic pressue assessments allowing for a correct and more precise appraisal of the problem without affecting the WFD classification (Vandekerkhove & Cardoso 2010). Non-indigenous species are especially important because they may impact ecosystems by altering biotic interactions, creating a severe pressure that is very difficult to reverse but often their impact is not wholly anthropogenic and species may evolve to be naturalized elements of constituent biocommunities. The specific pressures the non-inditgenous species' exert requires research and without research-based science (often based on monitoring data) it is inappropriate to prescribe any active management or restoration actions. However, certain notorious carnivores that did not exist in the wider Mediterranean region can be destructive in endemic-rich small streams (i.e.

Largemouth Bass, Sunfish). Species such as these must be regulated and their dispersal in Cyprus must be halted.

d) Monitoring fish assemblages through the use of electricity is now a widespread standardized method that is fairly easy to execute and low-cost. If this is combined with fry-net sampling and eel-trapping it is possible to gather data annually on Cyprus for a very low cost. This kind of work could also be supported by academic interest in the ecology of inland waters in Cyprus (i.e. collaboration with university departments etc).

e) Monitoring fish assemblages provides useful information for many aspects of water and resource management – however the value of monitoring may only show after several years of implementing such as standardized survey scheme. Certain attributes of the fish assemblage, that are relevant for WFD assessment (i.e. Reproduction, age-classes, species composition, abundance) and their variability in time and space may only be documented after several years of surveying. This is especially important in Mediterranean type streams where climatic variation plays a significant role in affecting the fish-based attributes.

f) Creating an index / or utilizing isolated metrics as indicators of river condition using fish in rivers may be an obvious objective, however it should not be the sole objective of this BQE and fish-based water management research on Cyprus. It must be realized that the concept of an integrated index using fish in variable a-typical Mediterranean streams has been seriously criticized. The variability of streams over the island, and the poor ecological integrity of the constituent systems may make such an index so generalized that it would not be useful in addressing specific problems (tracking pressure signals, etc). Although the concept remains controversial it is a policy-relevant target and this cannot be ignored. In a monitoring and assessment context; any attempt to develop a fish-index for Cyprus would represent significan strides in a state-of-the-art understanding of how river ecosystems and their biota function.

g) Beyond their use as statistically-validated metrics at a broad geographic scale (beyond the catchment level), some fishes are important and capable indicators for specific restoration requirements of local water bodies (e.g. assessing important restoration parameters downstream of dams). Fish can provide important qualitative information as to the trends taking place during and after restoration measures. These include fish responses to flow regime, habitat conditions (habitat refuges in intermittent water bodies), longitudinal connectivity, the affects of artificial barriers and the influence of river-mouth structure and functioning at coastal zone. It must be noted that other BQEs (macroinvertebrates or plants) do not respond to such restoration targets as well as fish in many instances.

Finally, if one is to study river ecosystems in Cyprus, information on fish populations is critically important. Increased attention must be paid to understanding the ecological vitality of Cyprus inland waters, and using fishes as indicators helps us understand how freshwater ecosystems function. Long-term persistence of populations for example is important in ecosystem functioning, and this means accepting the Mediterranean stream attributes of high interannual variation, gradually changing states and multiple equilibria. This understanding of temporal dynamics and change in freshwater ecosystems is important if those systems' ability to respond to changing environmental conditions is to be protected.

Specific research actions towards utilizing fish as bioindicator or in bioassessment studies should consider the following:

- Fish populations should be specifically studied and monitoried beneath dams where ecological flows are meant to be established. These include bellow Kannaviou Dam, Germasogeia Dam, Kouris Dam, and Arminou Dam. Specific refrence to fishes including a monitoring scheme must be established as part of the restoration actions below these and other dams; and targets must be set in order to respond to the need for the amelioration of river conditions (i.e. with respect to ecological potential in Heavily Modified Water Bodies). In the dams listed above fish may help effectively signal the restoration of ecological integrity (i.e. through the use of the Eel populations as bioindicators).
- A specific study on the Eel must be implemented. This must include an island-wide survey with the specific purpose of assessing populations and promoting the re-populations and re-colonization of former distributions. Specific works to restor connectivity-with-the-sea and inland connectivity must be proposed in all river basins areas where non-trivial eel populations are present.
- A specific study on Salmonids in Cyprus' rivers must be implemented. This must explore the genetic and population-based structure and population dynamics of Brown Trout. Recommondations and specific actions must be proposed on issues concerning the 'conservation' of the naturalized Brown Trout populations and the management of Rainbow Trout (including stocking regimes, delineation and management of trout streams etc).

Recommendation 3

Establish a cost-effective basic monitoring scheme for river fishes

Due to the premises in recommendation 1, it is our belief that a preliminary monitoring scheme for fish should be seriously considered on Cyprus. Three key attributes of the fish community—species composition, abundance and age structure (Annex V of 2000/60/EC)—must be included in the scheme(s) for fish-based classification in order to be WFD compliant. The specific development of such a scheme – in order to be effective must be based on sound science and strategically designed. Such a design requires a specific study and is beyond the scope of the present study. The study must determine how information gained from sampling and statistical analyses can be informative and practical to specific water management objectives.

Another requirement of using fish-based approaches as managemenet tools in water conservation, bioassessment and restoration is an understanding and operational application onf the refrence condition approach (this is also mandatory within the WFD). In Cyprus this is extremely difficult; perhaps more difficult than several island Mediterranean or island states in the EU due to the unique cultural landscape of Cyprus, the hypothesized DDT die-out during the last century and an intensive water management campaign that has created a proliferation of invasive non-indigenous species in Cyprus inland waters. Despite this it is still possible to research refrence conditions or build future desired states based on natural history understanding of type-specific river reaches on Cyprus[11]. The key premise, if one is to continue exploring the use of fish is to begin monitoring.

One of the simplest monitoring schemes possible would be to monitor 12 so-called priority sites and any sites where restoration measures are being made in Cyprus streams annually for a three year period initially.

That would mean a cost of approximately 3000 Euros per year for the 12 sites alone (if we are to budget 200 Euros per sample, as expressed in the text). However, the start-up costs of such a venture include the following: Purchase of high-powered efficient Eletrofisher (such as a Smith-Root 24L Electrofisher (approx: 7000 Euros)); Simple Monitoring Study and Database development (5000 Euros); training and certification of personell (5000 Euros); extra materials and equiptment (3000 Euros). In this way, with a

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[11] It is our understanding that most river ecosystems on Cyprus have been degraded to the point where neither their natural structure nor their functioning resembles their historical condition (i.e. their condition a half century or one century ago). Only the old-aged local inhabitants recall conditions in the rivers that the current generation may have difficulty imagining. The impact of the anti-malarial poisoning campaign (1948-1970) may also have had whole-sale catastrophic effects on river biota (especially vertebrates –aquatic and semi-aquatic species). It is clear that more historical research on the natural history of the rivers before 1960 is required to explore type-specific reference conditions. A specific study of this kind must be commissioned and must involve the efforts of experienced environmental historians as well as professional biologists and ecologists with specific background in this subject.

base-line start-up cost of approximately 20 000 Euros it is easily possible to have the resources to develop and maintain a monitoring scheme on Cyprus.

Specific criteria for the initial baseline monitoring scheme should include the following:

- A specifc "preliminary monitoring study" is required to craft the scheme for appropriate use in Cyprus. This study requires the involvement of several stakeholder agencies and organizations in Cyprus including the WDD of course. It is best to have a more inclusive participatory approach to a fish monitoring scheme than make in a theme-specific and narrow focused approach. The urgent and unmet need here is to build a simple useful scheme that monitors fish, which is effective in providing information which will help stem environmental degradation and act as a tool for management.
- The three key attributes of the fish community—species composition, abundance and age structure (Annex V of 2000/60/EC)—must be included in the scheme similarly to what was developed in this present study (identical protocols and sampling methodology can be used). A monitoring scheme for river fishes will have wider policy implications as well; and it should be known that the WFD is only one aspect of water policy information needs. The development and particular organization of a fish monitoring scheme should be openly discussed among scientists, managers, decision makers and interested members of the public since it involves issues of protected area conservation, restoration and biodiversity protection as well as the WFD obligations.
- The scheme should be based on a rapid assessment approach whereby the method provides a reasonable level of accuracy for use by a variety of users and in a variety of situations (these may meet the needs of both the WFD relevant water management and biodiversity conservation monitoring as well).

Recommendation 4

Incorporate fishes in ecological restoration projects

Restoration of Cypriot rivers is difficult especially when reference base-lines are so poorly studied – especially with respect to the biotic resources, ecological processes, temporal variability and specific conditions required to maintain “natural” or near-natural in-stream biota and riparian zones. One of the pivotal aspects of the WFD are measures to restore water bodies and this may be especially challenging in a system with shifting baselines and poor understanding (and misinterpretations) of the historic anthropogenic changes. Many water bodies are under particular stress because they remain dry for part of the year and this introduces high levels of uncertainty regarding the specific measureable targets and effectiveness of restoration prescriptions.

Restoration is defined as the return of an ecosystem to a close approximation of its condition prior to disturbance. In restoration, ecological damage to the resource is repaired. Both the structure and the functions of the ecosystem are recreated. Merely recreating the “form” without the ecosystemic functions, or the functions in an artificial configuration bearing little resemblance to a natural resource, does not constitute restoration. The goal is to emulate a natural, functioning, self-regulating system that is integrated with the landscape in which it occurs. In this respect restoration entails careful attention at the ecoystemic approach, and sound natural history understanding (Moss 2008).

In terms of utilizing fish in restoration issues on Cyprus the following actions are proposed:

- The Eel should be used as and indictor of restoration effectiveness in areas where restoration works are taking place, especially in lowland streams below dams. Eels have specific requirements for survival and longitudinal movment in streams and refrence to these needs must be taken into particular consideration in restoration measures.
- Ecological or environmental flows must be geared to take into consideration the river mouth opening during the period when glass eels enter streams (February – June). At this period the freshwater plume entering the sea attracts large numbers of glass eels and these move upward oftern crossing barriers and establishing themselves in adequate habitats. Conservation of the habitat refugia during the long summer drought is another imperative of this fish-based restoration managent of water flow regime manangement. In this respect specific delineated refugia habitats must remain “wet” throughout the long drought during any summer condition.
- The use of insecticides in streams and their impact on fishes must be researched. There is anectodal evidence of fish-kills caused by state-subsidized mosquito control campaigns but research into the effects of the chemicals and their toxicity in Cyprus in-stream biota has not been published. Particular care must be taken for use of any biocides that may affect the in-stream biota in protected areas.

- Adaptive management[12] approaches to restoration are important in strategically planning for executing and monitoring the effectiveness of restoration/rehailitiation targets and measures.

Knowledge of fish populations, their reaction to restorative measures and the specific targets and "future desired state" concerning fish populations must be assessed and monitored within an adaptive management approach to river restoration.

One more reason to consider fish within the wider issue of restoration on Cyprus is the WFD obligations towards measures for water bodies in protected areas. Many of the river valley of Cyprus including specific river stretches are included in the Natura 2000 protected area network. Until now no specific additional measures to reach the more stringent objectives within protected areas has been described or prescribed on Cyprus (Commission Staff Working Document, 2012). Native fishes can be used to promote the conservation of and more specific management actions in protected areas. This is especially important when protected areas such as the lower Chyrsochou river, Ezousa River, Diarizos Valley, Hapotami and several other lower elevation areas are investigated. In these and other protected areas special focus on eel habitat and eel movement must be promoted.

Recommendation 5

Help halt the spread of invasive non-indigenous species in inland waters

The influence of non-indigenous species in Cyprus in land waters is poorly researched. Some fish species may impact biotic interactions and cause problems; and as has been said before – this impact may be irreversible because non-indigenous fish are very difficult if not impossible to exterminate. Non-indigenous plants and animals including parasites are also spread inadvertently by fish introductions or through other ways (even by sampling for water quality). The issue of non-indigenous spread in inland waters deserves immediate attention.

Invasive species in Cyprus are a problem but the definition and specific pressures, stresses and ecosystem degradation incurred by non-indigenous species has been poorly been researched. Of the species that are now reproducing in the wild in Cyprus the following are known to have caused problems in biotic interrelations and on native organisms in aquatic ecosystems:

- o Largemouth Bass *Micropterus salmoides [carnivorous]*
- o Mosquitofish *Gambusia holbrooki [insectivorous]*

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[12] Adaptive management approaches incorporate a decision-making process that promotes flexible decision making htat can be adjusted in the face of uncertainties as outcomes from managmenet/restoration actions become better understood. The management/restoration process is besed on careful monitoring that both advances scientific understanding and help adjust operations as part of an iterative learning process. The process emphasizes learning by doing, and experimentation while helping meet specific and measurable restoration goals, increasing scientific knowledge and reducing tensions among stakeholders.

- Sunfish *Lepomis gibbosus[carnivorous-insectivorous]*
- Goldfishes *Carassius spp. [generalist; water-fouling]*
- Tilapia *Oreochromis sp. [carnivorous-insectivorous]*
- Rainbow Trout *Salmo trutta [carnivorous-insectivorous]*

This issue is important and especially with respect to management of waters it needs further research. It must be reiterated that without further study it is unknown what and how these and other non-indigenous fishes may affect.

Specific steps that must be taken include the following:

- Develop and Fish Invasive Species Strategy for Cyprus. Examine the pressures and impacts casued by the alien species on the island. Develop a scientifically justified rationale for interpreting the role and specific values of established naturalized non-indigenous aliens (i.e. Brown Trout).
- Involve all stakeholders in specific communication, seminars and workshops outlining the specific problem of Non-indigenous fishes in Cyprus and how to halt their spread.
- Establishment of “no-go areas” for stocking. Organize the way stocking is practiced and do not attempt to promote the spread of aggressive carnivorous species such as largemouth bass and sunfish.
- Exploration of opportunities for stocking regimes or specific introduction of fishes that do not damage natural integrity or ecological potential in reservoirs.

Recommendation 6

Consider the strategic re-introduction of particular fish species to Cypriot rivers as an act of ecological restoration.

One aspect of restoration may be the re-introduction or introduction of certain fish species in Cyprus rivers and other inland waters in an effort to restore ecological integrity (or prescribe better conditions for ecological potential in reservoirs or Heavily Modified Water Bodies). This issue is especially critical for the River Blenny (Salaria fluviatilis) which has certainly been extirpated from some rivers (if not from the entire island, as is probably the case). Government facilities for reproduction of fishes such as the River Blenny exist at Kalopanayotis Fish Hatchery (managed by DFMR) and could provide an important biodiversity-relevant example of ecological restoration. However, this or other introduction-actions need the following:

a). A thorough exploration of all water bodies on the island to explore where specific rare species exist and a conservation genetics study of their populations.

b) If populations are not found and the native species is officially registered as extinct; or if it is decided that other species be introduced, these must originate from populations within the nearest biogeographically related freshwater ecoregion (i.e. for the River Blenny, the Southern Anatolian Ecoregion, sensu Abell et al. 2008).

c) Contemporary knowledge of this kind of species restoration work should be organized only after a thorough conservation-relevant study by experienced specialists. This study may include the potential of introducing other species of fish beyond the River Blenny (i.e. Cyprinids, Mediterranean Salmonids). This kind of introduction of relevant biogeographically related species could off-set the indiscriminate dispersal of alien species that is taking place at this time.

Based on the above we recommend the following:

- A survey of the entire island for River Blenny populations in order to establish as soon as is possible if the species is extinct on the island. It must be made clear that the River Blenny may have existed in several small perennial flowing streams in many parts of the island in the past (as it still does on Crete and at least ten other mediterreanean islands). So it is imperative that it is shown that no existing populations may exist before any kind of species restoration campain is begun.
- A specific study on the re-introduction of River Blenny or the specific hatchery-based development of populations for introduction. This must include specific protocols for reintroduction is such rivers as the following: Chrysochou, Germasogeia, Diarizos, Hapotami, Ezousa, Limnitis, Pyrgos.
- A specific study for the potential introduction and regulation of new mediterreanean fish species into Cyprus inland waters in order to regulate the development and evolution of “biogeographically appropriate” fish assemblages in heavily modified water bodies, reservoirs and rivers. It must be said that this should be part of an ecological study that will explore the justification, criteria of selection and provide a protocol for this approach. Biogeographic affinity and regard for local biodiversity must be paramount within the goal of ameliorating introduced biotic assemblages[13].

Recommendation 7

Increase awareness and participation for an ecosystemic understanding of lotic waters, their management and conservation

Cypriot society has generally acquiesced to the degradation of the country’s rivers, in part because there is insufficient knowledge or awareness of the structure and functioning of local river ecosystems and the effects human actions have had on altering these ecosystems. For many years the concept “not at drop to the sea” has created misinterpretations of the natural functioning of rivers and the ecosystem values and conditions that European Directives now strive to restore. Communication and outreach

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[13] The concept of “engineering fish assemblages” in insular depauperate waters that are already infested with non-indigenous species or where species have gone extinct has been poorly explored and is especially relevant on Cyprus where human actions during many millennia of agriculture and species introductions has created biocommunities with many “introduced species”. The human-introduced species assemblages tend to evolve and become naturalized in more natural-functioning assemblages when their source areas are form nearby or neighbouring biogeographic regions. The freshwater ecoregional approach is appropriate here in helping define source areas and model assemblages for re-introduction or introduction.

by scientists and relevant government authorities is vital in creating public awareness and effective participation in restoration and the promotion towards a more effective and sustainable water management.

Biological monitoring in rivers can play an important part in a more integrated water management, and Cyprus should see compliance to the EU WFD procedure as an opportunity broadening the management and conservation of the country's inland waters. Biological data-gathering that is useful for water management and conservation can also affect public awareness and participation if it is disseminated. Utilizing biological quality elements such as fish creates a more integrated management and communications framework whereby the goal is to better understand measure and evaluate the consequences of human actions on aquatic systems.

Specific actions towards this recommendation include the following:

- Promote academic research into the above and involve several stakeholders in survey, monitoring and other aspects. Use the data and experience developed in scientific research work to produce lay man's reports and accessible popularized literature on this poorly known subject. Specific popularized "tools" may include a series of small coffee-table books that illustrate the importance of the fish biota in the rivers of Cyprus. The following are pertinent examples of titles:

A) A book: The Eel in Cyprus
B) A book: Rivers of Cyprus
C) A book: Fishes of the Rivers, Reservoirs and Wetland of Cyprus.

- Utilize the internet to create web-based tools for eduction, awareness and participation in observing river conditions, functioning and recording river biota. Specific citizen science approaches have worked very well in many jurisdictions. Examples may include:

A) A web-based education seminar or River ecology in Cyprus
B) A website that gives information on the rivers and all monitoring and research on rivers and their biota in Cyprus
C) A website that helps local residents participate as "Stream Keepers". These are special care-takers of stream reaches and they are provided with seminars, field protocols etc.

- Fish are a recreational resource and a large number of Cypriots are involved in inland angling in the reservoirs. Many Cypriots relate to fish as potential indicators in rivers and lakes so it is easy to use fish as "flag ships" for a biological understanding of the problems facing surface waters. The Eel, Mediterranean Toothcarp, River Blenny and Brown Trout are four species that are well suited to be used as flagships in conservation, water management, education and restoration campaigns.

Sophisticated electrofishing devises should be used by well trained personnel and in many cases they work even in high conductivity waters that usually impede sampling with electricity. (Sampling must proceed after conductivity measurements and adjustments are made; such as in the high-conductivity waters of the Pediaios).

In a rapid assessment monitoring procedure, sampled fish are measured more rapidly using a “size classes” (i.e. >5, 6-10,11-15,16-20 and so forth) therefore no exact measurements or weighing is involved. An escapee Rainbow Trout, identified from fin-erosion and form a result of being kept in fish farm enclosures (Evrychou Bridge, Kargotis)

When electrofishing is not possible other methods of standard fish data-collection can be employed when qualitative data is of interest. Fry net sampling and trapping fish are easily employed. Fisherman’s catch data is also of use, such as this illegal catch of young Carp at the Polemidia Reservoir (Garyllis).

Fig. 5.2. *Examples of data collection techniques that may be employed within a monitoring scheme.*

BIBLIOGRAPHY

In English

Abell R., Thieme M.L., Revenga C.,Bryer M.,Kottelat M., Bogutskaya N., Coad B., Mandrak N.,Contreras-Balderas S., Bussing W., Stiassny M.L.J.,Skelton P., Allen G.R.,Unmack P.,Naseka A., Ng R., Sindorf N., Robertson J., Armijo E., Higgins J.V., Heibel T.J., Wikramanayake E., Olson D., López H.L., Reis R.E., Lundberg J.G., Sabaj-Pérez M.H. & Petry P. (2008). Freshwater ecoregions of the world: a new map of biogeographic units for freshwater biodiversity conservation. BioScience 58: 403-414.

Adams S.B. & Warren M.L.jr. (2005). Recolonization by warmwater fishes and crayfishes after severe drought in upper coastal plain hill streams. Transactions of the American Fisheries Society 134 (5): 1173–1192. DOI: 10.1577/T04-089.1

Almada V.C., Robalo J.I., Levy A., Freyhof J., Bernardi G. & Doadrio I. (2009). Phylogenetic analysis of Peri-Mediterranean blennies of the genus Salaria: Molecular insights on he colonization of freshwaters. Molecular Phylogenetics and Evolution 52: 424-431.

Anastassiades G. (Unknown date). Fresh water fish culture in Cyprus. Unknown Source.

Angermeier P.L. & Davideanu G. (2004). Using fish communities to assess streams in Romania: initial development of an index of biotic integrity. Hydrobiologia 511: 65-78.

Aparicio E., Carmona-Catot G., Moyle P B. & García-Berthou E. (2011). Development and evaluation of a fish-based index to assess biological integrity of Mediterranean streams. Aquatic Conserv: Mar. Freshw. Ecosyst. 21: 324–337 (2011)

Baier F., Sparrow D.J. & Wiedl H.- J. (2009). The amphibians and reptiles of Cyprus. Edition Chimaira, Frankfurt amMain, Germany.

Banarescu P. (1960). Einige Fragen zur Herkunt und verbreitung der su¨sswa-sserfichfauna der europa¨ich-mediterranen Unterregion. Arch. Hydrobiol. 57 (1/2), 15–134

Bath H. (2003). Salaria fluviatilis (Asso, 1784). Pp. 97–121. In: Miller P.J. (ed.) The freshwater fishes of Europe. Vol. 8/1. Mugilidae, Atherinidae, Atherinopsidae, Blenniidae, Odontobutidea,Gobiidae.AULA-Verlag,Wiesbaden,Germany.

Beaumont WRC. (2011). Electric fishing: a complete guide to theory and practice. Game and Wildlife Trust, UK.

Benejam L., Angermeier P.L., Munne A. & Garcia-Berthou E. (2010). Assessing effects of water abstraction on fish assemblages in Mediterranean streams. Freshwater Biol 55: 628-642.

Benejam L., Aparicio E., Vargas MJ., Vila-Gispert A. & García-Berthou E. (2008). Assessing fish metrics and biotic indices in a Mediterranean stream: effects of uncertain native status of fish. Hydrobiologia 603: 197–210.

Bianco P.G., Ahnlet H. & P.S. Economidis (1996). The freshwater fishes from Eastern, and Large Mediterranean Islands with comments on their safety status. Acta Universitalis Carolinae-Biologica 40: 45-60.

Böhme W. & Wiedl H. (1994). Status and Zoogeography of the Herpetofauna of Cyprus with taxonomic and natural history notes on selected species (Rana, Coluber, Natrix, Vipera). Zoology in the Middle East 10: 31-52.

Bonar S.A. & Hubert W.A. (2002). Standard sapling of inland fish: benefits, challenges and a call for action. Fisheries 27(3):10-16.

Bonar S.A., Hubert W.A & Willis D.W. (2009). The North American Freshwater fish standard sampling project: improving fisheries communication. Fisheries 34 (7):340-344.

Bond N.R., Lake P.S. & Arthington A.H. (2008). The impact of droughts on freshwater ecosystems: an Australian perspective. Hydrobiologia 600:3–16. doi:10.1007/s10750-008-9326-z

Bunn S.E. & Arthington A.H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environ Manage 30(4): 492–507.

Caissie D. (2006). The thermal regime of rivers: a review. Freshwater Biology, 51: 1389-1406.

Champ, W.S.T., Kelly, F.L. and King, J.J. (2009). The Water Framework Directive: using fish as a management tool. Biology and Environment:Proceedings of the Royal Irish Academy 109B, 191–206.

CES/EIFAC (2006). Working Group on Eels, Report. Rome 23 27 January 2006. ICES CM 2006/ACFM:16.

Charalambidou I., Gucel S., Kassinis N., Turkseven N., Fuller W., Kuyucu A. & Yorganci H. (2008). Waterbirds in Cyprus 2007/08. Unit of Environmental Studies (Cyprus Center of European and International Affairs). UES-CCEIA/TCBA/CGF, Nicosia, Cyprus.

Charalambidou I. & Gucel S. (2009). Index of flora, fauna, biodiversity and nature conservation in Cyprus. UES-CCEIA/ESI/TCBA/GAG/, Nicosia, Cyprus.

Clarke K.R. & Warwick R.M. (1994). Similarity-based testing for community pattern: the two-way layout with no replication. Marine Biology, 118, 167–176.

Constantinides, ?. (Undated). Freshater fishing in Cyprus. Challenges and opportunities.

Constantinou, K.(1998). Anopheles (malaria) eradication in Cyprus. Parassitologia. 40(1-2):131-5

Copp G.H., P.G. Bianco, N.G. Bogutskaya, T. Eros, I. Falka, M.T. Ferreira, M.G. Fox, J. Freyhof, R.E. Gozlan, J. Grabowska, V. Kovac, R. Moreno-Amich, A.M. Naseka, M. Penaz, M. Povz, M. Przybylski, M. Robillard, I.C. Russell, S. Stakenas, S. Sumer, A. Vila-Gispert & C. Wiesner (2005). To be, or not to be, a non-native freshwater fish? Journal of Applied Ichthyology 21 (4): 242-262.

Côté M., Vinyoles D., Reynolds J.D., Doadrio I. & Perdices A. (1999). Potential impacts of gravel extraction on Spanish populations of river blennies Salaria fuviatilis (Pisces, Blenniidae). Biological Conservation 87 (3): 359–367. DOI: 10.1016/S0006-3207(98)00072-X

Council Regulation (EC), 2007/No 1100: of establishing measures for the recovery of the stock of European Eel: 23 p.

Crowder L.B. (2005). Back to the future in marine conservation. In: Marine Conservation Biology: The science of maintaining the sea's biodiversity (eds: Norse, E.A., and Crowder, L.B.). Pp. 19-29, Marine Conservation Biology Institute/ Island Press.

Cyprus Aquaculture Production Businesses (????). Interner-Based information page in accordance with article 59 of Directive 2006/88/EC and of Commission Decision 2008/392/EC, 38pp.

Davis A.J., Jenkinson L.S., Lawton J.L., Shorrocks B. & Wood S. (1998). Making mistakes when predicting shifts in species range in response to global warming. Nature 391 (6669): 783–786. DOI: 10.1038/35842

Dekker W. (2000). "A Procrustean assessment of the European Eel stock." ICES Journal of Marine Science 57(4): 938.

Demetropoulos A. & Neocleus D. (1969). The fishes and Crustaceans of Cyprus. Fisheries Bull.. no. 1: 1-21.

Doadrio and Bohme, unpublished; cited in: Doadrio I. & Carmona J.A. (2004) Phylogenetic relationships and biogeography of the genus Chondrostoma inferred from mitochondrial DNA sequences. Molecular Phylogenetics and Evolution, 33: 802–815

Dorow M., Beardmore B., Haider W. & Arlinghaus R. (2009). Winners and losers of conservation policies for European Eel, Anguilla anguilla: an economic welfare analysis for differently specialised Eel anglers. Fisheries Management and Ecology 17: 106–125

Dudgeon D., Arthington A.H., Gessner MO, Kawabata Z.I., Knowler D.J, Leveque C., Naiman R.J., Prieur-richard A.H., Soto D., Stiassny M.L.J. & Sullivan C.A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews 81: 163–182.

EC (2000). Water Framework Directive, 2000/60/EC.

EC (2005). Proposal for the recovery of the European Eel stock, COM(2005) 472.

Economou A.N. (2002). Defining reference conditions (WP3). Development, evaluation & implementation of a standardised fish-based assessment method for the ecological status of European rivers: A contribution to the Water Framework Directive. FAME project. http://fame.boku.ac.at/downloads/D3_reference_ conditions.pdf.

Economou A.N., Zogaris S., Chatzinikolaou Y., Tachos V., Giakoumi S., Kommatas D., Koutsikos N., Vardakas L., Blasel K. & Dussling U. (2007). Development of an ichthyological multimetric index for ecological status assessment of Greek mountain streams and rivers. Technical Report. Hellenic Center for Marine Research – Institute of Inland Waters / Hellenic Ministry for Development. Main Document: 166 pp. Appendices: 189 pp. ISBN: 978-960-98054-0-7.

Economou A.N., Zogaris S., Giakoumi S., Barbieri R. & Petridis D. (2003). Developing a biotic river typology and defining reference conditions in the rivers of Greece: a spatially-based approach. EESD Project: Development, Evaluation & Implementation of a Standardized Fish-based Assessment Method for the Ecological Status of European Rivers (FAME). Work Package 6, 35 pp.

EFI+ Consortium (2009). Manual for the application of the new European Fish Index – EFI+. A fish-based method to assess the ecological status of European running waters in support of the Water Framework Directive. Available at http://efi-plus.boku.ac.at/software/doc/EFI+Manual.pdf

Elvira B. (2001). Identification of non-native freshwater fishes established in Europe and assessment of their potential threats to the biological diversity. Convention on the conservation of European Wildlife and Natural Habitiats Standing Committee 21st meeting, 21pp.

FAME (2005). Fish-based Assessment Method for the Ecological Status of European Rivers – A Contribution to the Water Framework Directive. Final Report; Manual for the application of the European Fish Index – EFI, pp 41

Farrugio H. (2010). Elements of biology of the european Eel and factors affecting its population in the Mediterranean and Eastern Atlantic. GFCM Scientific Advisory Committee Transversal workshop on European Eel in the GFCM area Salammbo,Tunisia/23–24 September 2010. 10 pp.

Fatta,F., C. Michaelb,St. Canna-Michaelidoub, M. Christodoulidou, N. Kythreotoua,M. Vasquez. 2007. Pesticides, volatile and semivolatile organic compounds in the inland surface waters of Cyprus. Desalination 215 (2007) 223–236

Ferreira T., Oliveira J., Caiola N., Sostoa A., Casals F., Cortez R., Economou A.N., Zogaris S., Garcia-Jalon D., Ilheu M., Martinez Capel F., Pont D., Rogers C. & Prenda J. (2007). Ecological traits of fish assemblages from Mediterranean Europe and their responses to human disturbance. Fisheries Manag Ecol 14: 473- 481.

Foufopoulos J, Kilpatrick AM, Ives AR. (2011). Climate change and elevated extinction rates of reptiles from Mediterranean Islands. American Naturalist, 177(1):119-129.

Freyhof J. & Kottelat M. (2008). Anguilla anguilla. In. IUCN. 2010 The IUCN Red List of threatened species. Version 2010.1. www.iucnredlist.org. Downloaded on 10 April 2010.

Gallart F., Y. Amaxidis, P. Botti, G. Cane, V. Castillo, P. Chapman, J. Froebrich, J. Garcia-Pintado, J. Latron, P. Llorens, A. Lo Porto, M. Morais, R. Neves, P. Ninov, J.L. Perrin, I. Ribarova, N. Skoulikidis & M.G. Tournoud (2008). Investigating hydrological regimes and processes in a set of catchments with temporary waters in Mediterranean Europe. Hydrological Sciences Journal 53(3): 618-628.

Gasith A. & Resh V.H. (1999). Streams in Mediterranean climate regions: abiotic influences and biotic responses to predictable seasonal events. Annual Review of Ecology and Systematics 30, 51–81.

Geiger W., Alcorlo P., Baltana´s A. & Montes C. (2005). Impact of an introduced crustacean on the trophic webs of Mediterranean wetlands. Biological lnvasions 7: 49-73.

Geological Survey Department (1970). Hydrogeological map of Cyprus. Compiled by N.H.O. Tullstrom. Govt. Of Cyprus. Printed by D.Couvas & Sons Ltd, Limassol, Cyprus.

GHK (2006). Strategic evaluation on environmental and risk prevention under structural and cohesion funds for the period 2007-2013. National Evaluation report for Cyprus/ Directorate General Regional Policy. Contract No. 2005.CE.16.0.AT.016. 104 pp. Available online at: http//ec.europa.eu/regional_ policy/sources/docgener/evaluation/pdf/evalstrat_env/cy_main.pdf

Godinho F.N. & M.T. Ferreira (1994). Diet composition of largemouth black bass, Micropterus salmoides (Lacepède), in southern Portuguese reservoirs: its relation to habitat characteristics. Fisheries Management and Ecology 1: 129–137.

Godinho F.N., Ferreira M.T. & Santos J.M. (2000). Variation in fish community composition along an Iberian river basin from low to high discharge: relative contributions of environmental and temporal variables. Ecology of Freshwater Fish, 9: 22-29.

Godinho, F.N. & Ferreira, M.T. (1998). The relative influence of exotic species and environmental factors on an Iberian native fish community. Environmental Biology of Fishes 51, 41–51.

Gordon N.D., Mcmahon T.A., Finlayson B.L., Gipple C.J., Nathan R.J. (2004). Stream hydrology: An introduction for ecologists, 2nd edn. John Wiley & Sons Ltd., West Sussex.

Hadjisterikotis E. (Date Unrecorded). Review of biodiversity research results from Cyprus that directly contribute to the sustainable use of biodiversity in Europe. Unpublished report. Unit of Environmental Studies, Research Center – Intercollege. 29 p.

Hadjisterikotis E., Masala B. & D.S. Reese (2000). The origin and extinction of the large endemic Pleistocene mammals of Cyprus. Biogeographia XXI (2000), 593-606.

Hartje V., & Klaphake, A. (2006). Implementing the Ecosystem Approach for Freshwater Ecosystems – A case study on the Water Framework Directive of the European Union. Bundesamt für Naturschutz (BfN), Federal Agency for Nature Conservation.

Henrichs T. & J. Alcamo (2001). Europe's water stress today and in the future In: B. Lehner, T. Henrichs, P. Döll and J. Alcamo: EuroWasser - Model-based assessment of European water resources and hydrology in the face of global change. Kassel.

Holway, R.T. Pesticides and Public Health in Pacific Areas. Bioscience Vol. 14, No. 11, Nov., 1964

European Commission. (2009). Commission Decision 2009/310/EC of 2 April 1009 approving requests by Cyprus, Malta, Austria, Romania and Slovakia for exemption from the obligation to prepare an Eel Management Plan in accordance with Council Regulation (EC) No 1100/2007.

European Commission. (2007). Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel. Official Journal of the European Union L, 248(17), 22-9.

FAO. © 2004-2011. Cultured Aquatic Species Information Programme. Anguilla anguilla. Cultured Aquatic Species Information Programme. Text by The Danish Aquaculture Development Group (DANAQ). In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 1 January 2004.

Freyhof, J. & Kottelat, M. 2008. Anguilla anguilla. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <www.iucnredlist.org>. Downloaded on 07 July 2011.

ICES (2006). Report of the joint EIFAC/ICES Working Group Eel (WGEEL), 23–27 January 2006, Rome, Italy. ICES Document CM 2006/ACFM: 16. Available at http://www.ices.dk/reports/ACFM/2006/WGEEL/WGEEL06.pdf

ICES. 2008. Report of the ICES Advisory Committee, 2008. ICES Advice, 2008. Book 9. 345 pp.

ICES. 2009. Report of the ICES Advisory Committee, 2009. ICES Advice, 2009. Book 11. 71 pp.

ICES (2002). Cooperative Research Report no. 255.

ICES (2003). Report of the ICES Advisory Committee on Fishery Management

ICES (2006). Report of the ICES Advisory Committee on Fishery Management

ICES (2007). Status of introductions of non-indigenous marine species to the North Atlantic and adjacent waters 1992–2002. ICES Cooperative Research Report No. 284. 149 pp.

IMPASSE (2007). Environmental impacts of alien species in aquaculture. Sustainable Management of Europe's Natural Resources - Project no.: 044142, Deliverable 1.3, 26pp.

Jackson J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J. M. Pandolfi, C.H.

Peterson, R.S. Steneck, M.J. Tegner & R. Warner (2001). Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629-638.

Jacobson P.J., Jacobson K.M., Angermeier P.L. & Cherry D.S. (2004). Variation in material transport and water chemistry along a large ephemeral river in the Namid Desert. Freshwater Biol 44:481–491. doi:10.1046/j.1365-2427

Karr J.R. & Chu E.W. (1999). Restoring Life in Running Waters: Better Biological Monitoring. Island Press, Washington D.C. ISBN 1–55963–674–2, 206 pp.

Karr J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant & I.J. Schlosser (1986). Assessment of Biological Integrity in Running Waters: A Method and its Rationale. Illinois Natural History Survey Special Publication 5, Champaign, Illinois.

Kennard M.J., Arthington A.H., Pusey B.J. & Harch B.D. (2005). Are alien fish a reliable indicator of river health? Freshwater Biology 50: 174–193.

Kettle A.J., D. Heinrich, J.H. Barrett, N. Benecke & A. Locker (2008). Past distributions of the European freshwater Eel from archaeological and palaeontological evidence, Quaternary Science Reviews, 27, 1309–1334.

Klohn W. (2002). Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus , Water Development. Food and Agriculture Organization of the United Nations Land and Water Development Division tcp/cyp/8921 tcp/cyp/2801. Reassessment of the island's water resources and demand synthesis report.

Lake P.S. (2003). Ecological effects of perturbation by drought in flowing waters. Freshwater Biol 48: 1161–1172. doi: 10.1046/j.1365-2427

Larned S., Arscott D., Datry T. & Tockner K. (2008). Special Session - Intermittent Rivers: Global Phenomena and Unexplored Riverscapes I. The North American Benthological Society 56th Annual Meeting, 25-28 May, 2008

Larned S., Datry T., Arscott D. & Tockner K. (2010). Emerging concepts in temporary-river ecology. Freshwater Bioloγυ 55(4): 717–738. doi:10.1111/j.1365-2427.2009.02322.x

Lawson J., R. Darling, D. Penrose & J.D. Gregory (2002). Stream Identification and Mapping for Water-Supply Watershed Protection. In Proceedings, Watershed 2002, February 23-27, 2002, Fort Lauderdale, FL.

Legendre P. & Legendre L. (1998). Numerical Ecology. 2nd ed. Elsevier, Amsterdam

Leopold L. (1994). A view of the river. Harvard University Press.

Levick L., J. Fonseca, D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Scianni, D. P. Guertin, M. Tluczek & W. Kepner (2008). The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center, EPA/600/R-08/134, ARS/233046, 116 pp.

Magalhaes M.F., Beja P., Schlosser I.J. & Collares-Pereira M.J. (2007). Effects of multi-year droughts on fish assemblages of seasonally drying Mediterranean streams. Freshwater Biol 52: 1494–1510.

Magoulick D.D. & Kobza R.M. (2003). The role of refugia for fishes during drought: a review and synthesis. Freshwater Biol 48: 1186–1198.

Mathews W.J. (1998). Patterns in freshwater fish ecology. Chapman & Hall, New York

Miller P.J. (2003). The Freshwater Fishes of Europe Volume 8, Part I: Mugilidae, Atherinidae, Atherinopsidae, Blenniidae, Odonotbutdae, Gobiidae 1. Aula Verlag.

Moss, B. (2008). The Water Framwork Directive: Total environmenet or political compromise? Science of the Total Environment, 400:32-41.

Moyle P.B. & Light T. (1996). Fish invasions in California: do abiotic factors determine success? Ecology 77, 1666–1670.

Moyle P.B. & R.M. Yoshiyama (1994). Protection of Aquatic Biodiversity in California - a 5-Tiered Approach. Fisheries 19 (2): 6-18.

Moyle P.B. & Randall P.J. (1998). Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. Conservation Biology 6: 1318–1326.

Moyle P.B., Marchetti M.P., Baldrige J. & Taylor T.L. (1998). Fish health and diversity: justifying flows for a California stream. Fisheries 23: 6–15.

Muus B.J. & Dahlstroem P. (1971). Freshwater fishes of Britain and Europe. Collins Sons and Co. (New edition 1978).

NC Division of Water Quality (2005). Identification Methods for the Origins of Intermittent and Perennial streams, Version 3.1. North Carolina Department of Environment and Natural Resources, Division of Water Quality. Raleigh, NC.

OSPAR 2010. Background Document for European eel Anguilla Anguilla. Biodiversity Series.

Pandey, S. D., Virendra Misra & P. N. Viswanathan (1986). Effect of environmental pollutants on wildlife — a survey, International Journal of Environmental Studies, 28:2-3, 169-177

Pawson M.G., Tingley D., Padda G. & H. Glenn (2007). EU contract FISH/2004/011 on "Sport Fisheries" (or Marine Recreational Fisheries) in the EU. Final Report for The European Commission Directorate-General for Fisheries, 238 pp.

Pintér K. (2004). Future of the inland fisheries and aquaculture in the enlarged Europe. PROFET Workshop "Inland fisheries and freshwater aquaculture". 20-21. February 2004 – Budapest, Hungary, 7pp.

Plötner J, Baier F, Akın C, Mazepa G, Schreiber R, Beerli P, Litvinchuk SN, Bilgin CC, Borkin L, Uzzell T. (2012). Genetic data reveal that water frogs of Cyprus (genus Pelophylax) are an endemic species of Messinian origin. Zoosystems and Evolution, 88(2):261–283.

Prado, I. et al. (2012). The European refrence condition concept: A scientific and technical approach to identify minimally-impacted river ecosystems. Science of the Total Environment, 420: 33-43.

Pullin R.S.V., Palomares M.L., Casal C.V., Dey M.M. & D. Pauly (1997). Environmental impacts of tilapias, p. 554-570. In (K. Fitzisimmons, Editor) Tilapia Aquaculture. Proceedings from the Fourth International Symposium on Tilapia in Aquaculture, Volume 2. Northeast Regional Agricultural Engineering Service (NRAES) Cooperative Extension, Ithaca, New York. 808 p.

Rackham O. & Moody J. (1996). The making of the Cretan landscape. Manchester University Press.

Ryder D.S. & Boulton A.J. (2005). Redressing the limnological imbalance: trends in aquatic ecology, management and conservation in Australia. Hydrobiologia 552:159–166. doi:10.1007/s10750-005-1513-6

Shine C., Kettunen M., Genovesi P., Gollasch S., Pagad S. & Starfinger U. (2008). Technical support to EU strategy on invasive species (IAS) – Policy options to control the negative impacts of IAS on biodiversity in Europe and the EU (Final module report for the European Commission). Institute for European Environmental Policy (IEEP), Brussels, Belgium. 104 pp. + Annexes.

Skoulikidis N. (editor), A. Economou, I. Karaouzas, L. Vardakas, K. Gritzalis, S. Zogaris, E. Dimitriou & V. Tachos (2008). Hydrological and Biogeochemical Monitoring in Evrotas Basin. Final Technical Report 1, H.C.M.R. LIFE-ENVIRONMENT: LIFE05 ENV/GR/000245 «ENVIRON-MENTAL FRIENDLY TECHNOLOGIES FOR RURAL DEVELOPMENT.

Skoulikidis N.T., Vardakas L., Karaouzas I. Economou A.N., Dimitriou E. & Zogaris S. (2011). Assessing water stress in a Mediterranean lotic system: insights from an artificially intermittent river in Greece. Aquatic Sciences.

Smith K.G. & W.R.T. Darwall (2006). The status of Freshwater fish endemic to the Mediterranean basin. Gland, Switzerland and Cambridge.

Stephanou D. (1988a). Twenty years of experience in managing Cyprus reservoirs for angling. Editors: Densen, W.L.T. van, Steinmetz, B., Hughes, R.H. Management of freshwater fisheries: proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988.

Stephanou D. (1988b) The cage culture of rainbow trout, Salmo gairdneri, Richardson in Cyprus dams. Second Session of the EIFAC Working Party on Fish-Farm Effluents. Verona, Italy, 10–12 October 1988.

Stephanou D. (1998). Country Report: Cyprus. Department of Fisheries and Marine Research, Ministry of Agriculture, Natural Resources and the Enviroment. Nicosia, Cyprus, Freshwater aquaculture. CIHEAM - Options Mediteraneennes p. 303-326.

Stephanou D. (2007). Review of Aquaculture development in Cyprus. Unpublished report.

TempQsim Consortium (2006). Critical issues in the water quality dynamics of temporal rivers – evaluation and recommendations of the tempQsim project. In: Froebrich J, Bauer M (Eds.), Enduser Summary. Hannover, Germany

Thirgood J.V. (1987). Cyprus: a chronicle of its forests, land and people. University of British Columbia Press.

Theocharis M., Zogaris S., Economou A.N., Kapsimalis V. & Dimopoulos P. (2004). Restoration actions and monitoring at a Mediterranean river floodplain wetland: the Amvrakikos case-study. V International Symposium on Ecohydraulics "Aquatic Habitats: Analysis & Restoration", 11-17 Madrid Spain. IAHR Congress Proceedings, Vol. I: 582-588.

Torcu H., Aka Z. & İşbilir A. (2001). An investigation on fishes of "Turkish Republic of Northern Cyprus" [sic]. Turk J Vet . Anim. Sci., 25: 155-159.

Uys M.C. & J.H. O'keeffe (1997). Simple Words and Fuzzy Zones: Early Directions for Temporary River Research in South Africa. Environmental Management 21(4): 517–5

Vandekerkhove J. & Cardoso A.C. (2010). Alien species and the Water Framework Directive: Questionnaire results. European Commission Joint Research Centre, Institute for Environment and Sustainability. JRC 56502, EUR 24257 EN. ISBN 978-92-79-15053-1 ISSN 1018-5593, DOI 10.2788/64083.

Vardakas L., Tachos V., Zogaris S., Kommatas D., Koutsikos N., Chatzinikolaou Y., Skoulikidis N., Koutsoubas D. & Economou A. (2009). A fish-based index for assessing the biotic integrity of the Evrotas River (Greece). 11th ICZEGAR, 21-25 September 2009, Herakleion, Greece, Book of Abstracts p. 199.

Vila-Gispert A., García-Bertou E. & Moreno-Amich R. (2002). Fish zonation in a Mediterranean stream: effects of human disturbances. Aquatic Sciences 64, 163–170.

Dekker W. (2003). On the distribution of the European Eel (Anguilla anguilla) and its fisheries Can. J. Fish. Aquat. Sci./J. can. sci. halieut. aquat. 60(7): 787-799.

Waelkens, M., Poblome, J. Mumford G. et al., (2004) “Fish remains from archaeological sites as indicators of former trade connections in the Eastern Mediterranean”, Paléorient, vol. 30, no. 1, pp. 101-147,.

Wirth, M. C., and G. P. Georghiou. (1996). Organophosphate resistance in Culex pipiens from Cyprus. J. Am. Mosq. Control Assoc. 12:112–118.

Xenopoulos M.A. & D.M. Lodge (2006). Going with the flow: Using species-discharge relationships to forecast losses in fish biodiversity. Ecology 87 (8): 1907-1914.

Zenetos A., Pancucci-Papadopoulou M.A., Zogaris S., Papastergiadou E., Vardakas A.L., Aligizaki K. & Economou A.N. (2009). Aquatic alien species in Greece (2009): Tracking sources, patterns and effects on the ecosystem. Journal of Biological Research -Thessaloniki 12: 135 – 172.

Zogaris S., Chatzinikolaou Y., Koutsikos N., Oikonomou E., Economou A.N., Giakoumi S. & Ferreira M.T. (2011). Historical information and information on previous work done regarding fish in the rivers of Cyprus, and pre-selection of sampling sites. Hellenic Center for Marine Research / Instituto Superior de Agronomia, Universidade Técnica de Lisboa. Unpublished Report; Contract No. TAY 49/2010. Water Development Department, Republic of Cyprus.

Zogaris S., Y. Chatzinikolaou, E. Oikomonou, N. Koutsikos, L. Vardakas, S. Giakoumi, W.R. Baeumont & A.N. Economou (2012). Inland Fishes of Cyprus: Site-specific assemblages and distributions. 12th International Congress on Zoogeography and Ecology of Greece and the Adjacent Regions; Abstracts, 2000.

Zogaris S., Y. Chatzinikolaou, N. Koutsikos, A.N. Economou, E. Oikomonou, G., Michaelides, E. Hadjisterikotis, W.R. Baeumont & M.T. Ferreira (2012). Freshwater fish assemblages in Cyprus with emphasis on the effects of dams. Acta Ichthyologica et Piscatoria 42(3): 165-175.

Zogaris,S., Maclaine, J., Koutsikos, N., and Chatzinikolaou, Y. (2013). Does the River Blenny Salaria fluviatilis *(Asso, 1801) still survive on the Mediterranean island of Cyprus? (Submitted to the Journal of Natural History, In Review).*

In Greek

Ανώνυμος (2005). Ερευνητικός Σταθμός Καλλιέργειας Γλυκού Νερού Καλοπαναγιώτη. ΤΑΘΕ. Φυλλάδιο, 6 σελ.

Ζόγκαρης Σ. (2009). Συμβολή στη βιοτική ταξινόμηση των ποταμών της Ελλάδας με βάση την ιχθυοπανίδα και την παρόχθια βλάστηση. Διδακτορική Διατριβή. Πανεπιστήμιο Ιωαννίνων, Σχολή Διαχείρισης Φυσικών Πόρων και Επιχειρήσεων, Τμήμα Διαχείρισης Περιβάλλοντος και Φυσικών Πόρων. 422 σελ.

Ζόγκαρης Σ. (2012). Τα ψάρια στα εσωτερικά νερά της Κύπρου. Η Φύση, 135:38-41.

Ζώτος, Σ. (2006). Σημαντικές Περιοχές για τα Πουλιά της Κύπρου. Πτηνολογικός Σύνδεσμος Κύπρου. Ίδρυμα Λεβέντη. 132 σελ.

Κασίνης, Ν. (2009). Οι δραστηριότητες του Ταμείου Θήρας. Οιωνός (ΕΟΕ), 36:18-19.

Κουρτελλαρίδης Λ. (1990). Αποστολή «Μαύροι Κρεμμοί 29.5.1990». Δασικοί Θησαυροί, Τόμος XXXV: 37-43.

Κουρτελλαρίδης,Λ. (1997). Τα πουλιά που φωλιάζουν στην Κύπρο. Συγκρότημα Τράπεζας Κύπρου.

Ιωάννου, Γ & Μιχαηλίδης, Ν. (2011). Τα 100 σημαντικότερα είδη ψαριών των Κυπριακών θαλασσών. Τμήμα Αλιείας και Θαλασσίων Ερευνών, Υπουργείο Γεωργίας, Φυσικών Πόρων και Περιβάλλοντος. Λευκωσία. 110 σελ.

Οικονόμου Α.Ν., Μπαρμπιέρι Ρ., Στουμπούδη Μ., Νταουλάς Χ., Ψαρράς Θ., Γιακουμή Σ., & Παπαδάκης Β. (2001). Εκτίμηση της οικολογικής ποιότητας των εσωτερικών νερών με ιχθυοδείκτες. 10ο Πανελλήνιο Συνέδριο Ιχθυολόγων, Χανιά, 18-20 Οκτωβρίου, 297-300.

Οικονόμου Α.Ν., Ζόγκαρης Σ., Χατζηνικολάου Γ., Τάχος Β.Α., Γιακουμή Σ., Κομματάς Δ., Κούτσικος Ν., Βαρδάκας Λ., Blasel K. & Dussling U. (2007). Δημιουργία Ιχθυολογικού Πολυπαραμετρικού Δείκτη για την Εκτίμηση της Οικολογικής Κατάστασης Ορεινών Ρεμάτων και Ποταμών. Ελληνικό Κέντρο Θαλασσίων Ερευνών – Ινστιτούτο Εσωτερικών Υδάτων. Υπουργείο Ανάπτυξης, Δ/ση Υδατικού Δυναμικού & Φυσικών Πόρων. Κύριο Τεύχος 115 σελ. - Παραρτήματα 189 σελ.

Οικονόμου Α.Ν., Ζόγκαρης Σ., Χατζηνικολάου Γ., Γιακουμή Σ., Τάχος Β., Βαρδάκας Λ., Σκουλικίδης Ν., Δημητρίου Η., Μουσούλης Η. & Ε. Οικονόμου (2009). Μελέτη Ιχθυοπανίδας και προτάσεις για την διατήρησή της στην περιοχή του Υ/Η Έργου Ιλαρίωνα. ΔΕΗ Δ/ση Ανάπτυξης Εργών/ Ινστιτούτο Εσωτερικών Υδάτων, ΕΛΚΕΘΕ.

Παντελάς Β.Σ. (1996). Το Κυπριακό βιόκλιμα και οι καταληκτικές φυτοκοινωνίες. Δασικοί Θησαυροί, Τόμος 1996: 41-49.

Πανεπιστήμιο Frederick (2012). Ετοιμασία στρατιγικής για την βιοποικιλότητα στην Κύπρο. Κεφάλαιο 4: Στόχοι και μέτρα για τη διατήρηση της βιοποικιλότητας. Μελέτη σε εξέλειξη.

Πατσιάς Χ.Γ. (2003). Συριανοχώρι τη 18.2.1948. Δασικοί Θησαυροί Τόμος 2003: 38.

Περδίκης Γ. (1995). Τα παλιά πέτρινα γεφύρια: Το γεφύρι του Κελεφού (Τζιελεφού). Δασικοί Θησαυροί, Τόμος 1995: 19-22.

Στροφύλας Δ. & Παπαδοπούλου Α. (2010). Ξένα είδη - εισβολείς. Ένα οδοιπορικό της παγκόσμιας διασποράς χωροεπεκτατικών ειδών… ΚΠΕ Δραπετσώνας, σ. 201."

Τσιντίδης, Τ.Χ., Χατζηκυριακου, Γ.Ν., & Χριστοδούλου, Χ.Σ. (2002). Δέντρα και θάμνοι στην Κύπρο. Φιλοδασικός Σύνδεσμος Κύπρου / Ιδρυμα Α.Γ. Λεβέντη.

Χατζηνικολάου, Γ. (2007). Επίδραση διαχειριστικών πρακτικών στην ποιότητα νερού και στην οικολογία των ποταμών της Ελλάδας: Ο Πηνειός (Θεσσαλίας) ως ειδική περίπτωση μελέης. Διδακτορική Διατριβή, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης. Σχολή Θετικών Επιστημών, Τμήμα Βιολογίας-Τομέας Ζωολογίας. 229 σελ.

Χατζηνικολάου, Γ. (2001). Παρακολούθηση της οικολογικής ποιότητας των νερών και της δομής των ενδιαιτημάτων του ποταμού Αξιού. Μεταπτυχιακή Διατριβή. Μεταπτυχιακό Πρόγραμμα Περιβαλλοντικής Βιολογίας. Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης. Σχολή Θετικών Επιστημών, Τμήμα Βιολογίας. 130 σελ.

Χατζηχαραλάμπους Ε., Β. Τσιαούση και Μ. Κατσακιώρη (2006). Οδηγίες εκπόνησης σχεδίων διαχείρισης των περιοχών του Δικτύου NATURA 2000 στην Κύπρο. Ελληνικό Κέντρο Βιοτόπων-Υγροτόπων. Θεσσαλονίκη.

Internet

www.fishbase.org. Accessed 19 May 2011

www.fao.org. Accessed 19 May 2011

www.fishwise.co.za. Accessed 19 May 2011

www.sustainableeelgroup.com. Accessed 19 May 2011

foodmuseum.cs.ucy.ac.cy. Accessed 20 November 2012 (concerning Eels in Cyprus cooking)

www.piramaanadasosisviklas.info/eels-and-egg . Accessed 20 November 2012 (concerning Eels in Cyprus cooking)

APPENDIX

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1. Table 1. Research team & Acknowledgements
2. Fig. 1, 2. Activities Schedule and time chart and organization scheme.
3. Table 2. GIS Data sources and fields developed.
4. Fig. 3 Protocols & Field Sheets
5. Table 3. List of sampled sites.
6. Table 4. Anthropogenic pressures at sites.
7. Table 5. Fishes collected at electrofishing sites
8. Summary 1. An Heuristic List of Inland Water Fishes of Cyprus

Research team

Researcher	*Position in Project Team*
Dr. Stamatis Zogaris	*Expert 2 Project Manager (Geographer-Biologist)*
Dr. Maria Teresa Ferreira	*Expert 1 Scientifically responsible expert (Hydrobiologist)*
Dr. Yorgos Chatzinikolaou	*Environmental Scientist-Biologist (Potamologist)*
Nicholaos Koutsikos	*Ichthyologist*
Sofia Giakoumi	*Ichthyologist*
Vassilis Tachos	*Agronomist-Ichthyologist*
Yannis Kapakos	*Ichthyologist*
Dr. Alcibiades Economou	*Hydrobiologist- Ichthyologist*
Leonidas Vardakas	*Ichthyologist*
Dr. Nikolaos Skoulikidis	*Hydrogeologist*
Dr. Eleni Kalogianni	*Biologist-Historian*
Dr. Pedro Segurado	*Biologist*
Dr. Jose Maria Santos	*Ichthyologist*

Other Experts/ Field workers involved in the work:

Elena Oikonomou	*Water Management Expert, MSc Water Management*
William Beaumont	*Fish Ecologist – Electrofishing Sampling Expert (Game & Wildlife Conservation Trust, UK)*
Aris Vidalis	*Photographer-Environmental Interpretation Expert (Biodiversity East)*
Vasilis Hatzirvassanis	*Forester - Environmental Interpretation Expert (Biodiversity East)*
Roberta Barbieri	*Ichthyologist (HCMR)*

Field work assistance

It goes without saying that collecting samples of fishes in streams is an easy and enjoyable field venture, however several people with local knowledge usually become envolved if the a nation-wide survey is to be successful. In this case, we employed the efforts of over 15 people who went out of their way to volunteer and assist and be part of the field survey team. We are extremely grateful to the following persons who assisted in the field work:

Gerald Dőrflinger (WDD), Iakovos Tzortzis (WDD), Haris Nikolaou (Forest Department) Elli Tsirkali (Frederick University), Savvas Zotos (Frederick University), Evagoras Isaias (Pafos), Epaminontas Giannouris (Lefkosia), Paraskevi Manolaki (Paralimni), Georgos Michaelides (Pafos), Athina Papatheodopoulou (Terra Cypria), Lefkios Sergides (Terra Cypria), Salih Gucel (Middle East Technical University), Ioulianos Pantelides (DFMR), Kostantinos Moustakas (DFMR), Dimitris Zogaris (from Athens), Vassiliki Vlami (from Athens).

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Finally we must extend our appreciation to three volunteer field workers who became involved in the project after it had officially begun, Mr. WRC Beaumont, Aris Vidalis and Vasilis Hatzirvassanis provided their assistance during many days of field work. Dimitris Zogaris also participated in field sampling in the spring of 2010 and 2012.

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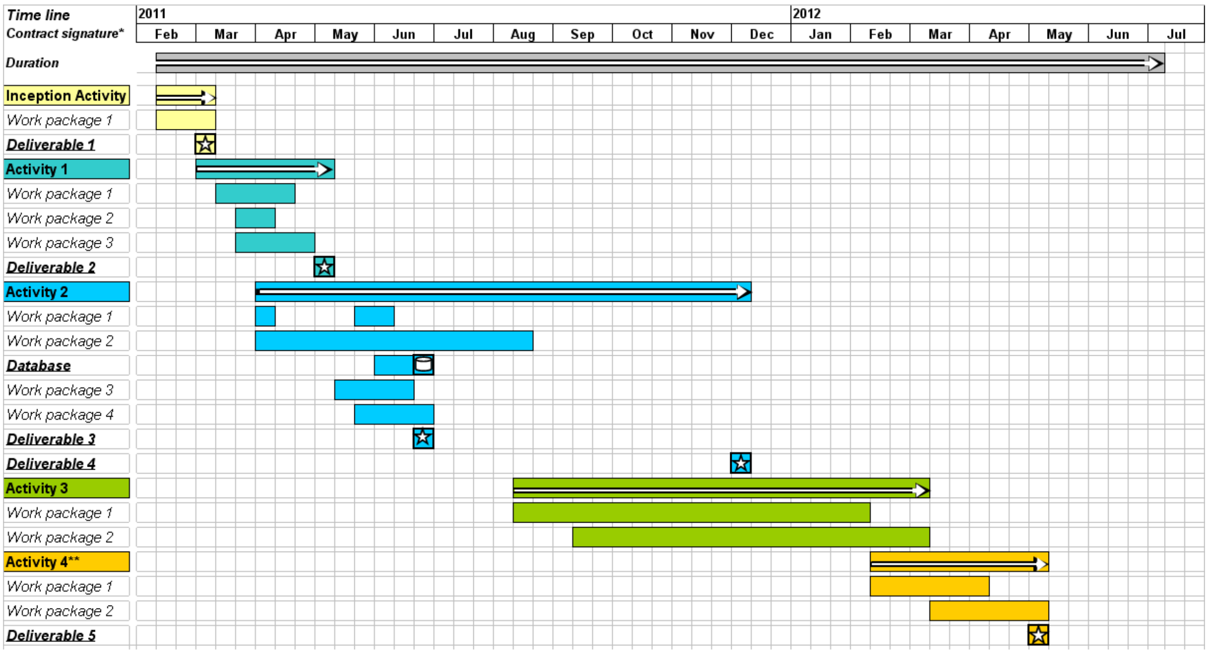
We thank Dr. Takis Tsintidis of the Forestry Service for hospitality and field support during our extensive field surveys. We are grateful to Smith-Root Inc. (Vancouver, Washington USA) for the free loan of their new LR-24 Backpack Electrofisher during the entire course of field sampling in the Spring-Summer of 2011.

Finally, we want to thank Dr. Radek Sanda from The Prague Museume (curator of Ichthyology) and Dr. Jorg Freyhof for examining material and photographs of fish specimens from Cyprus in order to confirm identifications.



** 8th February 2011, ** will be implemented if only it is considered by the Contracting Authority*

Fig. A.1. *Activities Schedule and time chart and organization scheme.*

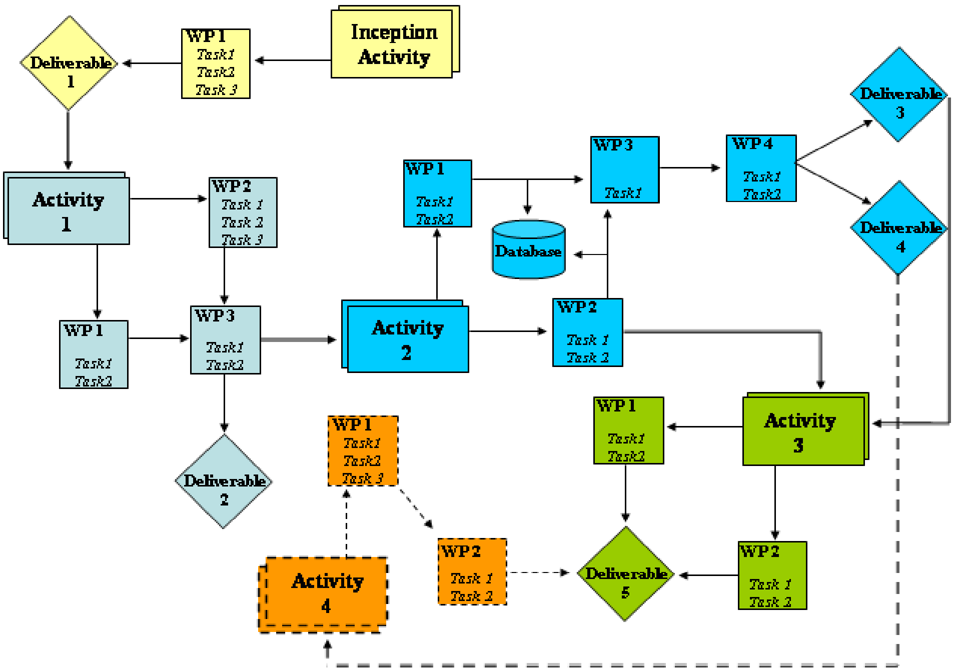


Fig. A.2. *Flowchart showing activities, work packages, tasks and deliverables of the project.*

Protocols & Field Sheets

HCMR-IIW //Rapid Ichtyo-Assessment Protocol

1. Researcher		**2.Fisher:**	**3.Completed by:**
4.Sampling Site	Code	Name	**5.Date**
6.Hydrographic Basin		**7. Course**	

8. Location Descriptions (nearest village; distance from bridges…).	**9. Reference site** Yes ☐ No ☐	**10. Status site** ------------

11. GPS Coordinates		**12. Altitude**	
		13. Slope	

14. Time	Start		Finish	
15.Sampling Instruments		**16.Sampling Effort**: A B C D		

17. Fished length (m)	**18.Fished area (m^2)**
19. Sampling details	☐ Whole ☐ other:

20. Flow regime	Permanent		Summer dry		Winter dry		Episodic	

21. SITE DIMENSIONS

LENGTH m:		
Width (m)	Left bank up to water	
	Wetted width	
	Right bank up to water	

22.WIDTH (m) **23. DEPTH** (m)

<1	%	<0.25			%
1≤L<5	%	0.25≤P<0.5			%
5≤L<10	%	0.5≤P<1			%
10≤L<20	%	≥1			%
≥20	%	Mean		Max	

24. SUBSTRATE (%)

Rock continuous		Sand <2mm	
Boulder >256mm		Silt	
		Clay	
Cobble 64-256mm		Organic	
Pebble 16-64mm		Artificial	
Gravel 2-16mm			

25. SHADEDNESS

Approximate % :	

26. WEATHER

27.VELOCITY (estim.)

< 0,1 m/s	
0,1-0,25 m/s	
0,25-0,5 m/s	
0,5-0,75 m/s	
0,75-1 m/s	
> 1 m/s	

28. PHYSICOCHEMICAL MEASUREMENTS

Conductivity (mS/m)		T° of air (° C)	
D.O.		T° of water (° C)	
PH		Turbidity	
Salinity			

29. HELOPHYTES		**30. BOTTOM VEGETATION**		**31. HABITAT TYPE %**	
Missing		Missing		Pool (deep/still)	
Isolated Rare		Algae/moss only		Glide (shallow/move)	
Sparce		Sparce		Run (deep/move)	
Intermidiate		Intermidiate		Riffle (shallow/rough)	
Rich		Rich		Rapid (steps/fast)	
Dominating sp.:		Dominating:		Other…………………	

32.Important Pressures:

32.Fish habitat Details:

Cover types sampled: logs/large woody debris, deep pools, overhanging vegetation, boulders/ cobble, riffles, undercut banks, thick root mats, dense macrophytes beds, isolated/backwater pools, marshy fringes, other natural cover types

33.Other Notes/ Interviews:(hydrology, modifications, pollution, introductions, historical fish presence, fishing methods&activities)

34.Site drawing:

Upstream

Downstream

Fish Length Class Protocol

River __________________ ***Total No fishes*** __________________

Site name __________________ ***Time of sampling*** __________________

Date __________________ ***Length (m)*** __________________

Species	***Length Class [cm]***									
	0+	***< 5***	***6 - 10***	***11 - 15***	***16 - 20***	***21 - 25***	***26 - 30***	***31 - 35***	***36 - 40***	***> 40***

QBR INDEX

Field data sheet

Riparian habitat quality

Date	

The score for each part cannot be negative or exceed 25

Total riparian cover Part 1 score

Score		
25	> 80 % of riparian cover (excluding annual plants)	
10	50-80 % of riparian cover	
5	10-50 % of riparian cover	
0	< 10 % of riparian cover	
+ 10	If connectivity between the riparian forest and the woodland is complete	
+ 5	If connectivity is above 50%	
- 5	Connectivity between 25 and 50%	
-10	Connectivity below 25%	

Cover structure Part 2 score

Score		
25	> 75 % of tree cover	
10	50-75 % of tree cover or 25-50 % of tree cover but 25 % covered by shrubs	
5	Tree cover below 50 % but shrub cover between at least 10 and 25 %	
0	Less than 10% of either tree or shrub cover	
+ 10	At least 50 % of the channel has helophytes or shrubs	
+ 5	25-50 % of the channel has helophytes or shrubs	
+ 5	Trees and shrubs are in the same patches	
- 5	Trees regularly distributed but shrub land is > 50 %Trees and shrubs distributed in separate patches,	
- 5	without continuity	
- 10	Trees distributed regularly, and shrub land < 50 %	

***Cover quality** (the geomorphologic type should first be stablished *)* Part 3 score

Score		*Type 1*	*Type 2*	*Type 3*	
25	Number of native tree species:	> 1	> 2	> 3	
10	Number of native tree species:	1	2	3	
5	Number of native tree species:	0	1	1 - 2	
0	Absence of native trees	-			
+ 10	The tree community is continuous along the river and covers at least 75% of the edge riparian area				
+ 5	The tree community is nearly continuous and covers at least 50% of the riparian area				
+ 5	The riparian community is structured in a gallery				
+ 5	The number of shrub species is:	> 2	> 3	> 4	
- 5	Presence of man-made buildings in the riparian area				
- 5	Presence of isolated species of non-native trees**				
- 10	Presence of communities of non-native trees				
- 10	Presence of garbage				

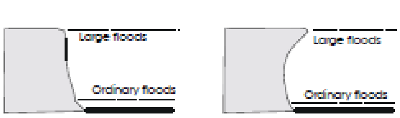
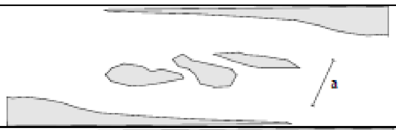
Channel alteration Part 4 score

Score		
25	Unmodified river channel	
10	Modified fluvial terraces, constraining the river channel	
5	Channel modified by discontinuous rigid structures along the banks	
0	Totally canalized river	
- 10	River bed with rigid structures (e.g wells)	
- 10	Transverse structures in the channel (e.g weirs)	

Final score (sum of level scores)	

*** Type of the riparian habitat (to be applied in Part 3, cover quality)**

The score is obtained by adding the scores assigned to the left and right river banks according to their slope. This value can be modified when islands or hard substrata are present.

		Score	
Slope and form of the riparian zone	River bank:	Left	Right
Very steep, vertical or even concave (slope > 75°) banks are not expected to be exceeded by large floods.		**6**	**6**
Similar to previous category but with a bankfull which differentiates the ordinary flooding zone from the main channel.		**5**	**5**
Slope of the banks between 45 and 75 °, with or without steps. Slope is the angle subtended by the line between the top of the riparian area and the edge of the ordinary flooding level of the river. (a > b)		**3**	**3**
Slope between 20 and 45 °, with or without steps. (a < b)		**2**	**2**
Slope < 20 °, large riparian zone.		**1**	**1**
Presence of one or several islands in the river			
Width of all the islands "a" > 5 m.		- 2	
Width of all islands "a" < 5 m.		- 1	
Percentage of hard substrata in which plants cannot root.			
> 80 %		Not applicable	
60 – 80 %		+ 6	
30 – 60 %		+ 4	
20 – 30 %		+ 2	
Total Score			

Geomorphologic type according to the total score

> 8	**Type 1**	Closed riparian habitats. Riparian forest, if present, reduced to a small strip. Headwaters.
5 to 8	**Type 2**	Headwaters or midland riparian habitats. Forest may be large and originally in gallery.
< 5	**Type 3**	Large riparian habitats, and potentially extensive forests. Lower courses.

**** Allochthonous trees species in the study area**
(These should be listed for each study area)
e. g. study area of Catalonia:
Populus deltoides
Populus x canadensis
Populus nigra ssp. italica
Salix babilonica
Ailanthus altissima
Celtis australis
Robinia pseudo-acacia
Platanus x hispanica
All fruit trees

ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ, ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
ΓΕΝΙΚΗ ΓΡΑΜΜΑΤΕΙΑ ΕΡΕΥΝΑΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΑΣ

ΕΛ.ΚΕ.Θ.Ε.
ΕΛΛΗΝΙΚΟ ΚΕΝΤΡΟ ΘΑΛΑΣΣΙΩΝ ΕΡΕΥΝΩΝ

ΕΡΕΥΝΑ ΓΙΑ ΤΗΝ ΠΑΡΟΥΣΙΑ ΨΑΡΙΩΝ ΣΤΟΥΣ ΠΟΤΑΜΟΥΣ ΤΗΣ ΚΥΠΡΟΥ

ΕΡΩΤΗΜΑΤΟΛΟΓΙΟ

Το ερωτηματολόγιο αυτό αποτελεί στοιχείο έρευνας για την εφαρμογή της Οδηγίας Πλαίσιο Περι Υδάτων 2000/60 από το Τμήμα Αναπτύξεως Υδάτων (ΤΑΥ 49/2010).

Οδηγίες Συμπλήρωσης Ερωτηματολογίου: *Παρακαλώ συμπληρώστε ένα ερωτηματολόγιο για κάθε ποταμιο σύστημα ή και κάθε ποτάμιο τμήμα που γνωρίζετε. Στις απλές απαντήσεις συμπληρώστε με "X", σε συγκεκριμένες ερωτήσεις απαντήστε γραπτώς στο κελί της ερώτησης. Αποστείλετε το ερωτηματολόγιο με ηλεκτρονικό ταχυδρομείο στον Δρ. Σταμάτη Ζόγκαρη (**zogaris@ath.hcmr.gr**).*

Θα ενημερωθείτε περαιτέρω στη συνέχεια μέσω της διεύθυνσης ή της διεύθυνσης ηλεκτρονικού ταχυδρομείου σας.

Α. ΑΤΟΜΙΚΑ ΣΤΟΙΧΕΙΑ

Ονοματεπώνυμο (<u>Προαιρετικό</u>):	
Φύλο :	☐ Άνδρας ☐ Γυναίκα
Σε ποια κατηγορία ανήκετε ως προς την ηλικία ;	☐18-25, ☐25-35, ☐35-45, ☐45-55, ☐55-65, ☐65+
Διεύθυνση: ή Διεύθυνση ηλεκτρονικού ταχυδρομείου :	

Β. ΣΤΟΙΧΕΙΑ ΠΟΤΑΜΙΟΥ ΣΥΣΤΗΜΑΤΟΣ / ΤΜΗΜΑΤΟΣ

Ποταμός :	
Ποτάμιο Τμήμα: περιγραφή :	
Πλησιέστερος οικισμός :	

Γ. ΣΤΟΙΧΕΙΑ ΓΙΑ ΤΗΝ ΠΑΡΟΥΣΙΑ ΨΑΡΙΩΝ

1. Τι ψάρια έχει το ποτάμι / ποτάμιο τμήμα;

☐ Καθόλου Ψάρια

☐ Μόνο Χέλι

☐ Χέλι και άλλα ψάρια

☐ Άλλα ψάρια

Παρακαλώ διευκρινίστε:

2. Τι ψάρια είχε το ποτάμι κατά το παρελθόν;

☐ Καθόλου Ψάρια

☐ Μόνο Χέλι

☐ Χέλι και άλλα ψάρια

☐ Άλλα Ψάρια

Παρακαλώ διευκρινίστε:

3. Πότε είδατε τελευταία άγριο χέλι στην Κύπρο;

☐ Πριν το '50

☐ Πριν το '60

☐ Πριν το '70

☐ Πριν το '80

☐ Πριν το '90

☐ Πριν το 2000

☐ Άλλη δεκαετία / περίοδο, Παρακαλώ διευκρινίστε:

☐ Δεν έχω δει ποτέ χέλι σε άγρια κατάσταση στην Κύπρο

4. Έχετε ψαρέψει χέλια, αν ναι, πότε τελευταία;

☐ Ναι ☐ Όχι

Αν **ΝΑΙ**, πότε συγκεκριμένα;	
και με πια/ποιες τεχνικές αλίευσης;	

5. Πιο ήταν το υψηλότερο υψόμετρο που εντοπίσατε χέλια;

Συγκεκριμένα :	

Πλησιέστερο Χωριό :	

6. Σήμερα που έχετε υπόψη σας ότι έχει ακόμη χέλια;

Συγκεκριμένα :	
Πλησιέστερο Χωριό :	

7. Άλλες Παρατηρήσεις:

ς

Table A.2. List of sampling sites

Note the columns show the following:

1. *Site number as shown on map that follows the Table bellow.*
2. *Site name as given by present research team.*
3. *Point X (geographic coordinates).*
4. *Point Y (geographic coordinates).*
5. *Method of data acquisition (in descending order of reliability): 1 = quantitative electrofishing; 2 = fry nets; 3 = observation of fish at site or recent data from experts; 4 = data from literature and/or interviews.*
6. *Period of investigation of specific site: 2009 = projects of HCMR in Cyprus; 2011 MAY = current project's first sampling trial; 2011 MAY-JU; 2012 April _May; 2012_July = current project's second sampling trial.*
7. *Quantitative: 1 = site was sampled in a quantitative way using electrofishing; 0 = only qualitative data (i.e. fish presence/absence or optical assessments made).*
8. *Fish Presence: 0 = no fish present and no evidence of fish during the 2011 survey; 1 = evidence of Eel only in recent years (as gathered from electrofishing, unstructured interview with experts and questionnaires); 2 = other fish species.*
9. *WB_Code. Site located within designated Water Body code.*
10. *Name of watershed which the site belongs to.*

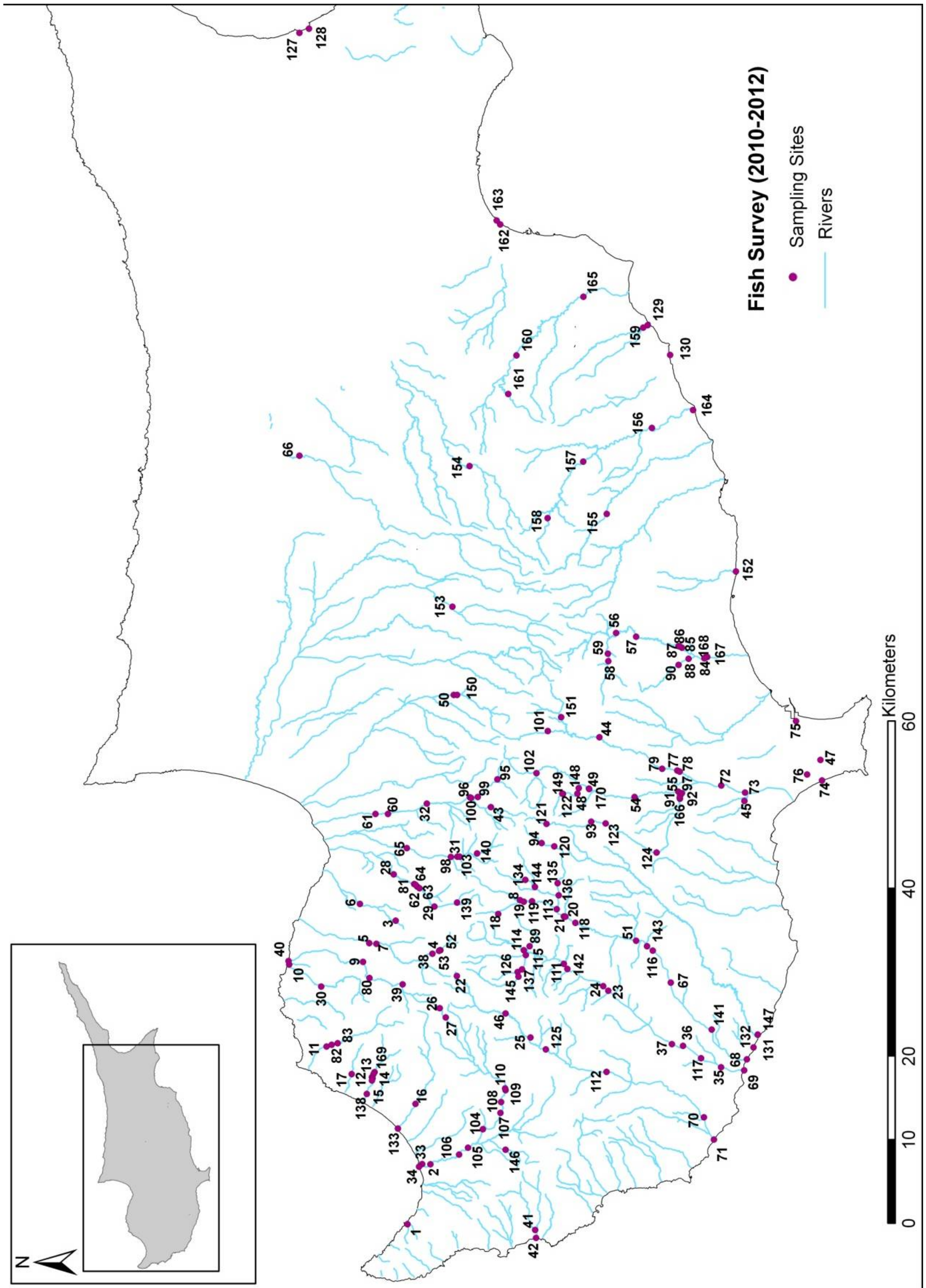
1	2	3	4	5	6	7	8	9	10
OBJECTID	SITE	POINT X	POINT Y	METHOD	PERIOD	QUANTITATIVE	FISH PRESENCE	WB_Code	WATERSHED
1	Aphrodites baths	440161,74	3879471,00	3	2009, 2012_JULY	0	0	CY_2-1-2_R1	East Akamas
2	Polis Mouth 2	447341,80	3876761,21	1	2011MAY	1	0	CY_2-2-6_R3-HM	Chrysochou
3	Kampos 1	476441,38	3880873,97	1	2010	1	0	CY_2-9-1_R1	Kampos
4	Fragma Tsakistras	472920,28	3875592,39	3	2011MAY	0	2	CY_2-8-1_R3	Limnitis
5	Kat Gef Limniti	473771,90	3884006,11	1	2010, 2011MAY_JU	1	0	CY_2-8-1_R3	Limnitis
6	Fragma Galinis	478453,04	3885114,12	4	2010	0	0	CY_2-9-4_R1-HM	Kampos
7	Gef Limniti	473685,56	3883173,89	3	2010	0	0	CY_2-8-1_R3	Limnitis
8	Agios Avvakoum	478886,68	3866158,68	1	2010	1	0	CY_1-2-1_R2	Diarizos
9	Pirgos 1	471519,54	3884741,94	1	2010	1	0	CY_2-7-1_R1	Pyrgos
10	Kato Pirgos	471217,59	3893488,52	3	2011MAY	0	0	CY_2-6-4_R1	Katouris
11	Fragma Pomou	461396,48	3889063,57	3	2010	0	2	CY_2-4-3_R3-HM	Xeros
12	Gialia Seep Pond	457738,80	3883704,35	1	2010	1	0	CY_2-3-8_R3	Makounta
13	Gialia Us Spring	458113,43	3883520,98	1	2010	1	0	CY_2-3-8_R3	Makounta
14	Gialia Spring	457616,55	3883626,42	1	2010	1	0	CY_2-3-8_R3	Makounta
15	Gialia Ds spring	457354,51	3883709,65	1	2010	1	0	CY_2-3-8_R3	Makounta
16	Fragma Argaka	454560,52	3878525,29	3	2011MAY	0	2	CY_2-3-5_R3-HM	Makounta
17	Fragma Ag Marina	458112,45	3886098,90	3	2009	0	2	CY_2-4-2_R3-HM	Xeros
18	Milikouri Spring	477228,42	3868733,36	3	2010	0	0	CY_1-2-1_R2	Diarizos

1	2	3	4	5	6	7	8	9	10
OBJECTID	SITE	POINT X	POINT Y	METHOD	PERIOD	QUANTITATIVE	FISH PRESENCE	WB_Code	WATERSHED
19	Pareklissoudi	478716,13	3865697,33	1	2010	1	2	CY_1-2-1_R2	Diarizos
20	Us Gef Tzelefou	476960,13	3860969,25	1	2010	1	2	CY_1-2-1_R2	Diarizos
21	Ds Gef Tzelefou	476924,72	3860767,23	1	2010, 2011MAY	1	2	CY_1-2-1_R2	Diarizos
22	Spring Dixaloi	469843,51	3873628,34	3	2010	0	0	CY_1-4-1_R3	Ezousa
23	Gef Salamiou Xeros	468081,17	3855699,27	1	2010	1	0	CY_1-3-5_R3	Xeros
24	Perasma Xeros	468626,36	3856313,56	1	2010	1	0	CY_1-3-5_R3	Xeros
25	Fragma Kannaviou	462490,65	3864912,93	3	2009	0	2	CY_1-4-3_R3-HM	Ezousa
26	Stavros kat camping	465988,66	3875664,23	3	2010	0	0	CY_2-2-4_R3	Chrysochou
27	Stavros Psokas 1	464880,05	3874947,44	3	2010	0	0	CY_2-2-4_R3	Chrysochou
28	Gef Xerou Lefkas	481985,53	3881119,62	3	2010	0	0	CY_3-1-2_R3-HM	Xeros
29	Fragma Kamenou Paidiou	478140,95	3876296,33	3	2010	0	2	CY_3-1-1_R3	Xeros
30	Fragma Katouri	468565,96	3889715,91	4	2010	0	2	CY_2-6-3_R1-HM	Katouris
31	Fragma Kalopanagioti	484093,85	3873586,74	3	2010	0	2	N/A	Marathasa
32	Gef Evrychou	490445,95	3877193,73	1	2011MAY	1	2	CY_3-3-1_R2	Kargotis
33	Polis Crys 1	447357,37	3877754,73	1	2010	1	0	CY_2-2-6_R3-HM	Chrysochou
34	Polis Mouth 1	447060,07	3878118,45	1	2011MAY	1	3	CY_2-2-6_R3-HM	Chrysochou
35	Asprokremma Ponds	458939,57	3842342,04	1	2011MAY	1	0	CY_1-3-9_R3-HM	Xeros
36	Finikas d/s prodam	461476,01	3846841,79	1	2011MAY	1	2	CY_1-3-5_R3	Xeros
37	Gef Choletria	461696,22	3848151,80	1	2011MAY	1	0	CY_1-3-5_R3	Xeros
38	Gef Mavres Sykies	472510,41	3876528,71	1	2011MAY	1	0	CY_2-8-1_R3	Limnitis
39	Vrondisia	468827,41	3880069,30	1	2011MAY	1	0	CY_2-7-1_R1	Pyrgos
40	Ekv PlatisPyrgoy	471624,33	3893566,73	1	2011MAY, 2011MAY_JU	1	1	CY_2-7-1_R1	Pyrgos
41	Avakas	439479,86	3864356,37	1	2011MAY	1	0	CY_1-8-1_R1	Avgas
42	Avakas Mouth	438542,67	3864247,85	1	2011MAY, 2012APR_MAY	0	0	CY_1-8-1_R1	Avgas
43	Us fishfarm Kargotis	490010,14	3869600,61	1	2011MAY	1	0	CY_3-3-1_R2	Kargotis
44	AgMamas Limnatis	498364,06	3856743,97	1	2011MAY	1	2	CY_9-6-5_R2	Kouris
45	Frag Kandou	490749,67	3839562,52	3	2011MAY	0	2	CY_9-6-82_R3	Kouris
46	Panagia Diakou Agia	465351,69	3867856,10	1	2010	1	2	CY_1-4-1_R3	Ezousa
47	Alyki Akrotiri	495655,08	3830566,91	3	2009	0	2	N/A	Akrotiri
48	Mesa potamos Kouri	491613,06	3859368,56	1	2011MAY	1	2	CY_9-6-35_R3	Kouris
49	Fragma Trimiklini	492185,48	3857966,04	3	2011MAY	0	0	CY_9-6-31_R3	Kouris
50	Fragma Xiliatos	503418,30	3873600,92	3	2009	0	2	CY_3-5-11_R3	Elias
51	Gefira Yerovassa	474055,59	3852393,71	3	2011MAY	1	0	CY_1-2-4_R3-HM	Diarizos
52	Yperchilistis Tsakistra	472882,85	3875699,31	1	2011MAY	1	2	CY_2-8-1_R3	Limnitis
53	Kat Fragma Tsakistras	472828,62	3875749,34	1	2011MAY	1	0	CY_2-8-1_R3	Limnitis
54	Ag Georgios	491219,57	3852584,09	1	2011MAY_JU	1	0	CY_9-6-4_R3-HM	Kouris
55	U/s Kouris confluence	491864,17	3847406,60	1	2011MAY_JU	1	2	CY_9-6-4_R3-HM	Kouris
56	Dierona	510823,34	3854775,75	1	2011MAY_JU	1	0	CY_9-2-2_R2	Germasogeia
57	Prastio	510372,57	3852405,25	1	2011MAY_JU	1	0	CY_9-2-31_R3	Germasogeia
58	U/s Arakambas dam	507461,58	3855691,89	1	2011MAY_JU	1	0	CY_9-2-11_R2	Germasogeia
59	D/s Arakambas dam	508365,27	3855757,27	1	2011MAY_JU	1	0	CY_9-2-1_R2-HM	Germasogeia
60	Katydata	489210,59	3881794,28	1	2011MAY_JU	1	0	CY_3-3-4_R3	Kargotis
61	Skouriotisa	489189,67	3883279,75	1	2011MAY_JU	1	0	CY_3-3-4_R3	Kargotis

1	2	3	4	5	6	7	8	9	10
OBJECTID	SITE	POINT X	POINT Y	METHOD	PERIOD	QUANTITATIVE	FISH PRESENCE	WB_Code	WATERSHED
62	U/s Kafizides dam	480530,21	3878357,27	1	2011MAY_JU	1	2	CY_3-1-1_R3	Xeros
63	D/s Kamenopaidi	480331,55	3878059,85	1	2011MAY_JU	1	2	CY_3-1-1_R3	Xeros
64	D/s Kafizides dam	480818,84	3878699,20	1	2011MAY_JU	1	2	CY_3-1-2_R3-HM	Xeros
65	U/s Lefka dam	485104,04	3879569,17	1	2011MAY_JU	1	2	CY_3-2-2_R3-HM	Marathasa
66	Pediaos Lefk	532016,17	3892279,45	1	2011MAY_JU	1	2	CY_6-1-2_R3-HM	Pediaios
67	D/s Life pond	469043,43	3848294,08	1	2011MAY_JU	1	2	CY_1-2-4_R3-HM	Diarizos
68	Ekvoles Diarizos	459880,19	3839293,28	3	2011MAY_JU	0	1	CY_1-2-4_R3-HM	Diarizos
69	Ekvoles Xeros	458560,78	3839604,18	1	2011MAY_JU, 2012APR_MAY	0	2	CY_1-3-9_R3-HM	Xeros
70	Achelia canal	452951,94	3844363,72	3	2011MAY_JU	0	2	CY_1-4-3_R3-HM	Ezousa
71	Ekvoles Ezousas	450282,96	3843184,10	1	2011MAY_JU, 2012APR_MAY	0	2	CY_1-4-3_R3-HM	Ezousa
72	D/s Kouris dam	492593,41	3842307,45	1	2011MAY_JU	1	2	CY_9-6-9_R3-HM	Kouris
73	D/s Kouris dam 2	491754,11	3839494,22	2	2011MAY_JU	0	0	CY_9-6-9_R3-HM	Kouris
74	Phassouri pits	493205,56	3830364,86	2	2011MAY_JU, 2012JULY	0	2	N/A	Akrotiri
75	Zakaki	500286,30	3833470,47	2	2011MAY_JU	0	2	N/A	Akrotiri
76	Phassouri reeds	493902,77	3832151,93	3	2011MAY_JU	0	2	N/A	Akrotiri
77	Alassa above bridge	494386,44	3847527,20	1	2011MAY_JU	1	0	CY_9-6-72_R3	Kouris
78	Alassa below bridge	494251,65	3847245,04	1	2011MAY_JU	1	2	CY_9-6-72_R3	Kouris
79	Limnatis flowmeter	494595,61	3849331,17	1	2011MAY_JU	1	0	CY_9-6-72_R3	Kouris
80	Fleva	469604,76	3883977,36	1	2011MAY_JU	1	0	CY_2-7-1_R1	Pyrgos
81	Kafizides dam	480731,40	3878542,41	3	2011MAY_JU	0	2	CY_3-1-2_R3-HM	Xeros
82	Livadi u/s dam	461616,26	3888456,32	1	2011MAY_JU	1	2	CY_2-4-4_R3	Xeros
83	Livadi u/s dam 2	461799,13	3887759,37	1	2011MAY_JU	1	0	CY_2-4-4_R3	Xeros
84	Germasogia d/s dam	507789,69	3844321,29	1	2011MAY_JU	1	0	CY_9-2-5_R3-HM	Germasogeia
85	Germasogia u/s dam	509061,85	3846962,91	1	2011MAY_JU	1	2	CY_9-2-31_R3	Germasogeia
86	Germasogia u/s flowmeter	509236,60	3847357,08	1	2011MAY_JU	1	0	CY_9-2-31_R3	Germasogeia
87	Germasogia d/s flowmeter	509241,39	3847238,81	1	2011MAY_JU	1	2	CY_9-2-31_R3	Germasogeia
88	Akrounta confluence	507733,93	3846189,95	1	2011MAY_JU	1	2	CY_9-2-4_R3-HM	Germasogeia
89	Lazarides 1	473394,47	3865015,58	1	2011MAY_JU	1	0	CY_1-3-1_R2	Xeros
90	Akrounta village	507000,75	3847361,09	1	2011MAY_JU	1	0	CY_9-2-4_R3-HM	Germasogeia
91	Kouris flowmeter	491136,14	3847228,21	1	2011MAY_JU	1	0	CY_9-6-1_R3-HM	Kouris
92	Kouris d/s flowmeter	491362,33	3847195,23	1	2011MAY_JU	1	2	CY_9-6-1_R3-HM	Kouris
93	Perapedi u/s bridge	488287,48	3857715,88	1	2011MAY_JU	1	0	CY_9-6-1_R2-HM	Kouris
94	Kalidonia trailhead	488001,58	3863019,31	1	2011MAY_JU	1	2	CY_9-6-1_R2	Kouris
95	Spilia	493346,35	3868835,57	1	2011MAY_JU	1	2	CY_3-3-1_R2	Kargotis
96	Kargotis confluence	491163,85	3872075,18	1	2011MAY_JU	1	0	CY_3-3-1_R2	Kargotis
97	Kouris u/s dam	491666,63	3846986,06	1	2011MAY_JU	1	2	CY_9-6-1_R3-HM	Kouris
98	Marathasa d/s fisheries	484061,03	3874359,02	1	2011MAY_JU	1	2	CY_3-2-2_R3-HM	Marathasa
99	Kakopetria Garillis	491238,90	3871154,29	1	2011MAY_JU	1	2	CY_3-3-1_R2	Kargotis
100	Garillis confluence	491123,36	3871938,59	1	2011MAY_JU	1	2	CY_3-3-1_R2	Kargotis
101	Potamitissa bridge	499098,41	3862849,37	1	2011MAY_JU	1	0	CY_9-6-5_R2	Kouris
102	Amiantos	494064,99	3864202,45	1	2011MAY_JU	1	0	CY_9-6-31_R3	Kouris
103	Marathasa u/s dam	484102,28	3873299,62	1	2011MAY_JU	1	2	CY_3-2-1_R2	Marathasa

1	2	3	4	5	6	7	8	9	10
OBJECTID	SITE	POINT X	POINT Y	METHOD	PERIOD	QUANTITATIVE	FISH PRESENCE	WB_Code	WATERSHED
104	D/s dam Evretou	451536,83	3870558,54	1	2011MAY_JU	1	0	CY_2-2-6_R3-HM	Chrysochou
105	Goudi bridge	449304,76	3872324,52	1	2011MAY_JU	1	1	CY_2-2-6_R3-HM	Chrysochou
106	Gef Skouli	448494,21	3873379,01	1	2011MAY_JU	1	0	CY_2-2-6_R3-HM	Chrysochou
107	Stavros Psokas u/s dam E	453465,52	3868478,29	1	2011MAY_JU	1	2	CY_2-2-4_R3	Chrysochou
108	U/s evretou dam 2	454779,87	3868405,29	1	2011MAY_JU	1	2	CY_2-2-4_R3	Chrysochou
109	D/s gef watermills Arama	456194,63	3867867,71	1	2011MAY_JU	1	2	CY_2-2-4_R3	Chrysochou
110	U/s gef watermills Arama	456399,43	3867926,51	1	2011MAY_JU	1	0	CY_2-2-4_R3	Chrysochou
111	Gef Roudias	471289,42	3860966,64	1	2011MAY_JU	1	2	CY_1-3-5_R3	Xeros
112	Amati	458373,74	3855907,15	1	2011MAY_JU	1	0	CY_1-4-3_R3-HM	Ezousa
113	Two bridges	477809,56	3861796,24	1	2011MAY_JU	1	2	CY_1-2-1_R2	Diarizos
114	Alonoui	472907,58	3865692,85	1	2011MAY_JU	1	2	CY_1-3-1_R2	Xeros
115	Stenoi	472336,36	3865481,06	1	2011MAY_JU	1	2	CY_1-3-1_R2	Xeros
116	Kisdasi	472860,15	3850436,24	1	2011MAY_JU	1	1	CY_1-2-4_R3-HM	Diarizos
117	Frag Asprokremmou	460005,69	3844715,37	3	2011MAY_JU	0	2	CY_1-3-8_R3-HM	Xeros
118	Fragma Arminou	476176,92	3859594,71	3	2011MAY_JU	0	2	CY_1-2-1_R2	Diarizos
119	DiarMid	478767,90	3864738,28	1	2012_JULY	1	3	CY_1-2-1_R2	Diarizos
120	finifisheries	485319,86	3862087,50	1	2012_JULY	1	2	CY_1-2-1_R2	Diarizos
121	Troodospicnik	485728,43	3863593,23	1	2012_JULY	1	0	CY_1-2-1_R2	Diarizos
122	Mesopotamos_camp	491592,48	3861058,26	1	2012_JULY	1	0	CY_9-6-35_R3	Kouris
123	AgMaura	488054,46	3856020,73	1	2012_JULY	1	2	CY_9-6-1_R3-HM	Kouris
124	Agamv	484600,84	3849982,98	1	2012APR_MAY, 2012_JULY	1	0	CY_9-6-1_R3-HM	Kouris
125	Kat_kannaviou	461054,73	3863099,41	1	2012_JULY	1	2	CY_1-4-3_R3-HM	Ezousa
126	d/sCedrus	470306,78	3866456,37	1	2012_JULY	1	2	CY_1-3-1_R2	Xeros
127	Silver Beach	582553,12	3892297,58	2	2012_JULY	1	2	N/A	Pediaios
128	Glapsides	583032,39	3891153,00	2	2012_JULY	1	2	N/A	Pediaios
129	Pouzis_ek	547608,58	3851031,37	2	2012APR_MAY	1	3	CY_8-5-1_R1	Pouzi
130	Maz_torrent	544062,50	3848372,66	3	2012APR_MAY	0	0	N/A	Pouzi
131	Ha_ek	462818,18	3837984,75	1	2012APR_MAY	1	2	CY_1-1-4_R3	Hapotami
132	Ichthyo_canal	461308,77	3838491,60	3	2012APR_MAY	0	1	N/A	Diarizos
133	Argaka_ek	451603,45	3880628,35	1	2012APR_MAY	1	3	CY_2-3-5_R3-HM	Makounta
134	Trieselies	481317,28	3865511,87	1	2012_JULY	1	0	CY_1-2-1_R2	Diarizos
135	Agiasma	480920,03	3861692,99	1	2012_JULY	1	2	CY_1-2-1_R2	Diarizos
136	Gefelias	479474,21	3861570,98	1	2012_JULY	1	2	CY_1-2-1_R2	Diarizos
137	Gerfyrka	470614,72	3865927,85	1	2012_JULY	1	2	CY_1-3-1_R2	Xeros (Pafos)
138	Gialan2	455747,98	3884317,83	1	2012_JULY	1	0	CY_2-3-8_R3	Gialia
139	Katgerakies	478598,99	3873599,01	1	2012_JULY	1	2	CY_3-1-1_R3	Xeros (Lefka)
140	Moutoulas	484484,99	3871240,77	1	2012_JULY	1	2	CY_3-2-1_R2	Marathasa
141	Souskiou	463428,77	3843443,44	1	2012_JULY	1	0	CY_1-2-4_R3-HM	Diarizos
142	u/s_vretsia	470666,65	3860533,23	1	2012_JULY	1	0	CY_1-3-5_R3	Xeros
143	u/skidasi	473382,62	3851104,51	1	2012_JULY	1	0	CY_1-2-4_R3-HM	Diarizos
144	Vrachos	480492,51	3864377,99	1	2012_JULY	1	2	CY_1-2-1_R2	Diarizos
145	Xeros_up	469768,93	3866329,33	1	2012_JULY	1	2	CY_1-3-1_R2	Xeros
146	AgParaskevi	449083,43	3867857,80	1	2012_JULY	1	2	CY_2-2-1_R3	Chrysochov
147	Ha_usek	462818,18	3837984,75	1	2012_JULY	1	3	CY_1-1-4_R3	Hapotami

1	2	3	4	5	6	7	8	9	10
OBJECTID	SITE	POINT X	POINT Y	METHOD	PERIOD	QUANTITATIVE	FISH PRESENCE	WB_Code	WATERSHED
148	Mesopot_katgef	492292,30	3859202,58	1	2012_JULY	1	2	CY_9-6-35_R3	Kouris
149	Mesapot_kataract	491631,84	3861146,08	1	2012_JULY	1	0	CY_9-6-35_R3	Kouris
150	d/sXiliatos	503417,43	3873999,38	1	2012_JULY	1	0	CY_3-5-1_R3-HM	Elea
151	Mylos	500753,32	3861278,82	1	2012_JULY	1	0	CY_9-6-52_R2	Kouris
152	Ek_moni	518173,69	3840582,91	2	2012APR_MAY	1	2	CY_9-1-4_R3	Moni
153	Maroulena_g	513972,59	3874157,80	1	2012_JULY	1	2	CY_3-7-3_R3-HM	Peristeronas
154	Dimalikos	530769,23	3872133,90	1	2012_JULY	1	2	CY_6-5-2_R3	Alikos
155	Valva	525052,65	3855884,50	1	2012_JULY	1	0	CY_8-8-1_R3	Maroni
156	Agtheodo	535334,73	3850532,79	3	2012APR_MAY	0	0	CY_8-7-4_R3-HM	Pentaschinos
157	dipot	531310,85	3858660,70	1	2012_JULY	1	2	N/A	Syrkatis
158	Kyprovasa	524544,75	3862876,76	1	2012_JULY	1	0	CY_8-7-11_R3	Syrkatis
159	Pouzis_1	547316,15	3851559,04	1	2012APR_MAY	1	0	CY_8-5-1_R1	Pouzi
160	Trem_u/sfalls	543989,92	3866576,38	1	2012APR_MAY	1	0	CY_8-4-1_R3-HM	Tremithos
161	Mosfilioti	539375,21	3867551,08	1	2012APR_MAY	1	0	CY_8-4-2_R3	Tremithos
162	Oroklini_can_west	559658,90	3868506,08	2	2012APR_MAY	1	3	N/A	Oroklini
163	Oroklini_can_east	560131,84	3868911,84	2	2012APR_MAY	1	2	N/A	Oroklini
164	Ek_Pent	537469,58	3845644,24	3	2012APR_MAY	0	0	CY_8-7-4_R3-HM	Pentaschinos
165	Trem_d/s_dam	551000,44	3858642,95	1	2012APR_MAY	1	0	CY_8-4-5_R3-HM	Tremithos
166	Kryos-u/s_bridge	491018,03	3847210,15	1	2012APR_MAY	1	0	CY_9-6-1_R3-HM	Kouris
167	Germ_b_weir	507963,47	3843982,91	1	2012APR_MAY	1	1	CY_9-2-5_R3-HM	Germasogeia
168	Germ_a_weir	507952,06	3844151,71	1	2012APR_MAY	1	3	CY_9-2-5_R3-HM	Germasogeia
169	Gialian1	458358,24	3883383,57	1	2012_JULY	1	2	CY_2-3-8_R3	Gialia
170	U/s Trimiklini	492238,57	3857978,31	1	2012_JULY	1	0	N/A	Kouris


Fish Survey (2010-2012)
Sampling Sites
Rivers
Kilometers
0
10
20
40
60
N

Site Map

Table A.1. Anthropogenic pressures at sites

		Morphological						Hydrological					Pollution					
ID	Site	Impoundment	Artificial substrate	Embankment	Riparian degradation	Canalization	Road density	Flow pattern deviation	Flow quantity deviation	Discontinuity upstream	Discontinuity downstream	Impervious area%	Chemical classification	Irrigation upstream area %	**BOD load**	**TN load**	**TP load**
1	Aphrodites baths	1	0%	80%	50%	10%	0,65%	50%	0%	0	0	0,00%	0,3	0,51%	5.050,9	942,6	61,3
2	Polis Mouth 2	1	30%	80%	80%	50%	4,34%	50%	50%	2	0	1,82%	0,3	18,77%	400.012,0	246.050,7	9.226,9
3	Kampos 1	1	0%	0%	50%	0%	1,53%	50%	50%	0	2	3,10%	0,3	18,87%	1.055,0	16.998,6	437,7
5	Kat Gef Limniti	0	0%	0%	10%	0%	1,91%	0%	50%	1	0	0,00%	0,3	0,00%	712,8	21.929,6	585,4
7	Gef Limniti	0	0%	0%	10%	0%	1,98%	90%	50%	2	0	0,00%	0,3	0,00%	708,6	21.162,1	563,4
8	Agios Avvakoum	0	0%	0%	10%	0%	1,29%	50%	15%	0	2	0,00%	0,3	1,22%	165,1	12.372,3	363,8
9	Pirgos 1	0	10%	30%	50%	50%	1,24%	90%	50%	0	0	0,00%	0,3	0,00%	1.627,5	15.984,6	492,2
10	Kato Pirgos	1	0%	0%	80%	30%	3,77%	90%	90%	0	0	7,83%	0,3	4,83%	18.133,7	4.463,2	194,9
13	Gialia Us Spring	0	0%	30%	30%	0%	0,93%	50%	15%	0	0	0,00%	0,3	0,20%	2.083,2	8.521,7	264,3
14	Gialia Spring	0	0%	0%	30%	0%	1,19%	50%	15%	0	0	0,00%	0,3	0,55%	2.144,9	8.780,7	272,3
15	Gialia Ds spring	0	10%	30%	80%	0%	1,31%	50%	15%	0	0	0,00%	0,3	0,74%	2.180,1	8.922,8	276,8
19	Pareklissoudi	0	0%	0%	0%	0%	1,31%	50%	15%	0	2	0,00%	0,3	1,20%	168,3	12.608,4	370,7
20	Us Gef Tzelefou	0	0%	0%	10%	0%	1,56%	50%	15%	0	3	1,63%	0,3	3,86%	11.958,0	54.565,5	1.967,0
21	Ds Gef Tzelefou	0	10%	0%	65%	0%	1,64%	50%	15%	0	4	1,63%	0,3	3,85%	11.963,8	54.599,2	1.968,3
23	Gef Salamiou Xeros	0	10%	0%	70%	0%	1,09%	50%	15%	0	1	0,46%	0,3	6,87%	103.078,1	77.424,5	3.198,9
24	Perasma Xeros	0	0%	0%	0%	0%	1,26%	50%	15%	0	1	0,47%	0,3	6,62%	99.798,5	76.395,9	3.132,0
26	Stavros kat camping	0	0%	0%	30%	0%	2,31%	90%	50%	0	1	0,00%	0,3	0,00%	631,7	936,2	24,8
27	Stavros Psokas 1	0	0%	0%	0%	0%	1,92%	90%	50%	0	1	0,00%	0,3	0,00%	1.620,3	2.395,3	63,3
28	Gef Xerou Lefkas	0	0%	0%	50%	0%	0,01%	90%	90%	3	2	0,00%	0,3	0,00%	369,0	25.943,2	1.001,8
32	Gef Evrychou	0	10%	0%	80%	0%	3,67%	50%	50%	2	0	3,24%	0,3	8,00%	26.485,9	58.085,0	1.694,8
33	Polis Crys 1	0	0%	30%	80%	0%	4,65%	50%	50%	1	0	1,85%	0,3	18,78%	401.451,1	246.651,8	9.244,6
34	Polis Mouth 1	0	0%	0%	55%	0%	4,80%	50%	50%	1	0	1,95%	0,3	18,95%	416.530,8	252.925,2	9.429,3
35	Asprokremma Ponds	1	0%	0%	70%	100%	3,86%	90%	90%	4	0	0,94%	0,3	11,75%	681.005,3	180.532,7	8.245,1
36	Finikas d/s prodam	0	0%	30%	50%	100%	1,82%	50%	15%	0	4	1,01%	0,3	11,95%	487.291,2	148.633,0	7.014,8
37	Gef Choletria	0	0%	0%	60%	0%	1,92%	50%	15%	0	3	0,78%	0,3	10,49%	417.608,0	137.685,3	6.510,4
38	Gef Mavres Sykies	0	0%	0%	0%	0%	1,60%	90%	50%	3	0	0,00%	0,3	0,00%	223,9	5.702,4	151,4
39	Vrondisia	0	0%	0%	0%	0%	1,11%	50%	15%	0	0	0,00%	0,3	0,00%	97,8	5.699,0	149,3
40	Ekv PlatisPyrgoy	0	0%	30%	50%	50%	3,69%	50%	15%	0	0	0,15%	0,3	1,42%	22.806,0	24.795,0	928,2
41	Avakas	0	0%	30%	25%	0%	1,77%	50%	15%	0	0	3,52%	0,3	5,59%	45.027,7	22.536,2	1.169,2
42	Avakas Mouth	0	0%	30%	30%	0%	1,84%	50%	15%	0	0	3,29%	0,3	5,22%	48.923,5	24.201,5	1.255,1
43	Us fishfarm Kargotis	1	10%	0%	50%	0%	2,95%	50%	15%	0	0	0,00%	0,3	0,00%	81,6	6.353,8	186,0
44	AgMamas Limnatis	0	0%	0%	20%	0%	1,93%	50%	50%	3	1	2,65%	0,3	39,73%	37.300,1	75.412,8	2.708,9
46	Panagia Diakou Agia	0	0%	30%	0%	0%	0,97%	50%	50%	0	3	0,00%	0,3	0,00%	10.487,1	14.104,1	375,1
48	Mesa potamos Kouri	0	0%	0%	0%	0%	3,02%	50%	15%	0	3	0,00%	0,3	0,00%	1.807,1	7.328,8	202,4
51	Gefira Yerovassa	0	0%	0%	80%	0%	2,38%	90%	90%	2	2	1,28%	0,3	11,42%	57.805,1	108.973,0	4.098,2
52	Yperchilistis Tsakistra	0	30%	30%	40%	0%	1,45%	90%	90%	4	0	0,00%	0,3	0,00%	181,3	4.610,8	122,5
53	Kat Fragma Tsakistras	0	0%	0%	10%	0%	1,42%	90%	90%	4	0	0,00%	0,3	0,00%	181,4	4.614,3	122,5
54	Ag Georgios	0	10%	80%	55%	0%	4,74%	50%	50%	3	3	4,04%	0,5	15,51%	41.873,0	87.638,3	2.682,8
55	U/s Kouris confluence	1	0%	0%	25%	0%	3,26%	50%	50%	1	4	3,54%	0,5	14,25%	59.494,8	107.397,5	3.391,8
56	Dierona	1	0%	0%	30%	0%	2,72%	50%	50%	4	0	0,69%	0,3	24,58%	46.559,3	54.270,4	2.406,5
57	Prastio	0	0%	0%	20%	0%	1,52%	50%	50%	3	2	0,58%	0,3	20,62%	72.148,1	64.571,2	2.859,6
58	U/s Arakambas dam	0	0%	0%	0%	0%	1,67%	50%	50%	0	4	0,72%	0,3	36,47%	18.315,4	27.166,3	1.116,8
59	D/s Arakambas dam	0	10%	30%	55%	50%	2,17%	90%	90%	4	0	0,64%	0,3	32,74%	20.733,6	30.773,5	1.265,1
60	Katydata	0	0%	0%	50%	0%	2,87%	50%	50%	1	0	4,67%	0,3	12,59%	102.506,9	93.256,5	2.700,3
61	Skouriotisa	1	10%	0%	55%	0%	2,99%	50%	50%	1	0	4,56%	0,3	13,20%	111.034,6	97.164,6	2.811,9
62	U/s Kafizides dam	1	0%	0%	5%	0%	0,00%	50%	50%	0	4	0,00%	0,3	0,00%	169,7	16.551,9	521,1

		Morphological						Hydrological					Pollution				
ID	Site	Impoundment	Artificial substrate	Embankment	Riparian degradation	Canalization	Road density	Flow pattern deviation	Flow quantity deviation	Discontinuity upstream	Discontinuity downstream	Impervious area%	Chemical classification	Irrigation upstream area %	**BOD load**	**TN load**	**TP load**
63	D/s Kamenopaidi	0	0%	0%	0%	0%	0,00%	50%	50%	3	3	0,00%	0,3	0,00%	165,5	16.354,0	510,9
64	D/s Kafizides dam	0	0%	0%	0%	0%	0,00%	90%	90%	4	0	0,00%	0,3	0,00%	178,5	16.975,3	542,8
65	U/s Lefka dam	1	0%	0%	50%	0%	2,04%	50%	50%	2	4	2,06%	0,3	9,77%	3.636,3	30.687,8	1.243,4
66	Pediaos Lefk	1	20%	80%	80%	100%	4,94%	90%	50%	1	0	19,84%	0,3	17,43%	983.023,4	296.333,6	20.102,4
67	D/s Life pond	0	0%	0%	30%	0%	1,05%	90%	50%	1	0	1,17%	0,3	14,85%	307.456,7	175.728,1	7.225,4
68	Ekvoles Diarizos	0	0%	0%	50%	0%	4,19%	90%	90%	1	0	1,24%	0,3	14,14%	590.119,7	232.747,6	10.520,0
69	Ekvoles Xeros	0	0%	0%	80%	0%	4,43%	90%	90%	3	0	0,93%	0,3	13,22%	738.738,0	190.628,9	8.538,3
70	Achelia canal	1	100%	80%	100%	100%	5,57%	90%	90%	3	0	2,27%	0,3	21,67%	454.044,5	233.722,5	9.321,8
71	Ekvoles Ezousas	1	0%	0%	80%	100%	7,27%	90%	90%	2	0	2,67%	0,3	21,85%	700.928,5	278.822,1	11.316,1
72	D/s Kouris dam	0	10%	0%	50%	0%	2,01%	90%	90%	4	0	2,14%	0,3	19,64%	364.445,5	301.690,2	12.678,8
73	D/s Kouris dam 2	0	0%	30%	50%	50%	3,34%	90%	90%	3	0	2,07%	0,3	19,75%	435.102,5	314.385,1	13.299,1
77	Alassa above bridge	1	0%	30%	65%	0%	2,98%	50%	50%	1	3	1,71%	0,3	26,36%	90.266,3	114.949,6	4.816,3
78	Alassa below bridge	0	0%	0%	65%	0%	3,07%	50%	15%	1	4	1,70%	0,3	26,34%	91.685,9	115.465,7	4.848,0
79	Limnatis flowmeter	1	10%	0%	15%	0%	2,29%	50%	15%	1	3	1,77%	0,3	27,07%	81.957,6	111.836,8	4.625,6
80	Fleva	0	0%	0%	0%	0%	0,91%	50%	15%	0	0	0,00%	0,3	0,00%	1.039,3	12.871,3	382,1
83	Livadi u/s dam	0	0%	0%	45%	0%	0,95%	50%	15%	0	0	0,00%	0,3	0,00%	3.016,5	12.503,0	345,0
84	Livadi u/s dam 2	0	0%	0%	0%	0%	0,86%	50%	15%	0	3	0,00%	0,3	0,00%	2.243,8	11.767,6	321,4
85	Germasogia d/s dam	0	0%	0%	65%	50%	2,73%	90%	90%	4	0	0,32%	0,3	16,80%	200.882,6	120.314,6	6.448,6
86	Germasogia u/s dam	1	0%	0%	25%	0%	1,84%	50%	15%	1	4	0,47%	0,3	16,64%	110.969,6	79.837,7	3.531,1
87	Germasogia u/s flowmeter	1	10%	80%	20%	0%	1,53%	50%	15%	0	3	0,47%	0,3	16,67%	110.556,9	79.673,3	3.523,9
88	Germasogia d/s flowmeter	0	0%	0%	15%	100%	1,62%	50%	15%	0	4	0,47%	0,3	16,66%	110.686,5	79.724,9	3.526,2
89	Akrounta confluence	1	0%	30%	75%	0%	2,24%	90%	50%	3	4	0,00%	0,3	18,87%	28.679,0	18.212,0	867,4
90	Lazarides 1	0	0%	0%	0%	0%	0,99%	50%	15%	0	1	0,00%	0,3	0,00%	12,8	3.765,4	98,7
91	Akrounta village	0	10%	30%	80%	50%	1,90%	90%	90%	4	0	0,00%	0,3	20,45%	26.457,3	16.805,6	800,2
92	Kouris flowmeter	1	10%	0%	0%	0%	3,47%	50%	50%	1	3	1,47%	0,3	19,02%	123.618,3	57.177,8	3.274,4
93	Kouris d/s flowmeter	0	0%	0%	5%	0%	3,54%	50%	50%	1	0	1,46%	0,3	18,85%	125.053,6	57.718,2	3.306,6
94	Perapedi u/s bridge	0	0%	30%	50%	0%	3,59%	50%	50%	3	1	4,59%	0,3	1,87%	4.305,4	8.548,3	378,9
95	Kalidonia trailhead	0	0%	0%	0%	0%	2,79%	50%	15%	0	2	0,00%	0,3	0,00%	834,5	1.710,6	74,5
96	Spilia	0	0%	0%	15%	0%	3,74%	50%	15%	0	0	0,00%	0,3	0,93%	17,1	3.867,1	102,5
97	Kargotis confluence	0	10%	0%	80%	0%	4,15%	50%	15%	0	0	0,91%	0,3	3,35%	531,9	22.485,6	632,0
98	Kouris u/s dam	1	0%	0%	60%	0%	3,62%	50%	50%	1	4	1,44%	0,3	18,70%	126.779,1	58.289,1	3.342,9
99	Marathasa d/s fisheries	0	0%	0%	25%	0%	1,59%	50%	50%	3	3	3,81%	0,3	10,86%	2.709,8	19.642,5	859,0
100	Kakopetria Garillis	0	0%	0%	25%	0%	3,93%	50%	50%	0	0	0,00%	0,3	0,40%	19,9	9.499,5	251,7
101	Garillis confluence	0	10%	0%	80%	0%	4,15%	50%	15%	0	0	0,67%	0,3	3,40%	135,9	21.728,2	609,3
102	Potamitissa bridge	0	0%	0%	80%	0%	3,86%	50%	15%	0	2	0,00%	0,3	61,87%	11.817,7	23.564,1	837,6
103	Amiantos	0	0%	0%	70%	0%	3,40%	50%	15%	3	2	0,76%	0,5	24,94%	4.189,6	17.041,1	470,7
104	Marathasa u/s dam	1	0%	0%	60%	0%	2,26%	50%	50%	0	4	3,41%	0,3	11,62%	2.554,2	17.744,0	789,0
105	D/s dam Evretou	0	0%	30%	80%	50%	3,20%	90%	90%	4	0	0,36%	0,3	4,10%	161.778,6	75.769,4	3.186,3
106	Goudi bridge	0	0%	30%	50%	0%	3,85%	50%	50%	3	0	1,65%	0,3	15,64%	311.118,5	201.878,3	7.873,5
107	Gef Skouli	0	10%	0%	65%	0%	3,62%	50%	50%	2	0	1,62%	0,3	15,97%	319.452,1	206.703,8	8.025,4
108	Stavros Psokas u/s dam E	1	0%	0%	40%	0%	2,87%	50%	15%	0	4	0,39%	0,3	3,45%	128.666,7	64.944,2	2.750,5
109	U/s evretou dam 2	0	0%	0%	55%	0%	2,95%	50%	15%	0	3	0,28%	0,3	1,74%	109.589,7	58.703,8	2.499,1
110	D/s gef watermills Arama	0	0%	0%	40%	0%	3,01%	50%	15%	0	3	0,13%	0,3	1,19%	76.584,8	47.890,7	2.063,4
111	U/s gef watermills Arama	1	0%	0%	35%	0%	2,90%	50%	15%	0	3	0,00%	0,3	1,26%	61.284,8	42.828,2	1.858,5
112	Gef Roudias	0	0%	30%	0%	0%	1,35%	50%	15%	0	1	0,00%	0,3	0,00%	13.777,9	44.759,6	1.277,0
113	Amati	0	10%	0%	30%	0%	4,02%	90%	50%	1	1	1,22%	0,3	19,27%	221.411,9	136.453,0	5.071,4
114	Two bridges	0	0%	0%	0%	0%	0,99%	50%	15%	0	3	2,79%	0,3	6,04%	10.860,7	33.113,7	1.291,3
115	Alonoui	0	0%	0%	0%	0%	0,92%	50%	15%	0	1	0,00%	0,3	0,00%	1,3	10.512,7	277,7
116	Stenoi	0	0%	0%	0%	0%	1,04%	50%	15%	0	1	0,00%	0,3	0,00%	12,9	4.455,5	118,0
117	Kisdasi	0	0%	0%	0%	0%	2,59%	50%	50%	1	2	1,30%	0,3	12,42%	163.773,3	153.372,5	6.004,0
118	Kat Fragma Kafiziedes	0	0%	0%	0%	0%	0,00%	90%	90%	3	0	0,00%	0,3	0,00%	180,1	17.051,4	546,7

Table A.2. Fishes collected at electrofishing sites

ID	SITE	Species	Size class										
			0+	<5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	Total
1	Aphrodites baths	Fishless											0
2	Polis Mouth 2	Fishless											0
3	Kampos 1	Fishless											0
5	Kat Gef Limniti	Fishless											0
7	Gef Limniti	Fishless											0
8	Agios Avvakoum	Fishless											0
9	Pirgos 1	Fishless											0
11	Fragma Pomou	Rutilus rutilus			1								1
12	Gialia Seep Pond	Fishless											0
13	Gialia Us Spring	Fishless											0
14	Gialia Spring	Fishless											0
15	Gialia Ds spring	Fishless											0
18	Milikouri Spring	Fishless											0
19	Pareklissoudi	Salmo trutta				1	3						4
20	Us Gef Tzelefou	Rutilus rutilus		7	20	2							29
21	Ds Gef Tzelefou	Rutilus rutilus			85	330	20						436
		Lepomis gibosus			1								
22	Spring Dixaloi	Fishless											0
23	Gef Salamiou Xeros	Fishless											0
24	Perasma Xeros	Fishless											0
32	Gef Evrychou	Oncorhynchus mykiss							1				1
33	Polis Crys 1	Fishless											0
34	Polis Mouth 1	Anguilla anguilla		1									113
		Mugil cephalus		112									
35	Asprokremma Ponds	Fishless											0
36	Finikas d/s prodam	Rutilus rutilus		3	90	10							104
		Ictalurus punctatus						1					
37	Gef Choletria	Fishless											0

ID	SITE	Species	Size class										Total
			0+	<5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	
38	Gef Mavres Sykies	Fishless											0
39	Vrondisia	Fishless											0
40	Ekv PlatisPyrgoy	Anguilla anguilla			1	1		3	2				7
41	Avakas	Fishless											0
42	Avakas Mouth	Fishless											0
43	Us fishfarm Kargotis	Fishless											0
44	AgMamas Limnatis	Oncorhynchus mykiss			6	1							7
46	Panagia Diakou Agia	Oncorhynchus mykiss			2								2
48	Mesa potamos Kouri	Salmo trutta	5				2	1					8
52	Yperchilistis Tsakistra	Gambusia holbrooki		15									15
53	Kat Fragma Tsakistras	Fishless											0
54	Ag Georgios	Fishless											0
55	U/s Kouris confluence	Rutilus rutilus			46	4	15						65
56	Dierona	Fishless											0
57	Prastio	Fishless											0
58	U/s Arakambas dam	Fishless											0
59	D/s Arakambas dam	Fishless											0
60	Katydata	Fishless											0
61	Skouriotisa	Fishless											0
62	U/s Kafizides dam	Rutilus rutilus				25							117
		Gambusia holbrooki		92									
63	D/s Kamenopaidi	Rutilus rutilus				2							7
		Oncorhynchus mykiss			3	1			1				
64	D/s Kafizides dam	Gambusia holbrooki		75									76
		Carassius auratus						1					
65	U/s Lefka dam	Rutilus rutilus			291	122							427
		Oncorhynchus mykiss			3	9		2					
66	Pediaos Lefk	Gambusia holbrooki	100	374									474
67	D/s Life pond	Gambusia holbrooki		41									41
68	Ekvoles Diarizos	Anguilla anguilla									1	1	2
69	Ekvoles Xeros	Dicentrarchus labrax			2								33
		Liza aurata			1								

ID	SITE	Species	Size class										Total
			0+	<5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	
		Mugil cephalus	30										
70	Achelia canal	Oreochromis aureus			5	15	10						34
		Carassius auratus					4						
71	Ekvoles Ezousas	Mugil cephalus		62	2								64
72	D/s Kouris dam	Gambusia holbrooki	220	771									991
73	D/s Kouris dam 2	Fishless											0
74	Phassouri pits	Mugil cephalus				12							125
		Atherina boyeri			6	2							
		Aphanius fasciatus		80	25								
75	Zakaki	Aphanius fasciatus		40									40
77	Alassa above bridge	Fishless											0
78	Alassa below bridge	Rutilus rutilus			311	22	2	3					358
		Micropterus salmoides			4	16							
79	Limnatis flowmeter	Fishless											0
80	Fleva	Fishless											0
82	Livadi u/s dam	Rutilus rutilus		4									26
		Micropterus salmoides		22									
83	Livadi u/s dam 2	Fishless											0
84	Germasogia d/s dam	Fishless											0
85	Germasogia u/s dam	Rutilus rutilus			60	42							104
		Oreochromis aureus						2					
86	Germasogia u/s flowmeter	Fishless											0
87	Germasogia d/s flowmeter	Rutilus rutilus			83	117							316
		Oreochromis aureus						14					
		Cyprinus carpio				2							
		Rutilus rutilus			50	50							
88	Akrounta confluence	Rutilus rutilus			10								1590
		Cyprinus carpio			3								
		Lepomis gibosus		2	25								
		Cyprinid fry	1550										
89	Lazarides 1	Fishless											0

ID	SITE	Species	Size class										
			0+	<5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	Total
90	Akrounta village	Fishless											0
91	Kouris flowmeter	Fishless											0
92	Kouris d/s flowmeter	Rutilus rutilus			124	12							138
		Perca fluviatilis				2							
93	Perapedi u/s bridge	Fishless											0
94	Kalidonia trailhead	Oncorhynchus mykiss		7	50	22	6	6	1				92
95	Spilia	Oncorhynchus mykiss			87			1					88
96	Kargotis confluence	Fishless											0
97	Kouris u/s dam	Rutilus rutilus			56	41	12	25					143
		Perca fluviatilis				2							
		Micropterus salmoides				7							
98	Marathasa d/s fisheries	Rutilus rutilus			2	1							5
		Oncorhynchus mykiss			2								
99	Kakopetria Garillis	Oncorhynchus mykiss								1			1
100	Garillis confluence	Oncorhynchus mykiss			3		1		1	1			6
101	Potamitissa bridge	Fishless											0
102	Amiantos	Fishless											0
103	Marathasa u/s dam	Rutilus rutilus		1	279			1					289
		Oncorhynchus mykiss			3								
		Gambusia holbrooki		5									
104	D/s dam Evretou	Fishless											0
105	Goudi bridge	Anguilla anguilla									1	1	2
106	Gef Skouli	Fishless											0
107	Stavros Psokas u/s dam E	Rutilus rutilus			2	102							253
		Micropterus salmoides		149									
108	U/s evretou dam 2	Rutilus rutilus				40							40
109	D/s gef watermills Arama	Rutilus rutilus				30							30
110	U/s gef watermills Arama	Fishless											0
111	Gef Roudias	Salmo trutta								1			1
112	Amati	Fishless											0
113	Two bridges	Salmo trutta		3	5	1							9
113	Two bridges	Rutilus rutilus			1								1

ID	SITE	Species	Size class										
			0+	<5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	Total
114	Alonoui	Salmo trutta			7		1	3					11
115	Stenoi	Salmo trutta						1					1
116	Kisdasi	Anguilla anguilla										4	4
119	DiarMid	Salmo trutta					2	4					7
		Anguilla anguilla										1	
120	finifisheries	Oncorhynchus mykiss			1	4	1						19
		Salmo trutta				1	4	6					
		Salmonid sp.		1	1								
121	Troodospicnik	Fishless											0
122	Mesopotamos_camp	Fishless											0
123	AgMaura	Oncorhynchus mykiss			1	17	2	9	4				33
124	Agamv	Fishless											0
125	Kat_kannaviou	Rutilus rutilus			15								15
126	d/sCedrus	Salmo trutta					1	2					3
127	Silver Beach	Mugil cephalus			10								266
		Liza ramada			6								
		Aphanius fasciatus		250									
128	Glapsides	Mugil cephalus		12	5								59
		Liza ramada		1									
		Aphanius fasciatus		40									
		Anguilla anguilla					1						
129	Pouzis_ek	Liza ramada		56									56
129	Pouzis_ek	Anguilla anguilla			4		1						5
130	Maz_torrent	Fishless											0
131	Ha_ek	Fishless											0
132	Ichthyo_canal	Anguilla anguilla										1	1
133	Argaka_ek	Liza ramada		40									40
134	Trieselies	Fishless											0
135	Agiasma	Salmo trutta					11	6					17
136	Gefelias	Salmo trutta						3	4				137
		Rutilus rutilus				115	15						
137	Gerfyrka	Salmo trutta					1		1				2

ID	SITE	Species	Size class										
			0+	<5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	Total
138	Gialan2	Fishless											0
139	Katgerakies	Oncorhynchus mykiss			4	9	1	3					17
139	Katgerakies	Gambusia holbrooki	1	5									6
140	Moutoulas	Oncorhynchus mykiss				4	2	5	2				13
141	Souskiou	Fishless											0
142	u/s_vretsia	Fishless											0
143	u/skidasi	Fishless											0
144	Vrachos	Salmo trutta					2	14	3	1		1	21
145	Xeros_up	Salmo trutta					7	3					10
146	AgParaskevi	Gambusia holbrooki		86									86
147	Ha_usek	Anguilla anguilla	23										105
		Liza ramada		12	70								
148	Mesopot_katgef	Salmo trutta				3	9	2					14
149	Mesapot_kataract	Fishless											0
150	d/sXiliatos	Fishless											0
151	Mylos	Fishless											0
152	Ek_moni	Dicentrarchus labrax			2								49
		Mugil cephalus		47									
153	Maroulena_g	Oncorhynchus mykiss			2	4		1	3				11
		Lepomis gibbosus					1						
154	Dimalikos	Gambusia holbrooki	110	1175	180								1506
		Carassius cf.gibellio		4	35								
		Carassius auratus				2							
155	Valva	Fishless											0
156	Agtheodo	Fishless											0
157	dipot	Rutilus rutilus			30	2							40
		Micropterus salmoides			8								
158	Kyprovasa	Fishless											0
159	Pouzis_1	Fishless											0
160	Trem_u/sfalls	Fishless											0
161	Mosfilioti	Fishless											0
162	Oroklini_can_west	Mugil cephalus		10									41

ID	SITE	Species	Size class										
			0+	<5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	>40	Total
		Gambusia holbrooki		30									
		Anguilla anguilla				1							
163	Oroklini_can_east	Gambusia holbrooki		6									11
		Liza ramada		5									
164	Ek_Pent	Fishless											0
165	Trem_d/s_dam	Fishless											0
166	Kryos-u/s_bridge	Fishless											0
167	Germ_b_weir	Anguilla anguilla	15										15
168	Germ_a_weir	Anguilla anguilla	5										13
		Rutilus rutilus	3	5									
169	Gialian1	Gambusia holbrooki		7									7
170	U/s Trimiklini	Fishless											0

Table A.3. From CANOCO Fig 4.12 (p.106)

1	Achelia canal	49	Gef Mavres Sykies	97	Mylos
2	Ag Georgios	50	Gef Roudias	98	Oroklini_can_east
3	Agamv	51	Gef Salamiou Xeros	99	Oroklini_can_west
4	Agiasma	52	Gef Skouli	100	Panagia Diakou Agia
5	Agios Avvakoum	53	Gefelias	101	Pareklissoudi
6	AgMamas Limnatis	54	Germ_a_weir	102	Pediaos Lefk
7	AgMaura	55	Germ_b_weir	103	Perapedi u/s bridge
8	AgParaskevi	56	Germasogia d/s dam	104	Perasma Xeros
9	Agtheodo	57	Germasogia d/s flowmeter	105	Pirgos 1
10	Akrounta confluence	58	Germasogia u/s dam	106	Polis Crys 1
11	Akrounta village	59	Germasogia u/s flowmeter	107	Polis Mouth 1
12	Alassa above bridge	60	Gialan2	108	Polis Mouth 2
13	Alassa below bridge	61	Gialia Ds spring	109	Potamitissa bridge
14	Alonoui	62	Gialia Spring	110	Pouzis_1
15	Amati	63	Gialia Us Spring	111	Pouzis_ek
16	Amiantos	64	Gialian1	112	Prastio
17	Argaka_ek	65	Glapsides	113	Silver Beach
18	Asprokremma Ponds	66	Goudi bridge	114	Skouriotisa
19	Avakas	67	Ha_ek	115	Souskiou
20	Avakas Mouth	68	Ha_usek	116	Spilia
21	Avakas Mouth	69	Ichthyo_canal	117	Stavros kat camping
22	D/s Arakambas dam	70	Kakopetria Garillis	118	Stavros Psokas 1
23	D/s dam Evretou	71	Kalidonia trailhead	119	Stavros Psokas u/s dam E
24	D/s gef watermills Arama	72	Kampos 1	120	Stenoi
25	D/s Kafizides dam	73	Kargotis confluence	121	Trem_d/s_dam
26	D/s Kamenopaidi	74	Kat Fragma Kafiziedes	122	Trem_u/sfalls
27	D/s Kouris dam	75	Kat Fragma Tsakistras	123	Trieselies
28	D/s Kouris dam 2	76	Kat Gef Limniti	124	Troodospicnik
29	D/s Life pond	77	Kat_kannaviou	125	Two bridges
30	d/sCedrus	78	Katgerakies	126	U/s Arakambas dam
31	d/sXiliatos	79	Kato Pirgos	127	U/s evretou dam 2
32	DiarMid	80	Katydata	128	U/s gef watermills Arama
33	Dierona	81	Kisdasi	129	U/s Kafizides dam
34	Dimalikos	82	Kouris d/s flowmeter	130	U/s Kouris confluence
35	dipot	83	Kouris flowmeter	131	U/s Lefka dam
36	Ds Gef Tzelefou	84	Kouris u/s dam	132	u/s_vretsia
37	Ek_moni	85	Kryos_u/s_bridge	133	u/skidasi
38	Ekv PlatisPyrgoy	86	Kyprovasa	134	U/sTrimiklini
39	Ekvoles Diarizos	87	Lazarides 1	135	Us fishfarm Kargotis
40	Ekvoles Ezousas	88	Limnatis flowmeter	136	Us Gef Tzelefou
41	Ekvoles Xeros	89	Livadi u/s dam	137	Valva
42	finifisheries	90	Livadi u/s dam 2	138	Vrachos
43	Finikas d/s prodam	91	Marathasa d/s fisheries	139	Vrondisia
44	Fleva	92	Mesa potamos Kouri	140	Xeros_ek
45	Garillis confluence	93	Mesopot_katgef	141	Xeros_up
46	Gef Choletria	94	Mesopotamos_camp	142	Yperchilistis Tsakistra
47	Gef Evrychou	95	Mosfilioti		
48	Gef Limniti	96	Moutoulas		

Table A.4. CANOCO Fig 4.14. (p.109)

1	Achelia canal	49	Gef Mavres Sykies	97	Mylos
2	Ag Georgios	50	Gef Roudias	98	Oroklini_can_east
3	Agamv	51	Gef Salamiou Xeros	99	Oroklini_can_west
4	Agiasma	52	Gef Skouli	100	Panagia Diakou Agia
5	Agios Avvakoum	53	Gefelias	101	Pareklissoudi
6	AgMamas Limnatis	54	Germ_a_weir	102	Pediaos Lefk
7	AgMaura	55	Germ_b_weir	103	Perapedi u/s bridge
8	AgParaskevi	56	Germasogia d/s dam	104	Perasma Xeros
9	Agtheodo	57	Germasogia d/s flowmeter	105	Pirgos 1
10	Akrounta confluence	58	Germasogia u/s dam	106	Polis Crys 1
11	Akrounta village	59	Germasogia u/s flowmeter	107	Polis Mouth 1
12	Alassa above bridge	60	Gialan2	108	Polis Mouth 2
13	Alassa below bridge	61	Gialia Ds spring	109	Potamitissa bridge
14	Alonoui	62	Gialia Spring	110	Pouzis_1
15	Amati	63	Gialia Us Spring	111	Pouzis_ek
16	Amiantos	64	Gialian1	112	Prastio
17	Argaka_ek	65	Glapsides	113	Silver Beach
18	Asprokremma Ponds	66	Goudi bridge	114	Skouriotisa
19	Avakas	67	Ha_ek	115	Souskiou
20	Avakas Mouth	68	Ha_usek	116	Spilia
21	Avakas Mouth	69	Ichthyo_canal	117	Stavros kat camping
22	D/s Arakambas dam	70	Kakopetria Garillis	118	Stavros Psokas 1
23	D/s dam Evretou	71	Kalidonia trailhead	119	Stavros Psokas u/s dam E
24	D/s gef watermills Arama	72	Kampos 1	120	Stenoi
25	D/s Kafizides dam	73	Kargotis confluence	121	Trem_d/s_dam
26	D/s Kamenopaidi	74	Kat Fragma Kafiziedes	122	Trem_u/sfalls
27	D/s Kouris dam	75	Kat Fragma Tsakistras	123	Trieselies
28	D/s Kouris dam 2	76	Kat Gef Limniti	124	Troodospicnik
29	D/s Life pond	77	Kat_kannaviou	125	Two bridges
30	d/sCedrus	78	Katgerakies	126	U/s Arakambas dam
31	d/sXiliatos	79	Kato Pirgos	127	U/s evretou dam 2
32	DiarMid	80	Katydata	128	U/s gef watermills Arama
33	Dierona	81	Kisdasi	129	U/s Kafizides dam
34	Dimalikos	82	Kouris d/s flowmeter	130	U/s Kouris confluence
35	dipot	83	Kouris flowmeter	131	U/s Lefka dam
36	Ds Gef Tzelefou	84	Kouris u/s dam	132	u/s_vretsia
37	Ek_moni	85	Kryos_u/s_bridge	133	u/skidasi
38	Ekv PlatisPyrgoy	86	Kyprovasa	134	U/sTrimiklini
39	Ekvoles Diarizos	87	Lazarides 1	135	Us fishfarm Kargotis
40	Ekvoles Ezousas	88	Limnatis flowmeter	136	Us Gef Tzelefou
41	Ekvoles Xeros	89	Livadi u/s dam	137	Valva
42	finifisheries	90	Livadi u/s dam 2	138	Vrachos
43	Finikas d/s prodam	91	Marathasa d/s fisheries	139	Vrondisia
44	Fleva	92	Mesa potamos Kouri	140	Xeros_ek
45	Garillis confluence	93	Mesopot_katgef	141	Xeros_up
46	Gef Choletria	94	Mesopotamos_camp	142	Yperchilistis Tsakistra
47	Gef Evrychou	95	Mosfilioti		
48	Gef Limniti	96	Moutoulas		

Summary Ichthyolgical Account: An Heuristic List of Inland Water Fishes of Cyprus[14]

There is no complete and authorized list of inland water fishes for the island (see Zogaris et al. 2012). Here we present a preliminary list based on all available information. This list is not complete and does not pretend to be; it is an exploratory account and is thus labled "heuristic". It should be noted that this list includes all species occuring in inland waters – which includes running and still waters in the interior of the shoreline (i.e. lagoons and "salt-lakes", canals, and artificial ditches, irrigation waters, reservoirs are included). Inlets or open brackish-like marine waters such as Potamos Liopetriou (Ammochostos District) are not included. Exploration of the occupied territory is incomplete and obviously there are some open lagoonal areas there that have not and some cannot be researched easily. Obviously, the overwhelming knowledge here is from the southern part of the island; but the occupied territory in the north is obviously included in this account.

The list is divided in to two parts: ***A****: Confirmed species, and* ***B****: Suspected, reported, and/or unconfimed species.*

Initially 21 species are shown as confirmed by our research on the island, seven of which represent native species. All these have been observed by the HCMR/ISA team during the study and by members of HCMR immediatley before the study period in the wild in Cyprus. (Obviously fishes seen in captivity or at hatchereis are not mentioned here). We have adequate evidence to include several other species but do not consider them (i.e. they have not been observed and are now shown in the catogory B section of the list; these include lacustrine species we know are restricted to reservoirs, for example).

Please note that all native species are <u>underlined</u> *(n=12) and of these, all are of marine orgin with the exception of the peripheral* Salaria fluviatils *and* Anguilla anguilla *and the secondary inland water/freshwater inhabitat* Aphanius fasciatus.

The following notations follow each Scientific Name:

- NIS = Non-indigenous species
- Native = Native to the country (in one case the word "Stocked" is provided for Dicentrarchus labrax where we are told that escapees are introduced by aquaculture).
- Marine = Euryhaline species of marine origin that enter inland waters.
- ESTABLISED = refers to species we know maintian self-sustaining reproducing populations in the wild.
- (F) = Information about species occurance taken from FishBase.
- *(DFMR)* = Information about species occurance taken from Department of Fisheries and Marine Research.

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[14] *This work is in the process of being published in a scientific journal; it represents the first modern list of the fish species of Cyprus.*

A. Confirmed On the Island of Cyprus.

Species observed by the HCMR team during the 2009-2012 survey period. Laboratory collections and photographs of nearly all of the species below exist.

1. *Alburnus alburnus NIS widespread ESTABLISED*
2. *Anguilla anguilla Native Catadromous*
3. *Aphanius fasciatus Native Brackish Waters*
4. *Atherina boyeri Native Marine*
5. *Abramis bjoerkna NIS*
6. *Carassius auratus NIS ESTABLISED*
7. *Carassius cf. gibelio*[15] *NIS ESTABLISED*
8. *Cyprinus carpio NIS ESTABLISED*
9. *Dicentrarchus labrax Native/Stocked Marine*
10. *Gambusia holbrooki NIS ESTABLISED*
11. *Ictalurus punctatus NIS ESTABLISED*
12. *Lepomis gibosus NIS ESTABLISED*
13. *Micropterus salmoides NIS ESTABLISED*
14. *Mugil cephalus Native Marine*
15. *Liza aurata Native Marine*
16. *Liza ramada Native Marine*
17. *Oncorhynchus mykiss ESTABLISED*
18. *Oreochromis aureus ESTABLISED*
19. *Perca fluviatilis NIS ESTABLISED*
20. *Rutilus rutilus NIS ESTABLISED*
21. *Salmo trutta NIS ESTABLISED*

B. Unconfirmed Speceis

It is certain that the above list covering only a small portion of all extant species. In this section species encountered in the literature and grey literature are provided. The number of species of fish in Cyprus freshwaters is larger than initially expected. Fishbase alone lists 31 species. The establishement of some species is questionable (however, no species that are present only in fish hatcheries or aquaculture are shown here, e.g. sturgeons). Of the following native species, it should be noted that Alosa fallax *is extremely important as a species which requires river-mouths and flowing rivers for spawning in Spring. The record fo this rare species is from Fishbase and has not yet been traced to its original source. Finally,* Salaria fluviatilis, *collected in 1907 from the Limasol District, has to our knowledge never before been confirmed on Cyprus, and may very well be extinct.*

[15] One specimen of a brownish Carassius collected from Alikos Stream (Kotsiatis) was examined in the laboratory at by Dr. Radek Sanda (Prague Museum) and showed morphological characteristics of Carassius gibelio but may also have been of hybrid stock.Genetic work on this population needs to be done; since this is the first record of this species on the island. The species coexists with Carassius auratus in the same river.

22. *Alosa fallax Native Marine/Freshwater Spawner (F)*
23. *Aspius aspius NIS (F)*
24. *Carassius carassius NIS (F)*
25. *Clarias gariepinus*[16] *NIS (F)*
26. *Ctenopharyngodon idella NIS (F)*
27. *Hypophthalmichthys molitrix NIS (F)*
28. *Liza saliens Native -Marine (F)*
29. *Neophis ophidion Native -Marine (F)*
30. *Oncorhychus clarkii NIS (F)*
31. *Oreochromis niloticus*[17] *NIS (F)*
32. *Salaria fluviatilis Native Freshwater (British Museum, London)*
33. *Salmo salar NIS (F)*
34. *Salvelinus alpinus NIS (F)*
35. *Salvelinus fontinalis NIS (F)*
36. *Sander lucioperca NIS-ESTABLISHED*[18] *(DFMR)*
37. *Syngnathus abaster Native Marine (F)*

Comments on the list

There is a large chance more species have been introduced, there is evidence that some species have been introduced and efforts are on the way to make more introductions (i.e. Tinca tinca was observed at Kalopanayotis Hatchery in 2011).

It must be reiterated that specific codes of practice for the introduction of freshwater organism on Cyprus must be established. Perhaps one of the problems with the introductions is that some species are sometimes not correctly identified by authorities. For some species and specimens from the wild this may need laboratory work and specialist examination(for example identifying wild-spawned Rainbow Trout is not easily done with confidence (see Fig. A., below). We believe a thorough review of the inland fishes of the island will bring to light yet more species, perhaps often brought in inadvertedly with carp introductions.

[16] This African catfish from the Nile is one of the oldest fishes to be transported alive to Cyprus (since classical times); its current status is unknown. Naturalized populations, from early transplantations of the species are found in Turkey and the Levant.

[17] This species hybridizes with O. aureus; it is said both were imported from Isreal. The specimen photos that of all individuals collected from Asprokremmos canal at Achelia and Germasogeia Reservoir were identified as O. aureus by Dr. J. Freyhof (Nov. 2012). Other populations have not been identified.

[18] DFMR confirm that Sander lucioperca is currently established within the Kouris Reservoir, perhaps elsewhere.

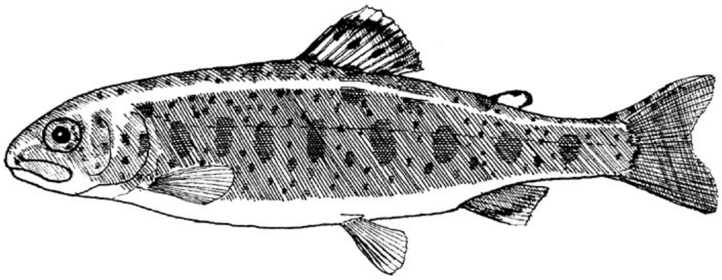

Fig. A.3 *Young-of-the-year Brown Trout (at Meso Potamous, Kouris) and a drawing of Young-of-the-year Rainbow Trout* Oncorhynchus mykiss. *Note the characteristic spots on the dorsal fin in the Rainbow Trout. This species has not yet been confirmed spawning wild in Cyprus but there is a very big likelyhood that it does at Kalydonia, in the upper Kryos and perhaps in the upper part of the Xeros (Lefkas), the Upper Marathasa and Kargotis.*