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FISH DIVERSITY AND TRADITIONAL FISHING METHODS IN SEMIARID IRRIGATED SYSTEM IN THE BAJO VINALOPÓ REGION, SOUTHEASTERN SPAIN

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ABSTRACT

The aim of this paper is to obtain a comprehensive picture of the importance of the fish fauna in the wetlands and coastal lagoons of the Bajo Vinalopó region (Alicante, South eastern Spain) and the ecological, historical and cultural value of the traditional knowledge on fishing maintained by local people. We have compiled data from different information sources: (1) the revision of historical archives, (2) personal interviews and collaborative research, and (3) ecological and water quality data. The results show that the area sustains important fish fauna diversity (17 species) and that local people have inherited a considerable traditional knowledge on fishing methods (11 modalities), on the maintenance and sound management of the water system and on the ecology and behaviour of fish. We conclude that a comprehensive consideration of all these ecological, historical and socio-cultural aspects related to fish and fishing shows clearly the value of this ecological and cultural heritage and provides a necessary base for a sustainable management of the area.

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1. Introduction

From last few decades, some authors (Huntington, 2000; Berkes et al., 2000; Reyes-García and Martí-Sanz, 2007) have emphasized the importance of human knowledge to ecologists, with a focus on Local Ecological Knowledge (LEK) or Traditional Ecological Knowledge (TEK), and in general, on Indigenous Knowledge (IK).

There have been many studies on the value of ecological knowledge of local fishing communities, including the relation to freshwater or transitional water bodies (Eythorson, 1993; Johannes, 2001; Baird, 2007; Meye and Ikomi, 2012). Several communities are dependent on the dynamics of aquatic resources, and as a result of their experience, have accumulated a wealth of knowledge which is of great value to formal investigation (Le Grusse et al., 2006). In Spain, this combination of scientific research, information gathering and ethnological research is well established, since the classical studies of Gandolfi (1916) or, especially, Pardo (1942, 1945) to another more recent Docavo (1979) and Mas (1986) or Flichman (1997) studies, with the latter basing his work on the consultation of numerous local historical sources (Parra and Abadía, 1999).

There has been much interest concerning knowledge of the biodiversity associated with irrigation channels. However, there are methodological difficulties associated with such work, because the study of this fish community, linked to water bodies and channel network and ponds, it is very difficult by the need for sample extraction. In other cases, hydroacoustic sampling is widely accepted as a method for enhancing fisheries assessments and is gaining momentum as a survey technique in shallow water environments (Krumme and Saint-Paul, 2003; Boswell et al., 2007). Most studies utilize acoustics to provide complementary estimates of fish abundance and density while relying on direct biological sampling to gain information on the composition of the fish community (Boswell et al., 2010). For a better management of this natural resource in the study area and in order to improve the catch per unit effort of the subsistence fisher folks, a knowledge of the rainy days, water levels, extent of flood in each season as well as the relative efficiency of the different fishing gears being used in the area is a *sine qua non* (Meye and Ikomi, 2012).

The main goal of this study is to evaluate fish diversity and local fishing methods in the traditional irrigated systems used in SE Spain, which has a high environmental and cultural value. We have compiled data from different information sources: (1) historical archives, bibliography and grey literature, (2) ethnological knowledge, obtained through personal interviews and collaborative research, and (3) ecological and water quality data, obtained in the field through standard measurement methods.

2. Materials and Methods

This study is intended to gather information related to fish and traditional fishing methods. A participatory GIS has been used in order to integrate the field information of traditional and local knowledge, with spatial reference (McCall and Minang, 2005).

The WADI (Water Demand Integration- INCO-CT2005-015226) project, funded by the European Commission, comparatively analyzed the ecological and socio-cultural aspects of a number of Mediterranean wetlands, with a view to developing more sustainable scenarios for their future development. In Spain, the site chosen to conduct the study was the Natural Park of El Hondo of Elche-Crevillente and its catchment area, which covers a good portion of the water system in the southern region of Bajo Vinalopó and the district of Vega Baja del Segura.

Study area

The study area is situated in the southern part of the geographical region known as the Bajo Vinalopó Region in its transition to the Bajo Segura, south of the province of Alicante and in the catchment area of the Natural Parks of El Hondo and the Salinas de Santa Pola, bounded by the UTM coordinates 30N: 667000, 4191000; 781000, 4321000.

The water system, which holds the fish populations under study, is composed of an intricate network of man-made channels, ponds and reservoirs, or natural water bodies which have been profoundly changed by man. In the area leading to the Vinalopó and Segura rivers, the degree of intervention is so large that operation of the water system is possible only through human presence. Remarkable energy levels are required, both for pumping water that feed certain portions of the system, as well as for the continued care that the extensive series of dams and canals require. This area of high ecological value is suffering severe degradation processes that seriously threaten its future, in addition to being one of the areas of greatest social conflict on the Iberian Peninsula.

The ombro type of the study area is semiarid Mediterranean (Rivas-Martínez and Arnaiz, 1983), with an average annual temperature of 18 °C, presenting two distinct periods, with strong rainfall in the autumn-winter season and very dry weather in summer, with average annual rainfall of 350 mm. The index indicates that within the thermal bioclimates of the xeric Mediterranean ocean, this area belongs to Thermo-Mediterranean thermotype (Pérez, 1994).

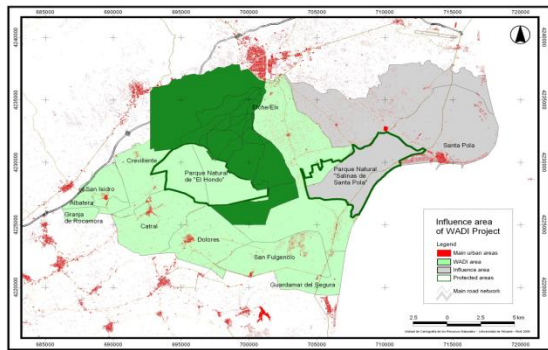


Figure 1: Influence area of WADI Project in Spain (El Hondo and Salinas de Santa Pola Natural Parks).

Methodology:

The methodology and results, concerning information related to fish and traditional fishing methods, are structured in three distinct sections depending on the source of the data obtained:

a) Historical and documentary analysis

First, the historical and documentary analysis focused on the review of any historical documentation that made some reference to fishing in the area, including both ancient sources as well as recent historical studies, in order to provide data relevant to understanding the historic role of fishing. Secondly, we carried out direct consultation of documentary funds relating to fisheries and management of wetlands preserved in the historical archives of the area, especially the AHE (Historical Archives of Elche), the Archives of Notary Protocols of Dolores and the archives of the local community irrigation managers, particularly Carrizales in Elche.

We have studied documentation such as administrative regulations and management plans, as well as reports of activities of the Park and plans for fishing in private farms. The review also included some of the scientific reports, published and unpublished, that are related to wildlife and fish from this area. Finally, the review also included an analysis of the portrayal of the conflict offered by the media, both in recent press and further in the past.

b) Traditional knowledge

Whilst the value of recording traditional ecological knowledge is recognized, collection of data presents a series of methodological problems which have not always been given due attention. The significance and relevance of the data obtained can only be assured through rigorous design (Davis and Wagner, 2003). It is necessary to follow the media in order to identify the "local experts" because these informants are the basis of the LEK research.

Forty-eight people were consulted, considered as local experts (seniors), were characterized by their long union to the rural

environment and rural practices (farmers, irrigators, shepherds, pond owners, etc) or who have practised fishing throughout their lives. It is not possible establish categories due to small population size which practicing this activity. Historically, this activity has been linked to male gender. So, we have only interviewed people about this gender. In our case, the relations of trust built with communities of irrigators (mainly Carrizales, El Progreso and Riegos de Levante) were instrumental in carrying out this research.

The semi-structured interviews addressed a number of key points relating to different fishing tackles, the season of the year in which they are used, types of captured species, the problems, etc. The information gathered in interviews was also contrasted with field observations, through what can be considered close to participant observation (Guasch, 1997). Thus, during days of field work researchers accompanied fishermen in their jobs, and participated in the preparation of materials, catching, processing of fish and in a range of dining and recreational activities and social relationships that are related to these tasks.

c) Scientific water monitoring

The study of water electrical conductivity (EC) in different environments is a parameter that expresses the total concentration of soluble salts in irrigation water and provides an indication of water quality. We also calculated the value of total dissolved solids (TDS) as well as water temperature, which affect this concentration. Random points were selected and geographically located in the network of channels and ponds as a representative sample of the study area, allowing time analysis of 31 sampling points. Measurements were taken directly in the field using a portable conductivity meter, CON 110, Eutech Instruments®, to avoid any disruption that may occur by transport of samples. Moreover, points at which water samples were taken were geo-referenced using Trimble GPS® and subsequently exported to ArcView® format (*.shp).

Excel 2003® was used to conduct a basic analysis of the data and to enable an evaluation of the frequency of usage of different fishing types and to estimate the most popular fish species.

d) Participatory GIS

For the construction of the GIS database, we used the 2000 year cartographic base of the Valencian Cartographic Institute (ICV), focusing on the layer linked to the water network and water bodies. This layer has been adapted to current realities in the region, incorporating toponymic information provided by informants. Another key image, also from the ICV, is the orthoimage mosaic covering the study area. Finally, 22 random points were selected and geographically located (UTM 30N reference system) in the network of channels and ponds as a representative sample of the study area (Figure 2) and in the Segura River (Figure 3). Moreover, points at which water

samples were taken were geo-referenced using Trimble GPS ® and subsequently exported to ArcGis ® format.

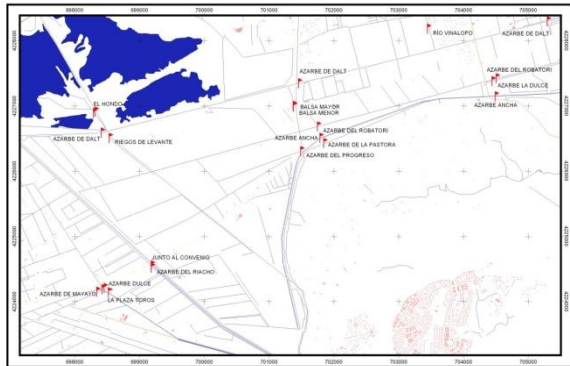


Figure 2: Sampling points in the bajo Vinalopó study area

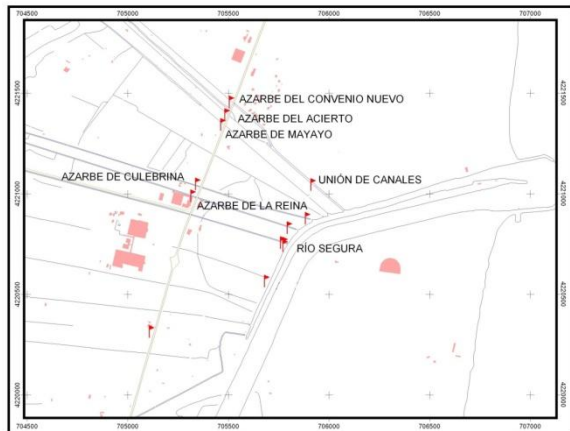


Figure 3: Sampling points in the Segura River mouth

In order to obtain information regarding the names of the network of canals and biodiversity associated with them, we conducted a series of 48 interviews. These interviews were semi-structured based on a number of key points relating to different types of fishing, the season of the year in which different methods are used, species that are caught, the problems, etc. The information gathered in interviews was also contrasted with field observations, through what can be considered close to participant observation (Guasch, 1997). The open nature of semi-structured interviews made it possible to discover several important issues not previously identified. Thus, during days of field work researchers accompanied fishermen in their jobs, and participated in the preparation of materials, catching, processing of fish and in a range of dining and recreational activities and social relationships that are related to these tasks.

People consulted, considered as local experts (seniors), were characterized by their long union to the rural environment and rural practices (farmers, positions in the community of

irrigators, owners of different purchasing power, informants from the areas of Spanish and Valencian speakers, etc) or who have practised fishing throughout their lives. It is not possible establish categories due to small population size which practicing this activity. Historically, this activity has been linked to male gender. So, we have only interviewed people about this gender.

Results and discussion:

a) Historical and documentary analysis

The historical documents show the considerable fish richness in the ancient lagoon (albufera) of Elche since Middle Ages. Some authors describe this area like a place with an important abundance of fish (Escolano, 1611; Sanz, 1954) and high species diversity (Esquerdo, 2002). According to a document from March 1st, 1802, the mullet of the lagoon was considered of higher quality than those captured on the beach (Ramos, 1973).

The information reveals the historical conflicts over the exploitation of fishery resources in the area, because the fishing was a major source of income of the lords of Elche, reaching 10% of total revenues of the lordship. In later centuries, the percentage will not be as high but will be important. Besides the historical significance of the fishery also shows off its significance in the landscape structure, because it should remain an important and regular flow of fresh water from the Segura River, been the only water resource in the area. The lords strove to maintain a channel of fresh water into the lagoon over the opposition of the neighbours of irrigated areas of Guardamar and Orihuela (Escolano, 1611).

The need to eliminate health problems associated with water in the catchment area of the old lagoon triggered a series of conflicts that confront the health of the area and the exploitation of the fishery resource (Alonso, 1950; Canales and Vera, 1985; Gil and Canales, 1987). The fishery remained important in the irrigation channels and azarbes integrated in the new landscape resulting from drain lands and agricultural colonization of the eighteenth century. Many documents from the eighteenth and nineteenth centuries refer disputes between farmers and fishing tenants. The azarbes were leased by the Irrigators Communities for fishing using traditional methods in exchange for money or payment in kind. This arrangement was in force until 1965 (Belda et al., 2008).

Two elements are to make the situation more complex during the twentieth century. On the one hand, the private irrigation companies that take remaining water from the Segura River or the drainage of irrigated areas to supply the Campo de Elche. This action favours the creation of new water bodies on the landscape, standing out the construction of reservoirs of El Hondo. In fact, the companies exploited the fishery resources, producing conflicts between administration and local people (Sansano, 2000).

In 1980, a new factor appeared with profound implications: the conservationism. The ecological richness will wake an increasing interest in the zone from birdwatchers and conservation groups. In 1988, the area is declared a Natural Site, and subsequently Natural Park in 1994.

It is significant that the regulations of the Park prohibit the use of all types of traditional fishing methods because they restrict the "sport fishing" in ditches and channels. In the fishing preserves is necessary the approval by the Fishing Management Plan. This will generate a series of conflicts with frequent importance in the media. The review of environmental documentation shows limited scientific studies on fish and fisheries. A local LIFE Program includes a conservation plan to preserve interesting indigenous species such as *Aphanius iberus* and *Valencia hispanica* (Torralva et al., 2002).

b) Traditional knowledge

The area sustains important fish fauna diversity (17 species) and local people have inherited a considerable traditional knowledge on fishing methods (11 modalities). This is relevant on the maintenance and sound management of the water system and on the ecology and behaviour of fish. The frequency of awareness refers to the number of citations that have been recorded, for each fish species and capture method, for all the interviews. In an indirect way, this provides crucial information on the diversity of fishes and techniques in the study area.

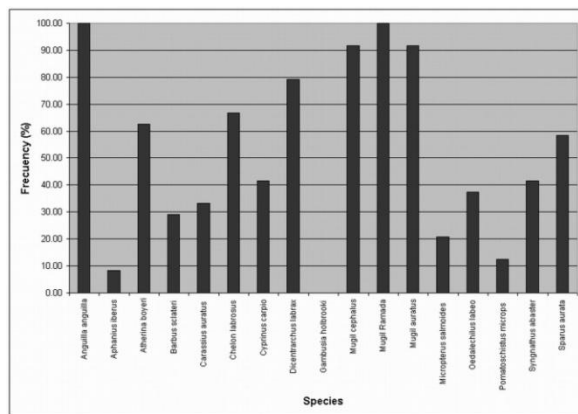


Figure 4: Frequency of fish species in the Bajo Vinalopó irrigated network

The frequency of use refers to the number of citations that have been recorded for each of the fish species (Figure 4) and traditional fishing methods (Figure 5), for all interviews. In an

Indirect way, this provides interesting data on the socio-cultural heritage and traditional use of natural resources.

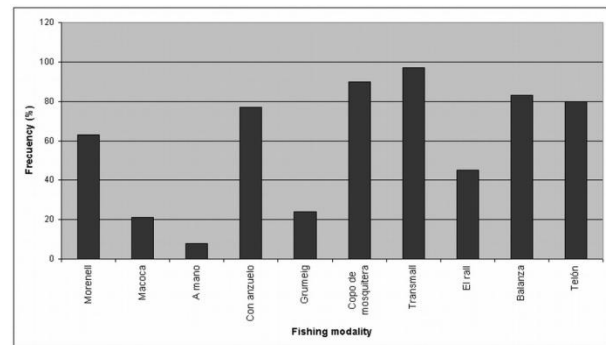


Figure 5: Traditional fishing methods in the Bajo Vinalopó irrigated network

The data collected has allowed to know the changes in the fish community produced in recent decades. Compared with the data presented by Mas (1986) on the number of species of freshwater fish mostly in the Segura River, according to data derived from the study, has increased significantly (9 species recognized in 1986) and are similar to those presented by Andreu-Soler et al., 2006 (18 species recorded) and Oliva-Paterna et al., 2007 (16 species recorded).

Based on the data obtained, we have detected a total of 17 species of fish, either in the field samplings either by the information provided by informants. Of the total 15 species of them (88.23%) currently consumed or are consumed at any time by fishermen in the area. Thus, all species, the ones that has not been used for cooking by such informants are *gambusia* and *fartet*.

Thus, the richness of traditional fishing techniques (11 modalities), and popular knowledge about fish and their exploitation, are the legacy of the long historical relationship between humans and biological resources from the marsh (Annex 1). For their popularity are among these modalities, the *transmall* (95.83%), *telón* (91.67%) and *balanza* (83.33%). By contrast, probably due to the difficulty, the type of fishing "by hand" (*a mano*) is the lowest among the fans informants interviewed (8.33%).

c) Water monitoring and participatory GIS

The most important results obtained from the study, with a differentiation between the system of canals and azarbes ($n = 16$) and the system of ponds and reservoirs ($n = 6$) are presented in Tables 1 and 2.

Point	Conductivity (mS/cm)	TDS (ppt)	Species	Richness
Azarbe Ancha	13.98	7.88	<i>Anguilla anguilla</i> <i>Aphanius iberus</i> <i>Cyprinus carpio</i> <i>Mugil cephalus</i> <i>Mugil ramada</i> <i>Mugil auratus</i> <i>Sparus aurata</i>	7
Azarbe de Dalt	11.60	5.83	<i>Atherina boyeri</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i>	3
Azarbe del Acierto	10.15	5.10	<i>Anguilla anguilla</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i>	3
Azarbe del Convenio	13.92	6.94	<i>Anguilla anguilla</i> <i>Aphanius iberus</i> <i>Atherina boyeri</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i> <i>Mugil ramada</i> <i>Mugil auratus</i>	7
Azarbe del Mayayo	5.20	2.63	<i>Anguilla anguilla</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i>	3
Azarbe del Riacho	7.78	3.85	<i>Anguilla anguilla</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i>	3
Azarbe del Robatori	12.80	6.35	<i>Anguilla anguilla</i> <i>Aphanius iberus</i> <i>Cyprinus Carpio</i> <i>Dicentrarchus labrax</i> <i>Mugil cephalus</i> <i>Mugil ramada</i> <i>Mugil auratus</i> <i>Sparus aurata</i>	8
Azarbe Dulce	5.34	2.65	<i>Carassius auratus</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i>	3
Azarbe La Culebrina	8.60	4.27	<i>Anguilla anguilla</i> <i>Atherina boyeri</i> <i>Cyprinus carpio</i> <i>Mugil cephalus</i>	4
Azarbe La Pastora	14.80	7.43	<i>Anguilla anguilla</i> <i>Mugil cephalus</i>	2
Azarbe La Reina	6.49	3.26	<i>Anguilla anguilla</i> <i>Mugil cephalus</i>	2
Canal del Progreso	8.26	4.16	<i>Anguilla anguilla</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i> <i>Mugil auratus</i>	4
Canal de Levante	6.38	3.4	<i>Anguilla anguilla</i> <i>Cyprinus carpio</i> <i>Mugil cephalus</i>	3
Mayayo (Plaza toros)	5.30	2.67	<i>Anguilla anguilla</i> <i>Mugil cephalus</i>	2
Río Segura	5.59	2.79	<i>Anguilla anguilla</i> <i>Barbus sclateri</i>	12

			<i>Cyprinus Carpio</i> <i>Dicentrarchus labrax</i> <i>Gambusia holbrooki</i> <i>Mugil cephalus</i> <i>Mugil auratus</i> <i>Micropterus salmoides</i> <i>Oedalechilus labeo</i> <i>Pomatoschistus microps</i> <i>Syngnathus abaster</i> <i>Sparus aurata</i>	
Río Vinalopó	13.49	6.67	<i>Anguilla anguilla</i> <i>Carassius auratus</i> <i>Cyprinus Carpio</i> <i>Gambusia holbrooki</i> <i>Mugil cephalus</i> <i>Micropterus salmoides</i>	7

Table 1. Water quality and diversity of fish in the canals and azarbes of the Bajo Vinalopó-Vega Baja Region.

Point	Conductivity (mS/cm)	TDS (ppt)	Species	Richness
Balsa mayor Sivaes	8.42	4.16	<i>Anguilla anguilla</i> <i>Carassius auratus</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i> <i>Mugil auratus</i>	5
Balsa menor Sivaes	8.21	4.10	<i>Anguilla anguilla</i> <i>Carassius auratus</i> <i>Cyprinus Carpio</i> <i>Mugil cephalus</i> <i>Mugil auratus</i>	5
El Charcol norte	17.78	10.90	<i>Anguilla anguilla</i> <i>Chelon labrosus</i> <i>Gambusia holbrooki</i> <i>Mugil cephalus</i> <i>Mugil auratus</i> <i>Sparus aurata</i>	6
El Charcol sur	21.70	8.91	<i>Anguilla anguilla</i> <i>Chelon labrosus</i> <i>Gambusia holbrooki</i> <i>Mugil cephalus</i> <i>Mugil auratus</i> <i>Sparus aurata</i>	6
Hondo (Levante)	18.96	9.54	<i>Anguilla anguilla</i> <i>Aphanius iberus</i> <i>Atherina boyeri</i> <i>Cyprinus carpio</i> <i>Gambusia holbrooki</i> <i>Mugil cephalus</i> <i>Mugil auratus</i>	7
Hondo (Poniente)	16.22	8.07	<i>Anguilla anguilla</i> <i>Aphanius iberus</i> <i>Cyprinus Carpio</i> <i>Gambusia holbrooki</i> <i>Mugil cephalus</i> <i>Mugil auratus</i>	6

Table 2. Water quality and diversity of fish in the ponds and reservoirs of the Bajo Vinalopó-Vega Baja Region.

In accordance to the water quality we can say that the salt concentration is higher in the sampled ponds (15.22 ± 5.63 mS / cm) than in the sampled channels (9.66 ± 3.82 mS / cm). These results agree with local knowledge and they probably influence the abundance and distribution of the ichthyofauna. By the other hand, it should also be noted that, although they have the maximum value of conductivity (21.70 mS / cm) in the area of Bajo Vinalopó, with an average value of conductivity of 10.74 ± 4.68 mS / cm, are lower than those azarbes at the mouth of the Segura River (12.90 ± 4.98 mS / cm), due to the leaching of nutrients from agricultural fields would affect the conductivity of the water. However, the low water quality into channels may be synonymous of a high abundance of fishes, especially the case of mullet and eel. Some channels appear to have been maintained over time as a source of supply of fish resources. The azarbes *Ancha*, *Convenio* and *Robatorio*, north of the study area in the vicinity of El Hondo Natural Park, appear to have a higher quality for fishing due to greater regularity in the water flow and saline concentrations. In contrast, *Dulce* and *de Dalt*, which are azarbes of irrigation, show greater irregularity in the concentration of salts, due to rainfall and water regulation to which they are subjected, and therefore have fewer resources available, which is translated, according to the informants, into a lower abundance of fish.

The system of azarbes, which reaches the final stretch of the River Segura, and management measures applied, are key determinants of the physical and chemical characteristics of water. Depending on the nature of the land and on measures employed there will be a higher or lower concentration of salts and nutrients, turbidity of the water, and so on. This is the case of azarbes of *Mayayo* and *Culebrina* which present a greater amount of mud and hence higher turbidity, which together with a lower rate of salinity, result in lower quality for the species prized for fishing in the area.

Segura River presents the most important richness (12 fish species), because it is a transitional zone between freshwater and the sea buffer area, being possible find typical species of both environments. By the other hand, generally, the azarbes present low richness values due to pollution phenomenon and lost of water flow, which caused the eutrophication processes by which channels gradually age and become more productive to algal group. These algal blooms led to oxygen depletion and resultant fish kills. Many native fish species disappeared, to be replaced by species more resistant to the new conditions, especially *Cyprinidae* Family.

Conclusions:

The historical analysis provides important insights on the antiquity of the practice of fishing in the area and its historical importance for the configuration of present landscape, on the historical transformations of fishing rights and conflicts (including conflicts with recent conservation decisions), and on the present decline of fish fauna and local fishing culture. We conclude that a comprehensive consideration of all these

ecological, historical and socio-cultural aspects related to fish and fishing shows clearly the value of this ecological and cultural heritage and provides a necessary base for sustainable management of the area.

In order to establish new management plans, according to ecological values in the study area, the local ecological knowledge on the wealth of the fish fauna is very important. By the other hand, stakeholders are the role of authentic information reservoirs because they are experts about the fish populations, fish distributions, temporal evolution and the best form to manage the hydrological infrastructures. Complementary, historical documents show this local knowledge as an inheritance of some centuries of environmental exploitation and modulation. By this reason, the knowledge of stakeholders needs to be captured now; when these people die, local ecologic knowledge disappears.

The knowledge of stakeholders shows that mullet and eel have the most popularity into local fisheries. In respects to fish methods, the Transmall, Telón and Balanza are the usually used by the fishermen. It is necessary to remember the role of stakeholders as key piece in order to conserve the ethnological heritage.

Management plans have to consider these patrimonial values in order to design the best exploitation strategies. So, fishing could be an economic resource that would help to promote new tourism and educational strategies in the study area. However, we must bear in mind the importance that decision makers have gotten in the History, contributing to modulation of the South part of Alicante Province. Traditional management should be a strategic tool to guarantee sustainable exploitation and to conserve threatened species.

Stakeholders are the role of authentic information reservoirs because they are experts about the fish populations, fish distributions, temporal evolution and the best form to manage the hydrological infrastructures. Complementary, historical documents show this local knowledge as an inheritance of some centuries of environmental exploitation and modulation. Awareness of the local fish and its traditional use as feed resource is high among local users. By this reason, residents and users of the system are critical to the maintenance and transmission of a rich cultural heritage, which otherwise would have fallen into oblivion.

GIS used to represent geographical, biological and ethnological characteristics of local water resources are a valuable tool for the development of management strategies related to the conservation of the freshwater and transitional water bodies and surrounding landscapes and maintain their cultural diversity. In order to improve GIS database is basic to incorporate place names to provide a means of identifying and locating areas which would otherwise be difficult to study. Finally, species diversity is greater in the system of canals and azarbes that in the system of ponds and reservoirs. The main channel of the River Segura, being the collector of the network

of azarbes, presents the highest values of biodiversity. The intensification of agricultural uses in the zone of influence of the network of channels has a direct impact on the quality and availability of water and, therefore, on the diversity of fish fauna.

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