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TELEOST SPECIES RECORDED IN TUNIS SOUTHERN LAGOON AFTER ITS ENVIRONMENTAL RESTORATION (NORTHERN TUNISIA, CENTRAL MEDITERRANEAN)

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ABSTRACT

During the investigations conducted after an environmental restoration of Tunis Southern Lagoon, close to the Gulf of Tunis in northern Tunisia, 62 teleost species were collected, 48 of which were recorded in the area for the first time. Of the 62 teleosts, 13 were sedentary, 26 marine and 23 regular migratory species. Their occurrence in the area is discussed in the present article.

Key words: Osteichthyes, teleosts, environmental restoration, Tunis Southern Lagoon, Tunisia, Central Mediterranean

SPECIE DI TELEOSTEI SEGNALATE NELLA LAGUNA MERIDIONALE DI TUNISI DOPO UN RESTAURO AMBIENTALE (TUNISIA SETTENTRIONALE, MEDITERRANEO CENTRALE)

SINTESI

Le ricerche condotte nella laguna meridionale di Tunisi, prossima al Golfo di Tunisi, nella Tunisia settentrionale, in seguito ad un restauro ambientale, hanno portato alla raccolta di 62 specie di teleostei, 48 delle quali sono state segnalate per la prima volta per quest'area. Delle 62 specie raccolte, 13 sono sedentarie, 26 marine e 23 specie che migrano regolarmente. L'articolo discute il loro ritrovamento in quest'area.

Parole chiave: Osteitti, Teleostei, restauro ambientale, laguna meridionale di Tunisi, Tunisia, Mediterraneo centrale

INTRODUCTION

The Lagoon of Tunis, adjoining the city of Tunis, is located in the southwestern Gulf of Tunis (Figs. 1, 2). It is divided in two areas by a navigation channel, *i.e.* into Tunis Northern Lagoon and Tunis Southern Lagoon. In the past, both areas were severely anthropically polluted (Zaouali, 1983; Ben Souissi, 2002). They required a thorough environmental restoration, which has been recently indeed achieved (Vandenbroek & Ben Charrada, 2001; Ben Souissi, 2002; Ben Souissi *et al.*, 2003). Investigations were carried out in Tunis Southern Lagoon to assess the restoration influence on the inside environment. They showed a significant improvement of ecological parameters and allowed to record invertebrate species previously unknown in the lagoon, the nearby Gulf of Tunis, and beyond, along the Tunisian coast. With special regard to ichthyofauna, Mějri *et al.* (2004; *in press*) reported on the occurrence of seven elasmobranch species, while Ben Souissi *et al.* (2004) confirmed for the first time the John Dory, *Zeus faber* 1758, in a perimediterranean lagoon. Further investigations provide additional records of teleost species in Tunis Southern Lagoon, allowing us to evaluate whether there is a significant improvement in environmental parameters after the restoration of the area and the role of marine flux in teleost diversity. So, a historical comparison of Tunis Southern Lagoon ichthyofauna before and after the environmental restoration is made. The teleost species recently found in the area are listed and their occurrence discussed. Moreover, a comparison between ichthyofauna of Tunis Southern Lagoon and those of other perimediterranean lagoons is carried out.

MATERIAL AND METHODS

At present, Tunis Southern Lagoon covers 720 ha, with a regular depth at about 2 m throughout the lagoon, except in restricted areas where it reaches 4 m at the most (see figure 2).

It appears as an elongated ellipse directed SW-NE, $36^{\circ}46'47''$ and $36^{\circ}48'00''$ N, and $10^{\circ}12'22''$ and $10^{\circ}16'41''$ E. The navigation channel, 10 km long and max. 12 m deep, constitutes *pro parte* the northern border of Tunis Southern Lagoon.

Before the environmental restoration, the mean monthly salinity ranged between 30.9 and 48.9 psu; after the restoration, it ranged between 37 and 38.3 psu and the monthly average was 37.8 psu (Ben Souissi *et al.*, 2003). Moreover, both monthly and annual temperature values did not show significant differences before and after the restoration (Ben Souissi *et al.*, 2003). Ben Souissi *et al.* (1999, 2000, 2001, 2003) showed that both nitrates and phosphorus rates reached high levels in both water and sediments before the environmental restoration. By contrast, Ben Souissi *et al.* (2003) ob-

served a significant reduction of both nitrates and phosphorus rates after the environmental restoration.

Our ichthyofaunal investigations were regularly conducted between 2001 and 2004. Juvenile as well as adult fishes were directly collected at fishing sites throughout the area, three times per week, at least, soon after they were landed. They were caught mainly by gill-nets and trawls, occasionally by cast-nets, landing-nets, anglers and diving. Fresh and sometimes alive specimens were examined. The species recorded in Tunis Southern Lagoon before and after the environmental restoration were divided into three categories following Quignard & Zaouali (1980).

The first category includes sedentary species that are generally of small size and are abundantly as well as regularly caught all year round in the lagoons. The second category comprises species entering the lagoons occasionally or accidentally straying from migratory movements. They develop and reproduce only in offshore areas. The third category concerns species of which fry and juveniles (0+) enter the lagoons to find sufficient resources and to develop. These species constitute a mid-term between the two above categories; they are 'mixed species' or rather regular migratory species.

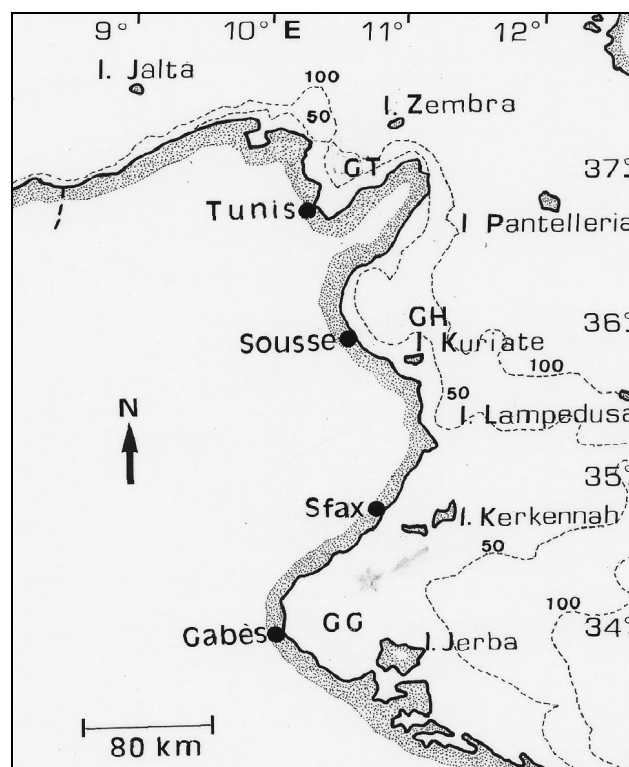


Fig. 1: Map of Tunisia, with the Gulf of Tunis (GT), the Gulf of Hammamet (GH), and the Gulf of Gabès (GG).
Sl. 1: Zemljevid Tunizije s Tuniškim (GT), Hammamet-skim (GH) in Gabeškim zalivom (GG).

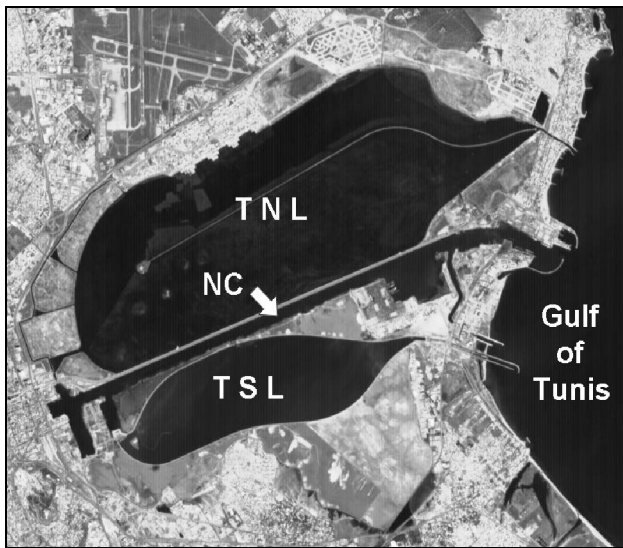


Fig. 2: Map of Tunis Lagoon, divided by navigation channel (NC) in two areas: Tunis Northern Lagoon (TNL) and Tunis Southern Lagoon (TSL) after the environmental restoration.

Sl. 2: Zemljevid Tuniškega zaliva – ki ga navigacijski kanal (NC) deli na dve območji: Tuniško severno laguno (TNL) in Tuniško južno laguno (TSL) – po njegovem okoljskem restavriranju.

With special regard to their abundance in Tunis Southern Lagoon, four categories of species were also considered:

- species abundantly caught throughout the year, commonly caught throughout the year, or during one or some periods of the year;
- species frequently caught throughout the year or in one or some periods of the year;
- species rarely caught throughout the year or in some period of the year;
- species occasionally caught.

Moreover, in order to characterize teleost biodiversity in Tunis Southern Lagoon, we followed Bradai *et al.* (2004) who consider three categories of species based on their geographic distribution, such as: Atlanto-Mediterranean (AM), cosmopolitan (C), endemic (E) and their affinities comprising three categories, such as species belonging to cold water fauna (CWF), thermophilous species (TS) and unclassified (U).

RESULTS

Of the 62 species recorded to date, 13 were sedentary (21%), 26 marine (42%) and 23 regular migratory species (37%). Of the 48 species recorded for the first time in Tunis Southern Lagoon, eleven were sedentary, 15 marine and 22 regular migratory species.

Most of the observed specimens were juveniles. However, some species such as *Atherina boyeri*, *Belone belone* and *Zosterisessor ophiocephalus* comprised mature specimens expelling spermatozoa or oocytes when caught. Of the species recorded in Tunis Southern Lagoon, six are commonly caught all the year round in the area, *i.e.* *Mugil cephalus*, *Anguilla anguilla*, *Liza aurata*, *Liza ramada*, *Diplodus annularis* and *Dicentrarchus labrax*, which are considered to be of economical interest.

Of the 62 teleost species recorded, 4 were abundantly, 33 commonly, 22 rarely and 3 occasionally caught in the area (Tab. 1). This suggests that many of the species probably began to establish themselves in Tunis Southern Lagoon. Moreover, of the 13 sedentary species, 3 were endemic, and 10 Atlanto-Mediterranean, with regard to their marine affinities, 7 species were unclassified, and 6 thermophilous. Of the 26 marine species, 1 species was endemic, 24 Atlanto-Mediterranean and 1 cosmopolitan, 17 belonged to thermophilous fauna, a single one to cold water fauna and 8 were unclassified. Of the 23 regular migratory species, a single species was endemic, the remaining 22 Atlanto-Mediterranean; 17 were thermophilous teleost species, 4 unclassified and 2 belonged to cold water fauna.

DISCUSSION

Fisheries have been reported in the Lagoon of Tunis since the early Antiquity. Furthermore, El Bekri (1068) noted presence of two large farming sites in the area close to the sea (we think that they probably were rudimentary local fish-trappings, their vernacular name is '*charfia*'). Among the fish species abundantly caught in the area, he cited the striped sea bream, the gilt-head sea bream and the flat head grey mullet.

Fishermen from Lagoon of Tunis are drawn on one of the large tapestries carried out in order to commemorate Tunis taken by Charles the Fifth. Peyssonnel (1724), given a thorough description of the rudimentary fish-trappings, probably *charfia*, also named '*bordigou*' or '*peschiere*' used at the beginning of the 18th century.

Further, new fishing gears were introduced, such as fish-trappings, gill-nets, chest-nets and cast-nets (Chamfrault, 1955), and for eels exclusively, a passive fishing device, the '*capéchade*', derivative of a hoop net (Quignard & Farrugio, 1981).

Between 1896 and 1958, fisheries were regulated by grants in order to improve their economical productivity (Fagès & Ponzeverra, 1908). However, since 1958, the Office National des Pêches de Tunisie (ONP) controlled both exploitation and commercialization of the lagoon production. At present, the ONP no longer exists; the fish-trappings were removed and fishing is not supported by statistical data.

Tab. 1: List of the three categories of teleost species recorded in Tunis Southern Lagoon. *: species recorded for the first time in the area; (A): abundantly caught throughout the year; (C): commonly caught throughout or in one or some periods of the year; (R): rarely caught in one or some period of the year; (O): occasionally caught; (AM): Atlanto-Mediterranean; (Cm): cosmopolitan; (E): endemic; (CWF): cold water-fauna; (TS): thermophilous species; (U): unclassified.

Tab. 1: Seznam treh kategorij kostnic, zabeleženih v Tuniški južni laguni. *: vrsta zabeležena prvič v tem območju; (A): ujeta v velikem številu skozi vse leto; (C): ujeta skozi vse leto ali le v nekaterih letnih obdobjih; (R): redko ujeta v enem ali v nekaterih letnih obdobjih; (O): občasno ujeta; (AM): atlantsko-sredozemska; (Cm): kozmopolitska; (E): endemična; (CWF): mrzloljubna favna; (TS): toploljubna vrsta; (U): neopredeljena.

Sedentary species	Marine species	Regular migratory species
<i>Aphanius fasciatus</i> (R, E, U)	<i>Anguilla anguilla</i> (C, AM, CWF)	<i>Balistes carolinensis</i> * (R, AM, TS)
<i>Atherina boyeri</i> (C, AM, U)	<i>Mugil cephalus</i> (C, Cm, TS)	<i>Diplodus puntazzo</i> * (R, AM, TS)
<i>Gobius niger</i> * (A, AM, U)	<i>Chelon labrosus</i> (C, AM, U)	<i>Sardinella aurita</i> * (R, AM, TS)
<i>Zosterisessor ophiocephalus</i> * (R, E, TS)	<i>Liza aurata</i> (C, AM, U)	<i>Spicara flexuosa</i> * (R, AM, U)
<i>Salaria basilica</i> * (A, E, U)	<i>L. ramada</i> (C, AM, U)	<i>S. meana</i> * (R, AM, U)
<i>Labrus mixtus</i> * (R, AM, U)	<i>L. saliens</i> (C, AM, U)	<i>Bothus podas podas</i> * (R, AM, TS)
<i>Symphodus cinereus</i> * (R, AM, TS)	<i>Zeus faber</i> * (C, AM, TS)	<i>Epinephelus marginatus</i> * (R, AM, TS)
<i>S. melops</i> * (R, AM, TS)	<i>Scorpaena porcus</i> * (A, AM, TS)	<i>Merluccius merluccius</i> * (C, AM, CWF)
<i>S. tinca</i> * (R, AM, TS)	<i>Dicentrarchus labrax</i> (C, AM, U)	<i>Pagellus erythrinus</i> * (C, AM, CWF)
<i>Hippocampus hippocampus</i> * (C, AM, TS)	<i>Lithognathus mormyrus</i> (C, AM, TS)	<i>Pagrus auriga</i> * (R, AM, TS)
<i>H. guttulatus</i> * (C, AM, TS)	<i>Sparus aurata</i> (C, AM, TS)	<i>Pomatomus saltatrix</i> * (O, AM, TS)
<i>Syngnathus acus</i> * (C, AM, U)	<i>Diplodus annularis</i> * (A, AM, TS)	<i>Sardina pilchardus</i> * (C, AM, TS)
<i>S. typhle</i> * (C, AM, U)	<i>D. vulgaris</i> * (C, AM, TS)	<i>Scomber scombrus</i> * (C, AM, TS)
	<i>D. sargus</i> * (C, E, TS)	<i>Symphodus ocellatus</i> * (O, E, TS)
	<i>Sarpa salpa</i> (C, AM, TS)	<i>Trachinotus ovatus</i> * (O, AM, U)
	<i>Boops boops</i> * (C, AM, TS)	<i>Trigla lucerna</i> * (R, AM, U)
	<i>Belone belone</i> * (C, AM, U)	<i>Labrus merula</i> * (R, AM, TS)
	<i>Solea vulgaris</i> (C, AM, U)	<i>L. viridis</i> * (R, AM, TS)
	<i>S. senegalensis</i> * (C, AM, TS)	<i>Conger conger</i> * (R, AM, TS)
	<i>Mullus barbatus</i> * (C, AM, TS)	<i>Gobius gobitis</i> * (R, AM, TS)
	<i>M. surmuletus</i> * (C, AM, TS)	<i>Umbrina cirrosa</i> * (C, AM, TS)
	<i>Sphyaena sphyraena</i> * (C, AM, TS)	<i>Dentex dentex</i> * (R, AM, TS)
	<i>Trachurus trachurus</i> * (C, AM, TS)	<i>Dactylopterus volitans</i> * (R, AM, TS)
	<i>Sardinella maderensis</i> * (C, AM, TS)	
	<i>Serranus scriba</i> * (R, AM, TS)	
	<i>Engraulis encrasicolus</i> * (C, AM, U)	

Zaouali (1988) globally considered three historical phases in the development of fisheries in the Lagoon of Tunis. During the first phase, lasting between the partition of the lagoon in two areas, 1895 and 1920 approximately, fishery production focused on species of economic interest, but the targeted species was the gilt-head sea bream. During the second phase, from 1920 to the beginning of the eighties, mullets were the most captured qualitatively and quantitatively. During the third phase concomitant to the degradation of the ecosystem, the fisheries production mainly comprised eels. An analysis of flesh removed from some fish species showed high values of heavy metals (see Ben Souissi et

al., 2000; Ben Souissi, 2002). So, constant decline of fishery production was observed, and a comparative study showed that it reached 250 tons in 1928 (Chamfrault, 1955) against 18 tons in 1995 (ONP, unpubl. data).

With special regard to the species recorded in Tunis Southern Lagoon, Zaouali (1988) noted that the available data are based on check-lists, which mainly reported commercially interesting species. Of the 14 species recorded in Tunis Southern Lagoon, two were sedentary and 12 were regular migratory species; no marine species were recorded. The first category comprised small size species not included in statistical reports.

A significant increase of fish species reported after the environmental restoration of Tunis Southern Lagoon appears in Table 1. Formerly, the area exhibited a low fish biodiversity as the consequence of heavy pollution. At present, the significant increase in fish biodiversity shows that the area is submitted to the influence of marine flux.

The ichthyological investigation showed that of the 62 species identified in the area, 48 were recorded for the first time in Tunis Southern Lagoon, with all the marine and most of the regular migratory species, especially elasmobranch species, among them (see Table 1). They are included among the 160 teleost species reported in the Gulf of Tunis (Bradaï *et al.*, 2004).

Most of the recorded species were Atlanto-Mediterranean, and only some of them were endemic, which confirms the role of the nearby Gulf of Tunis in population settlement of Tunis Southern Lagoon. However, most of the recorded species were thermophilous and generally found in warm water, although temperature of Tunis Southern Lagoon did not increase significantly. The relative abundance of these species is possibly due

to fact that the waters of the Gulf of Tunis are probably becoming warmer, the same as in other Mediterranean areas (see Francour *et al.*, 1994). By contrast, the occurrence of cold water species shows that several species took refuge in a restricted but also protected area, probably for trophic relations, such as *Sphyraena sphyraena*, *Trigla lucerna*, *Dentex dentex* and *Dactylopterus volitans*, which are generally found in deeper waters.

In Table 2, the number of species recorded in some perimediterranean lagoons is summarized. The ichthyological specific richness, observed in Tunis Southern Lagoon due to the recent fishes' intrusion in the area, confirms the success of the environmental restoration of the area. Moreover, it is interesting to point out a significant decrease of fish species in the Lagoon of Ghar El Melh. Between 1985 and 1995, Rhomdane (1985) recorded 49 and Ach-Ben Fadhel (1995) 38 species, 11 species disappeared from the area, including three elasmobranch species, which are rarely found in lagoons (see Capapé *et al.*, 2004; Méjri *et al.*, 2004). This difference is not due to sampling but to the fact that at the lagoon is subjected to pollution pressures, similar to those

Tab. 2: Ichthyological specific diversity observed in perimediterranean lagoons.

Tab. 2: Ihtiolška specifična pestrost v obmediteranskih lagunah.

Lagoon	Area	No. species	Authors
Gruissan	South. France	12	Gourret (1897)
Canet	South. France	13–15	Gourret (1897); Hervé (1978)
Méjean	South. France	14	Paris & Quignard (1971)
Prévost	South. France	14–31	Gourret (1897); Paris & Quignard (1971); Favry <i>et al.</i> (1998)
Pierre-Blanche	South. France	15–29	Paris & Quignard (1971); Le Corre & Autem (1982)
Bages-Sigean	South. France	18–22	Gourret (1897); Cahet <i>et al.</i> (1974)
Frontignan	South. France	19	Paris & Quignard (1971)
Lapalme	South. France	19–29	Gourret (1897); Cambrony (1984)
Salses-Leucate	South. France	25–27	Gourret (1897); Hervé (1978)
Ayrolle-Campagnol	South. France	29	Gourret (1897)
Bourdigou	South. France	32	Cambrony (1984)
Mauguio	South. France	24–71	Quignard <i>et al.</i> (1989); Bouchereau <i>et al.</i> (1990)
Berre	South. France	38–55	Huve <i>et al.</i> (1973)
Thau	South. France	70	Paris & Quignard (1971)
Biguglia	Corsica	8	Ximenès (1980)
Urbino	Corsica	37	Ximenès (1980)
Diana	Corsica	41	Ximenès (1980)
Nador	North. Morocco	28	Guélorget <i>et al.</i> (1985)
Bizerte	North. Tunisia	30	Zaouali (1984)
Ichkeul	North. Tunisia	22	Chaouachi (1995); Chaouachi & Ben Hassine (1998)
Ghar El Melh	North. Tunisia	49	Romdhane (1985)
Ghar El Melh	North. Tunisia	38	Ach-Ben Fadhel (1995)
Bahiret El Biban	South. Tunisia	20	Lemoalle & Vidy (1984)
Tunis South. Lagoon	North. Tunisia	14	Zaouali-Laidain (1974): prior to restoration
Tunis South. Lagoon	North. Tunisia	62	Present study: post restoration

previously reported for Tunis Northern and Southern Lagoons, and will further be a subject of environmental restoration.

Moreover, in the sample, both marine and regular migratory species were qualitatively and quantitatively dominant, some species are currently and regularly caught in the area, throughout the year. Prior to the lagoon environmental restoration, no marine species were recorded in the area, moreover, for instance, *Z. faber*, to our knowledge, was recorded for the first time in a perimediterranean lagoon (Ben Souissi *et al.*, 2004).

As the water quality has been improved considerably, it enabled numerous floristic and faunistic invertebrate communities to reproduce and develop in the area (Ben Souissi, 2002; Ben Souissi *et al.*, 2003). So, their availability constitutes the main ecological support for further development of fish species. Moreover, among the specimens captured in the area, many of them were

juveniles, and these findings suggest that some species could develop and reproduce in the area (see Ben Souissi *et al.*, 2004).

The success of a definite establishment of fish populations remains speculative. Intrusion of some species is fortuitous. Fish overlaps, which involve further competition pressures, cannot be excluded. The present observations on fish communities are based on small samples and are not sufficient to provide an estimate of their absolute abundance. Moreover, migrations outside and inside the lagoon demand the greatest possible attention, especially further works in population dynamics.

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KOSTNICE, UGOTOVLJENE V TUNIŠKI JUŽNI LAGUNI PO NJENEM OKOLJSKEM RESTAVRIRANJU (JUŽNO SREDNJE SREDOZEMLJE)

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POVZETZEK

Med raziskavami, opravljenimi po okoljskem restavriranju Tuniške južne lagune nedaleč od Tuniškega zaliva, je bilo zabeleženih 62 vrst pravih kostnic, 48 med njimi prvič v tem območju. Med vsemi 62 kostnicami je bilo 13 sedentarnih, 26 morskih in 23 rednih selečih se vrst. Avtorji v pričujočem članku razpravljajo o njihovem pojavljanju v raziskovanem območju.

Ključne besede: Osteichthyes, kostnice, okoljsko restavriranje, Tuniška južna laguna, Tunizija, osrednje Sredozemlje

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