

AM ANNALES

Anali za istrske in mediteranske študije
Annali di Studi istriani e mediterranee
Annals for Istrian and Mediterranean Studies
Series Historia Naturalis, 32, 2022, 2





ANNALES

**Anali za istrske in mediteranske študije
Annali di Studi istriani e mediterraneei
Annals for Istrian and Mediterranean Studies**

Series Historia Naturalis, 32, 2022, 2

ISSN 1408-533X
e-ISSN 2591-1783

UDK 5

Letnik 32, leto 2022, številka 2

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Tisk/Stampa/Print:

Založništvo PADRE d.o.o.

Izdajatelj/Editori/Published by:

Zgodovinsko društvo za južno Primorsko - Koper / Società storica del Litorale - Capodistria®

Inštitut IRRIS za raziskave, razvoj in strategije družbe, kulture in okolja / Institute IRRIS for Research, Development and Strategies of Society, Culture and Environment / Istituto IRRIS di ricerca, sviluppo e strategie della società, cultura e ambiente®

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SI-6330 Piran / Pirano, Fornace/Fornace 41, tel.: +386 5 671 2900, fax +386 5 671 2901;**e-mail:** annales@mbss.org, **internet:** www.zdjp.si

Redakcija te številke je bila zaključena 23. 12. 2022.

**Sofinancirajo/Supporto finanziario/
Financially supported by:**

Javna agencija za raziskovalno dejavnost Republike Slovenije (ARRS) in Mestna občina Koper

Annales - Series Historia Naturalis izhaja dvakrat letno.**Naklada/Tiratura/Circulation:** 300 izvodov/copie/copiesRevija *Annales, Series Historia Naturalis* je vključena v naslednje podatkovne baze / *La rivista Annales, series Historia Naturalis* è inserita nei seguenti data base / *Articles appearing in this journal are abstracted and indexed in:* BIOSIS-Zoological Record (UK); Aquatic Sciences and Fisheries Abstracts (ASFA); Elsevier B.V.: SCOPUS (NL); Directory of Open Access Journals (DOAJ).To delo je objavljeno pod licenco / *Quest'opera è distribuita con Licenza / This work is licensed under a Creative Commons BY-NC 4.0.*Navodila avtorjem in vse znanstvene revije in članki so brezplačno dostopni na spletni strani <https://zdjp.si/en/p/annalesshn/>
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VSEBINA / INDICE GENERALE / CONTENTS

BIOTSKA GLOBALIZACIJA
GLOBALIZZAZIONE BIOTICA
BIOTIC GLOBALIZATION**Murat BILECENOĞLU & M. Baki YOKEŞ**

New Data on the Occurrence of Two Lessepsian Marine Heterobranchs, *Plocamopherus ocellatus* (Nudibranchia: Polyceridae) and *Lamprohaminoea ovalis* (Cephalaspidea: Haminoeidae), from the Aegean Sea 267
 Novi podatki o pojavljanju dveh lesepskih morskih polžev zaškrjarjev, *Plocamopherus ocellatus* (Nudibranchia: Polyceridae) in *Lamprohaminoea ovalis* (Cephalaspidea: Haminoeidae), iz Egejskega morja

Gianni INSACCO, Aniello AMATO, Bruno ZAVA & Maria CORSINI-FOKA

Additional Capture of *Halosaurus ovenii* (Actinopterygii: Notacanthiformes: Halosauridae) in Italian Waters 273
 Novi ulov vrste *Halosaurus ovenii* (Actinopterygii: Notacanthiformes: Halosauridae) v italijanskih vodah

Christian CAPAPÉ, Christian REYNAUD & Farid HEMIDA

First Record of Marbled Stingray, *Dasyatis marmorata* (Chondrichthyes: Dasyatidae) from the Algerian Coast (Southwestern Mediterranean Sea) 281
 Prvi zapis o pojavljanju marmoriranega morskega biča, *Dasyatis marmorata* (Chondrichthyes: Dasyatidae) iz alžirske obale (jugozahodno Sredozemsko morje)

Maria CORSINI-FOKA & Bruno ZAVA

Second Occurrence of *Siganus javus* (Siganidae) in the Mediterranean Waters 287
 Drugi zapis o pojavljanju progastega morskega kunca, *Siganus javus* (Siganidae), v sredozemskih vodah

Daniel GOLANI, Haim SHOHAT & Brenda APPELBAUM-GOLANI

Colonisation of Exotic Fish Species of the Genera *Pseudotropheus* and *Aulonocara* (Perciformes: Cichlidae) and the Decline of Native Ichthyofauna in Nahal Amal, Israel 293
 Naseljevanje eksotičnih vrst rib iz rodov *Pseudotropheus* in *Aulonocara* (Perciformes: Cichlidae) in upad domorodne ribje favne v reki Nahal Amal, Izrael

Panayotis OVALIS & Maria CORSINI-FOKA

On the Occurrence of *Velolambrus expansus* (Brachyura, Parthenopidae) in Hellenic Waters 301
 O pojavljanju rakovice vrste *Velolambrus expansus* (Brachyura, Parthenopidae) v grških vodah

Saul CIRIACO, Marco SEGARICH, Vera CIRINÀ & Lovrenc LIPEJ

First Record of the Long-Jawed Squirrelfish *Holocentrus adscensionis* (Osbeck, 1765) in the Adriatic Sea 309
 Prvi zapis o pojavljanju vrste veveričjaka *Holocentrus adscensionis* (Osbeck, 1765) v Jadranskem morju

Christian CAPAPÉ, Vienna HAMMOUD, Aola FANDI & Malek ALI

First Record of Moontail Bullseye *Priacanthus hamrur* (Osteichthyes, Priacanthidae) from the Syrian Coast (Eastern Mediterranean Sea) 317
 Prvi zapis o pojavljanju lunastorepega velikookega ostriža *Priacanthus hamrur* (Osteichthyes, Priacanthidae) s sirske obale (vzhodno Sredozemsko morje)

SREDOZEMSKI MORSKI PSI
SQUALI MEDITERRANEI
MEDITERRANEAN SHARKS**Hakan KABASAKAL, Erdi BAYRI & Görkem ALKAN**

Distribution and Status of the Great White Shark, *Carcharodon carcharias*, in Turkish Waters: a Review and New Records 325
 Status in razširjenost belega morskega volka (*Carcharodon carcharias*) v turških vodah: pregled in novi zapisi o pojavljanju

Alen SOLDI

200 Years of Records of the Basking Shark, *Cetorhinus maximus*, in the Eastern Adriatic 343
 Dvesto let opazovanj morskega psa orjaka, *Cetorhinus maximus*, v vzhodnem Jadranskem morju

Hakan KABASAKAL, Ayşe ORUÇ, Cansu LKILINÇ, Efe SEVİM, Ebrucan KALECİK & Nilüfer ARAÇ

Morphometrics of an Incidentally Captured Little Gulper Shark, *Centrophorus uyato* (Squaliformes: Centrophoridae), from the Gulf of Antalya, with Notes on Its Biology 351
 Morfometrija naključno ujetega globinskega trneža, *Centrophorus uyato* (Squaliformes: Centrophoridae), iz Antalijskega zaliva z zapiski o njegovi biologiji

Christian CAPAPÉ, Almamy DIABY, Youssof DIATTA, Sihem RAFRAFI-NOUIRA & Christian REYNAUD Atypical Claspers in Smoothhound, <i>Mustelus mustelus</i> (Chondrichthyes: Triakidae) from the Coast of Senegal (Eastern Tropical Atlantic) 359 <i>Netipična klasperja navadnega morskega psa, Mustelus mustelus (Chondrichthyes: Triakidae) iz senegalske obale (vzhodni tropski Atlantik)</i>	Marijana HURE, Davor LUČIĆ, Barbara GANGAI ZOVKO & Ivona ONOFRI Dynamics of Mesozooplankton Along the Eastern Coast of the South Adriatic Sea 411 <i>Dinamika mezozooplanktona vzdolž vzhodne obale južnega Jadrana</i>
Hakan KABASAKAL, Ayşe ORUÇ, Ebrucan KALECIK, Efe SEVİM, Nilüfer ARAÇ & Cansu ILKILINÇ Notes on a Newborn Kitefin Shark, <i>Dalatias licha</i> : New Evidence on the Nursery of a Rare Deep-Sea Shark in Northeastern Levant (Turkey) 367 <i>Zapis o najdbi skotenega klinoplavutega morskega psa, Dalatias licha: novi dokaz o jaslicah redkega globokomorskega morskega psa v severovzhodnem levantu (Turčija)</i>	Abdelkarim DERBALI, Kandeel E. KANDEEL, Aymen HADJ TAIEB & Othman JARBOUTI Population Dynamics of the Cockle <i>Cerastoderma glaucum</i> (Mollusca: Bivalvia) in the Gulf of Gabes (Tunisia) 431 <i>Populacijska dinamika navadne srčanke Cerastoderma glaucum (Mollusca: Bivalvia) v Gabeškem zalivu (Tunizija)</i>
IHTIOLOGIJA ITTILOGIA ICHTHYOLOGY	Vasiliki K. SOKOU, Joan GONZALVO, Ioannis GIOVOS, Cristina BRITO & Dimitrios K. MOUTOPOULOS Tracing Dolphin-Fishery Interaction in Early Greek Fisheries 443 <i>Sledenje interakcij med delfini in ribiči v zgodnjih grških ribiških dejavnostih</i>
Nadia BOUZZAMMIT, Hammou EL HABOUZ, El hassen AIT-TALBORJT, Zahra OKBA & Hassan EL OUIZGANI Diet Composition and Feeding Strategy of Atlantic Chub Mackerel <i>Scomber colias</i> in the Atlantic Coast of Morocco 377 <i>Prehrana in prehranjevalna strategija lokarde (Scomber colias) ob atlantski obali Maroka</i>	Pavel JAMNIK, Matija KRŽNAR & Bruno BLAŽINA Novi najdišči pleistocenske favne pod Kraškimi robom. Smo končno našli tudi jamo <i>Grotta dell'Orso</i> ? 451 <i>Two New Sites of Pleistocene Fauna under Karst Edge. Has a Grotta dell'Orso Cave Been Finally Found?</i>
FLORA FLORA FLORA	OCENE IN POROČILA RECENSIONI E RELAZIONI REVIEWS AND REPORTS
Amelio PEZZETTA Le Orchidaceae di Albona (Labin, Croazia) 393 <i>Kukavičevke Labina (Hrvaška)</i>	Andreja PALATINUS Book Review: Plastic Pollution and Marine Conservation. Approaches to Protect Biodiversity and Marine Life 471
FAVNA FAVNA FAVNA	Kazalo k slikam na ovitku 473 <i>Index to images on the cover</i> 473
Murat BILECENOĞLU & Melih Ertan ÇINAR The Mauve Stinger, <i>Pelagia noctiluca</i> , Has Expanded Its Range to the Sea of Marmara 405 <i>Mesečinka (Pelagia noctiluca) je razširila svoj areal do Marmarskega morja</i>	

COLONISATION OF EXOTIC FISH SPECIES OF THE GENERA
PSEUDOTROPHEUS AND *AULONOCARA* (PERCIFORMES: CICHLIDAE)
AND THE DECLINE OF NATIVE ICHTHYOFAUNA IN
NAHAL AMAL, ISRAEL

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ABSTRACT

*In the present study, the ichthyofauna of Nahal Amal, a small river in Israel, was sampled annually from 1998 to 2021. The local ichthyofauna was found to have 27 taxa of which ten are native species and 17 are exotic. Until 2010 the dominant species was the indigenous cichlid *Astatotilapia flavijosephi* (Lortet, 1883) which was first replaced for two years by cichlid specimens belonging to the genus *Pseudotropheus*. These were later replaced by specimens of another cichlid genus *Aulonocara* which presently dominates the site. It is suggested that the exotic species entered the site as escapees or following release from the hatchery located on the river's bank or by aquarium hobbyists.*

Key words: colonisation, cichlids, freshwater, Nahal Amal, Israel

COLONIZZAZIONE DI SPECIE ITTICHE ESOTICHE DEI GENERI *PSEUDOTROPHEUS*
E *AULONOCARA* (PERCIFORMES: CICHLIDAE) E DECLINO DELL'ITTIOFAUNA
AUTOCTONA A NAHAL AMAL, ISRAELE

SINTESI

*Nel presente studio l'ittiofauna del Nahal Amal, un piccolo fiume in Israele, è stata campionata annualmente dal 1998 al 2021. L'ittiofauna locale è risultata composta da 27 taxa, di cui dieci specie autoctone e 17 esotiche. Fino al 2010 la specie dominante era il ciclido indigeno *Astatotilapia flavijosephi* (Lortet, 1883), sostituito per due anni da esemplari appartenenti al genere *Pseudotropheus*. Questi ultimi sono stati poi sostituiti da esemplari di un altro genere di ciclidi, *Aulonocara*, che attualmente domina il sito. Si ipotizza che le specie esotiche siano entrate nel sito in seguito a fughe o al rilascio dall'incubatoio situato sulla riva del fiume, o da parte di acquariofili.*

Parole chiave: colonizzazione, ciclidi, acqua dolce, Nahal Amal, Israele

INTRODUCTION

The invasion and establishment of exotic species in new environments is a major global issue. In aquatic environments, they are a significant cause of biodiversity loss. The main concern is that non-native species will outcompete native species and alter the ecosystem, damaging the habitat, hybridizing with local species and/or introducing new parasites and diseases. They may adversely affect the local commercial fishery as well as tourism. In freshwater habitats, the colonisation of non-indigenous fish presents an even greater potential risk than in marine environments, since freshwater fish often have small and isolated populations with a high rate of endemism which renders them particularly prone to extinction (Moyel & García-Berthou, 2011). In the present paper, a long-term study of the ichthyofauna of a small river, Nahal Amal, in the Beit-She'an Valley (Emek Hama'ayanot), Israel, was carried out. The stream was sampled annually in order to study the long-term dynamics and changes caused by anthropogenic activity.

MATERIAL AND METHODS

Study site

The study site, Nahal Amal, locally known as Nahal Assi, is a small river located at $32^{\circ}30'0.5.82''\text{N}$ $35^{\circ}27'38.97''\text{E}$, 1650 m downstream from its source at Ein Amal. At the study site the width of Nahal Amal is 30 m. (Fig. 1).

Its discharge ranges from 1700 to 2700 m³/hour with an average of 1800 m³/hour. The water temperature is consistently high, 24–26 °C, throughout the year, with a salinity of ca. 1100 mg/liter (~ 2 psu) (Rozenberg & Mendel, 1977; Nir, 1989; Kabara-Leykin & Romem, 2020). The northern bank is covered with thick continuous vegetation, mainly Bulrush reed, (*Typha domingensis* (Persoon, 1807)) while the southern bank has spaces between vegetation, allowing access to the stream (Fig. 1). The water depth is 50–70 cm. Until 2010–2011 the substrate was covered with Soft Hornwort (*Ceratophyllum submersum* L., 1763) which was later removed (Y. Lahav, *pers. comm.*), leaving only some debris of large branches on a very deep muddy substrate.

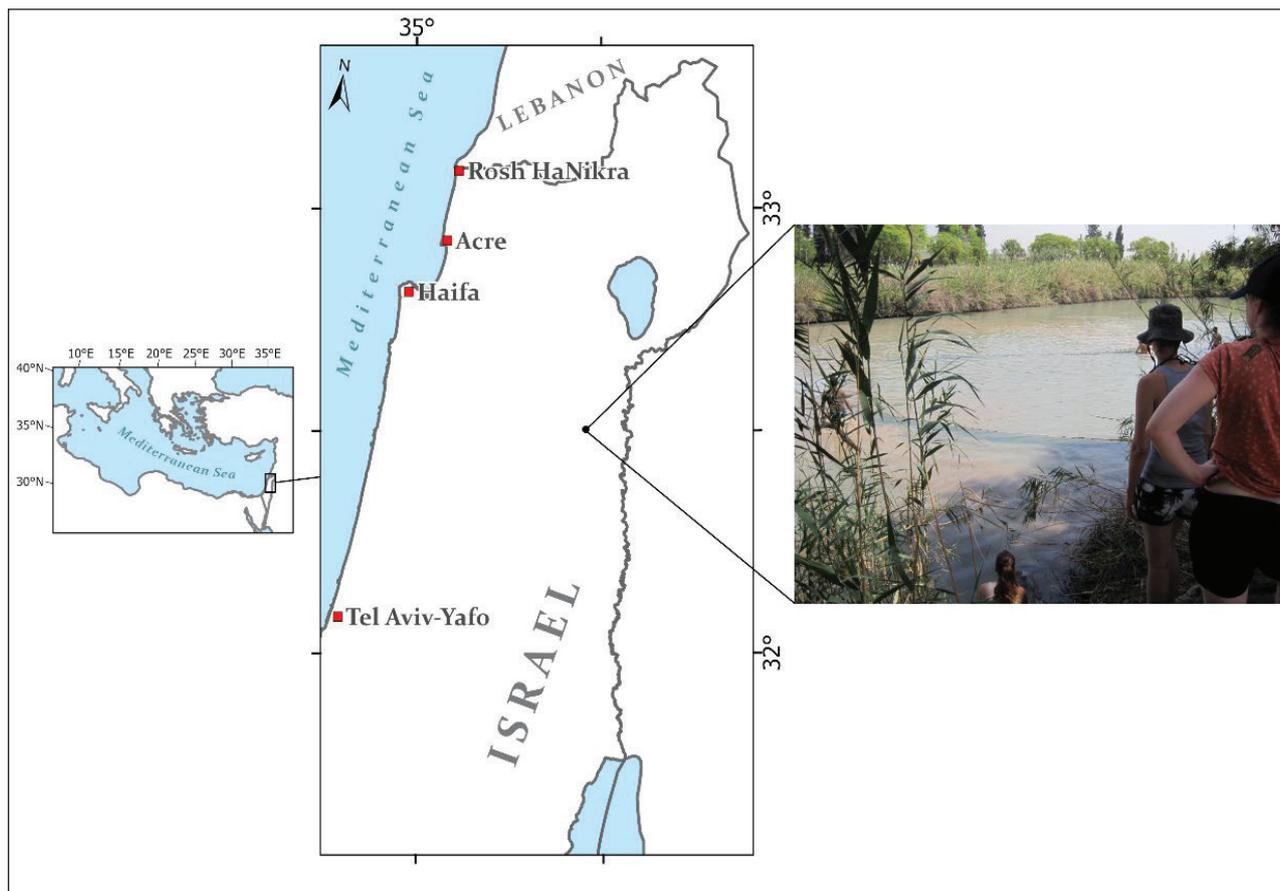


Fig. 1: Maps and photo of study site Nahal Amal.

Sl. 1: Zemljevid in fotografija obravnavanega območja Nahal Amal.

Sampling

The samples were collected with a 30 m long beach seine net, with decreasing mesh size from 40 mm, knot to knot, to 2 mm at the center (Fig. 2).

Each sampling consisted of three sequential hauls, covering ca. 2,000 m². Fish from all three hauls were combined. Species were identified to the lowest possible taxa and counted. Due to taxonomic complexity and a high rate of hybridization (Joyce *et al.*, 2011; Genner & Turner, 2012) all specimens of the genera *Pseudotropheus* (Regan, 1922) and *Aulonocara* (Regan, 1922) were identified only to the generic level. We distinguished between these two genera by the following characteristics: *Pseudotropheus* have numerous small, deeply embedded scales on the breast region (Schraml, 1998) while *Aulonocara* are characterized by an enlargement of the sensory canal on the head (Snoeks, 2004) and very large sensory pores in the enlarged infraorbital bones (Konings, 2016). During the years 1998-2010 and 2018-2019, sampling was conducted annually during the months April-June, while during 2011-2017 two samples were collected each year during the same months. Several specimens from each species were saved and deposited in the Fish Collection of the Hebrew University (HUJ).

RESULTS

A total of 27 fish taxa were collected in the present study, in addition to two species, the Black Carp (*Mylopharyngodon piceus*, (Richardson, 1846)) and the Red Drum (*Sciaenops ocellatus*, (Linnaeus, 1766)), that were observed and photographed but were not collected (Tab. 1).

Of the species that were collected, ten are indigenous species and 17 are exotic, of which one was the hybrid of the Striped Bass (*Morone saxatilis* (Walbaum, 1792)) and the White Bass (*M. chrysops* (Rafinesque, 1820)), a likely aquaculture escapee. Another such species was the golden strain of the Blue Tilapia (*Oreochromis aureus*). Five additional species were found: The common carp - *Cyprinus carpio*, Blue Tilapia - *Oreochromis aureus*, Nile tilapia - *O. niloticus*, Thinlip grey mullet - *Chelon ramada* and the Flathead grey mullet - *Mugil cephalus*; these are non-native species that are known to be cultured in local aquaculture and are thus likely escapees. An additional species, the Mosquito fish (*Gambusia affinis*), was introduced to Israel in the 1920's for the purpose of malaria control and is currently present in almost all freshwater bodies in Israel (Goren & Ortal, 1999; Golani & Mires, 2000). Six of the collected species are popular in the aquarium trade in Israel: Vermiculated sailfin catfish - *Pterygopichthys djunctivus*, Amazon sailfin catfish - *P. pardalis*, Yucatan molly - *Poecilia velifera*, Green swordtail - *Xiphophorus helleri*, Convict cichlid - *Amatitlania nigrofasciata* and the Malawi eyebiter *Dimidichromis comptessiceps* and the genera *Aulonocara* and *Pseudotropheus*. Figure 3 reveals a clear shift of the river's ichthyofauna composition; until 2009 the indigenous cichlid *Astatotilapia flavijosephi* was the dominant species, but then in 2010 began to decline sharply. During the following two years (2011-2012), specimens of the exotic genus *Pseudotropheus* displayed an increase and were most common, but by 2013 specimens of another exotic genus, *Aulonocara* increased and since has dominated the stream fish assemblage until the end of this study.

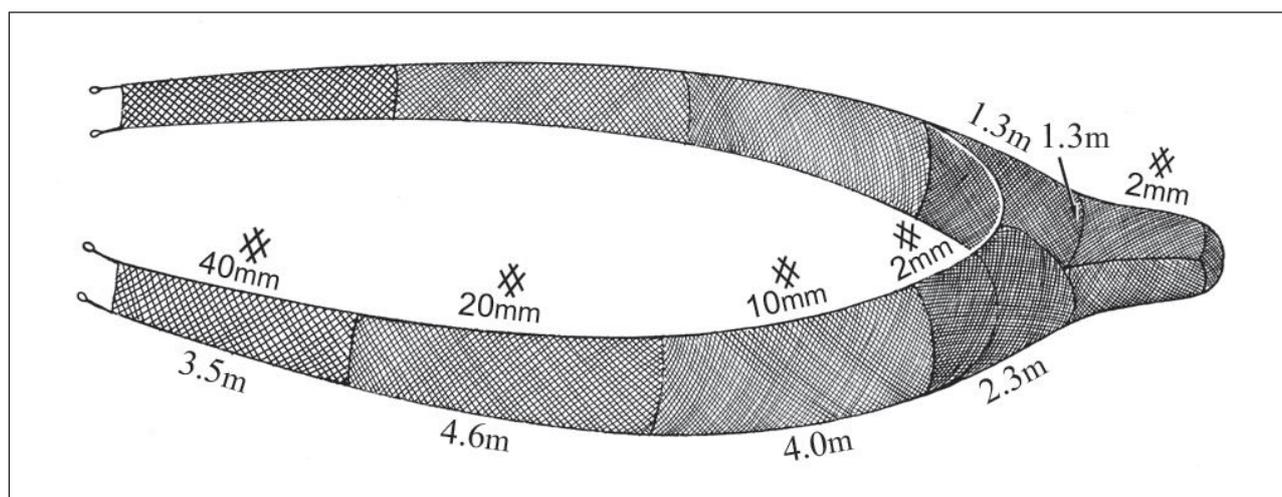


Fig. 2: Experimental beach seine used in the present study.
Sl. 2: Poskusna povlečna mreža, uporabljena v pričujoči študiji.

Tab: 1: List of species sampled in Nahal Amal in the present study. I - indigenous spp., E – exotic spp., O – species observed, photographed, but not collected.

Tab: 1: Seznam vrst rib v reki Nahal Amal v pričujoči raziskavi. I – domorodne vrste, E – eksotične vrste, O – vrste, ki so bile opažene in fotografirane, vendar niso bile ulovljene.

Family	Species	
CYPRINIDAE	<i>Acanthobrama lissneri</i> Tortonese, 1952	I
	<i>Barbus longiceps</i> Valenciennes, 1842	I
	<i>Caracobarbus canis</i> (Valenciennes, 1842)	I
	<i>Cyprinus carpio</i> Linnaeus, 1758	E
	<i>Hemigrammocapoeta nana</i> (Heckel, 1843)	I
	<i>Garra rufa</i> (Heckel, 1843)	I
CLARIDAE	<i>Clarias gariepinus</i> (Burchell, 1822)	I
LORICARIIDEA	<i>Pterygoplichthys disjunctivus</i> (Weber, 1991)	E
	<i>Pterygoplichthys pardalis</i> (Castelnau, 1855)	E
CYPRINODONTIDAE	<i>Aphanius mento</i> (Heckel, 1843)	I
POECILIDAE	<i>Gambusia affinis</i> (Baird & Girard, 1853)	E
	<i>Poecilia velifera</i> (Regan, 1914)	E
	<i>Xiphophorus helleri</i> Heckel, 1848	E
MORONEIDAE	<i>Morone saxatilis</i> X <i>Morone chrysops</i>	E
CICHLIDAE	<i>Amatitlapia nigrofasciata</i> (Günther, 1867)	E
	<i>Astatotilapia flavijosephi</i> (Lortet, 1883)	I
	<i>Aulonocara</i> sp. Regan 1922	E
	<i>Coptodon, zillii</i> (Gervais, 1848)	I
	<i>Dimidichromis compressiceps</i> (Boulenger, 1908)	E
	<i>Labidochromis caeruleus</i> Fryer, 1956	E
	<i>Oreochromis aureus</i> (Steidachner, 1864)	E
	<i>Oreochromis aureus</i> - orange morph	E
	<i>Oreochromis niloticus</i> (Linnaeus, 1758)	E
	<i>Pseudotropheus</i> spp. Regan, 1922	E
	<i>Sarotherodon galilaeus</i> (Linnaeus, 1758)	I
MUGILIDAE	<i>Chelon ramada</i> (Risso, 1827)	E
	<i>Mugil cephalus</i> Linnaeus, 1758	E
CYPRINIDAE	<i>Mylopharyngodon piceus</i> (Richardson, 1846)	O
SCIAENIDAE	<i>Sciaenops ocellatus</i> (Linnaeus, 1766)	O

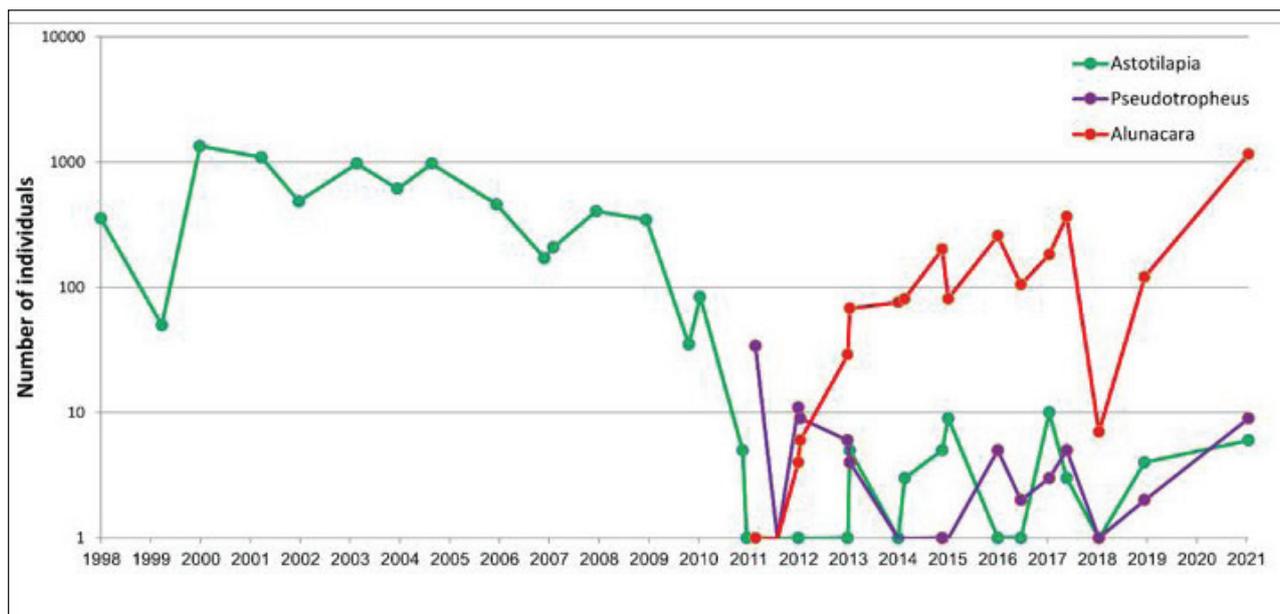


Fig. 3: Number of specimens of the three main taxa in each sample in Nahal Amal. Green – *Astatotilapia flavijosephi*, Purple – *Pseudotropheus* spp., Red – *Aulonocara* spp.

Sl. 3: Število primerkov treh glavnih taksonov v posameznem vzorcu v reki Nahal. Zeleno – *Astatotilapia flavijosephi*, vijolično – *Pseudotropheus* spp., rdeče – *Aulonocara* spp.

DISCUSSION

Fish introduction to the freshwater system of Israel has been studied by several ichthyologists (Ben-Tuvia, 1981; Goren & Ortal, 1999; Golani & Mires, 2000). The families and lower taxa that were excluded from these studies were Loricariidae with *Pterygoplichthys disjunctivus* and *P. pardalis* which were included in a later study (Golani & Snovsky, 2013) and Cichlidae with *Amatitilapia nigrofasciata*, *Dimidichromis compressiceps*, *Labidochromis caeruleus* and the genera *Aulonocara* and *Pseudotropheus*.

The main finding of this study is a clear shift in the ichthyofauna of Nahal Amal. Until the year 2009 Nahal Amal ichthyofauna was heavily dominated by the native cichlid *Astatotilapia flavijosephi* (171–1340 specimens per sample), followed by a sharp decrease of 35–85 specimens per sample during 2010. In the following years 2011–2020, this species was represented by only a few individuals (1–10 individuals per sample). During the years 2011–2012 specimens belonging to the exotic genus *Pseudotropheus* were the most abundant in sampling and a few specimens of another exotic genus, *Aulonocara*, first appeared in the samples. From 2013 until the end of the study, *Aulonocara* gradually became the dominant species in Nahal Amal, reaching 1060 specimens per sample in 2021.

Two scenarios are possible regarding the observed ichthyofauna changes. One scenario is that the removal of the Soft Hornwort in 2010–2011 led to a rapid decline of the indigenous *Astatotilapia flavijosephi* population, leaving the ecosystem vacant or underutilised, thus enabling exotic species to exploit and dominate the Nahal Amal ecosystem. Alternatively, it is possible that individuals of the exotic species were already present in the river in 2010 and 2011 but were overlooked in sampling and they succeeded to outcompete native species.

Golani & Snovsky (2013) assumed that the probable origin of the exotic fish in Nahal Amal was due to escapees from a fish hatchery that was located on the bank of Nahal Amal. According to E. Lahav (*pers. comm.*), this hatchery ceased operating in 2006 but when active, it was concerned only with amelioration and husbandry of aquaculture species, mainly of the family of Cichlidae (*Oreochromis niloticus*, *O. mossambicus* (Peters, 1852), and *O. urolepis* (Norman, 1922), known also as *O. hornorum*). However, it is highly likely that during the hatchery's operation prior to its demolition, additional species were held in the facility, including the Malawi cichlids (*pers. obs.*). Therefore, the origin of *Pseudotropheus* and *Aulonocara* in Nahal Amal could have resulted from spillover from the hatchery, as well as release or escapees from aquarium hobbyists.

Both genera *Pseudotropheus* and *Aulonocara* are endemic to Lake Malawi. Species belonging to these genera are thermophilic, omnivorous, maternal mouth brooders and inhabit habitats similar to that of Nahal Amal. According to Barlow (2002), maternal mouth brooders have an advantage in colonising new habitats. Member of the genus *Pseudotropheus* have been recorded as exotic species in the United States, in Nevada and Hawaii (Nico, 2019). Indeed, Malawi cichlids are popular worldwide in the aquarium trade, including in Israel.

It is interesting to note that five indigenous species (Lissner's bleak - *Acanthobrama lissneri*, Longhead barbel - *Barbus longiceps*, *Hemigrammocapoeta nana*, *Garra rufa* and *Aphanius mento*) were not collected in this study site after the removal of the Soft Hornwort in 2010-2011. Three indigenous species, *Carasobarbus canis*, *Coptodon zillii* and *Sarotherodon galilaeus*, were sampled in similar numbers (2-26 per sample) throughout the study, both as juveniles and adults, thus indicating that they are spawning in Nahal Amal.

The probability that the exotic fishes of Nahal Amal will unintentionally spread to other locations of the freshwater ecosystem of Israel is highly unlikely. The winter temperature in regional fish ponds plummets to 10°C, which is below the tolerance limit of these thermophilic exotic Lake Malawi-originated fish. Indeed, about 200 m east of the study site, Nahal Amal water is collected and used following dilution with water from other near-by springs, for irrigation and filling aquaculture fish pond.

CONCLUSIONS

The present study of colonisation of exotic species in Nahal Amal is a long term case study demonstrating the phenomenon which may represent grave risk to native fish species and their competitive exclusion by exotic species, a risk that is particularly keen in freshwater systems. It is incumbent upon fresh water management to monitor, control, and as much as possible, prevent the entry of invasive species, to preserve the wellbeing of native species and ensure the conservation of the local ecosystems.

NASELJEVANJE EKSOTIČNIH VRST RIB IZ RODOV *PSEUDOTROPHEUS* IN
AULONOCARA (PERCIFORMES: CICHLIDAE) IN UPAD DOMORODNE RIBJE FAVNE
V REKI NAHAL AMAL, IZRAEL

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POVZETEK

Avtorji so v pričujoči raziskavi vzorčili ihtiofavno v Nahal Amalu, manjši reki v Izraelu v letih od 1998 do 2021. Lokalno ihtiofavno tvori 27 taksonov, od katerih je 10 domorodnih vrst in 17 eksotičnih vrst. Do leta 2010 je prevladovala domorodna vrsta ostrižnika *Astatotilapia flaviiosephi* (Lortet, 1883), ki sta jo najprej nadomestili dve drugi vrsti ostrižnikov iz rodu *Pseudotropheus*. Te pa so kasneje zamenjale vrste iz še enega rodu ostrižnikov *Aulonocara*, ki danes prevladujejo na lokaliteti. Najverjetneje so se tujerodne vrste na lokaliteti pojavile zaradi pobega ali namernega izpusta iz vzrejnega centra na rečnem bregu ali zaradi akvaristov.

Ključne besede: naseljevanje, ostrižniki, sladke vode, Nahal Amal, Izrael

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