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*Campanula laciniata* L. - Astypalea, Dodecanese (Aegean Sea)

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***Campanula laciniata* L. (Campanulaceae)** - Perennial with a thick woody base. Stem stout, erect (10-60 cm). Basal leaves several, spatulate to oblanceolate, lacinate or deeply crenate, puberulent or subglabrous. Cauline ones ovate, slightly lacinate or dentate, sessile or subsessile. Flowers in a short, dense, cylindrical raceme. Calyx teeth triangular, much shorter than corolla tube. Corolla broadly campanulate, open, 40-50 mm wide at apex, sky-blue, often with whitish centre. Lobes broadly triangular. Style exserted. *Campanula laciniata* is an Aegean endemic present in the two floristic regions Kik (Cyclades) and KK (Crete and Karpathos). Until now its presence has been reported for Crete, Karpathos, Astypalea, Amorgos, Anafi, Folegandros, Sikinos and Sifnos. It's considered Rare (R) according to the Red Data Book of Rare and Threatened Plants of Greece (1995) with a restricted range. *Campanula laciniata* is a chasmophytic plant very impressive, that grows in scattered, small populations, with one to a few individuals, on inaccessible calcareous vertical cliffs. Calcareous cliffs, especially inside gorges, offer a stable and specialized habitat for chasmophytic plants. Cliff ravines and crevices through microclimatic conditions, have constituted suitable sites for survival of these species affected from unfavorable climatic changes, grazing pressure and competition with other species.

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## A contribution on rodents fauna of the Jaz Murian depression, southeast Iran

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### ABSTRACT

The Jaz Murian depression in the southeast of Iran bounded by deserts and mountains is a special corridor for penetration of Arabian and Indian fauna. The region demonstrates harsh desert climate. This study was designed to reveal rodent diversity of the region in the light of geographic features. Totally, 127 specimens belonging to 5 families and 14 genera and 15 species were captured using live-traps and hand-net. As a result, the depression enjoys Oriental and Ethiopian elements (*Acomys dimidiatus* Cretzschmar, 1826, *Gerbillus nanus* Blanford, 1875 and *Meriones libycus* Lichtenstein, 1823) which could pass Arabian deserts penetrating Iran from northern shores of Persian Gulf. Also, the region is a penetration route for Oriental species such as *Tatera indica* Hardwicke, 1807, *Golunda ellioti* Gray, 1837, *Meriones hurrianae* (Jerdon, 1867) and *Mus musculus* Linnaeus, 1758. The Jaz Murian depression is considered as the southernmost boundary of distributional range of *Apodemus witherbyi* Thomas, 1902 in the world. The Jaz Murian depression is supposed as a cross road between Palaearctic, Ethiopian and Oriental realms.

### KEY WORDS

The Jaz Murian depression; Rodent's diversity; Palaearctic; Ethiopian and Oriental realms.

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### INTRODUCTION

Knowledge about faunal composition of a region will aid in maintaining and controlling its biodiversity and clarifying the evolutionary history of the area. Also, it can provide information about communication routes of animals between realms and lead to postulate filters and barriers (Darvish et al., 2014). Specially, these kinds of explorations in combination with geographical and topographic information can help us to postulate the processes through which diversification of new lineages and endemism occur. Small mammals such as rodents

are first reaching mammals to isolated ecosystems and predecessors for establishing populations by dispersal after vicariance events (Lomolino et al., 2005). In addition, rodents play a key role in balancing the ecosystems as common members in food chains (Shuai et al., 2006).

Moreover, documentation of rodent's diversity can help preventing and controlling public health challenges (Stenseth et al., 2003). They are known as important pests and they are reservoirs of some zoonotic diseases (Nateghpour et al., 2013). Besides, they may cause economic problems and damages to agricultural crops (Schiller et al., 1999). So, investi-

gations shedding light on diversity and species richness of rodents can provide valuable information from biogeographic, economic and medical aspects.

The Jaz Murian depression in the southeast of Iran is a special route for exchange between Arabian and Indian fauna (Wessels, 1955; Misonne, 1959). Because of hard accessibility to the region bounded by deserts and mountains and its harsh climate some limited studies had been focused on diversity of mammals of the region (Blanford, 1875, 1876, 1877; Zarudny, 1896, 1898; Lay, 1967). Etemad (1978), Firouz (1999) and Ziaie (2008) have also reported some species of rodents inhabiting the region in their checklists of mammals of Iran but, some of these literature were recently revised (Musser & Carleton, 2005) and some records were added based on studies accomplished in Rodentology Research Department of Ferdowsi University (Siah-sarvie & Darvish, 2007; Karami et al., 2008; Dianat et al., 2010; Darvish et al., 2014; Darvish et al., 2015). In this study, rodent fauna of the Jaz Murian depression was investigated and its diversity was discussed in the light of biogeographic view.

## MATERIAL AND METHODS

### *Study area*

The Jaz Murian depression is a broad oval in the southeast Iran covering about 25000 to 30000 square miles (Fisher, 1968). East-west extension of Jebal Barez-Shah Savaran-Bazman Mountain chains separates this depression from Lut desert in the north. In addition, continuation of the Zagros through Bashagerd to Makran Mountains in the south isolated the region from coastal area of Persian Gulf (Fisher, 1968). In fact, the southern part of the region stands with mountainous range reaching 4000 feet but there is a corridor in northern Fanuj with highlands less than 2850 feet above sea level (Harrison, 1943). The region receives two seasonal streams, Halilrud (on the west) and Bampur River (on the east) (Fisher, 1968). The depression also receives discharge of temporary streams and drainage of the rainfall from surrounding highlands (Lay, 1967). Lay (1967) also described the region as a dry land with the lowest precipitation in Iran

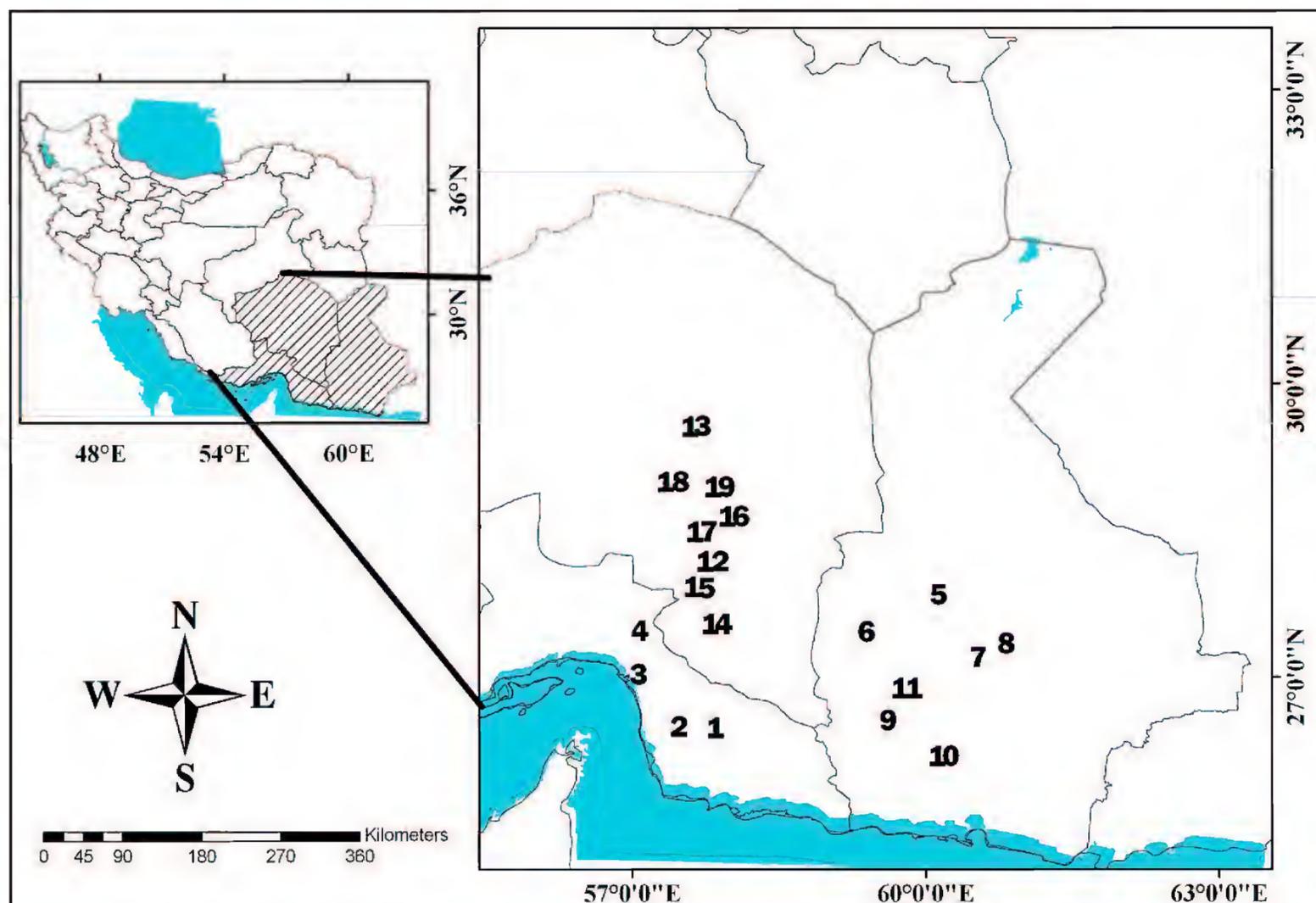


Figure 1. Maps of southeastern Iran with collecting sites for different specimens of rodents.

and abruptly falling temperature during nights with the main vegetation including *Acacia*, *Gymnocarpus*, *Tamarix* and *Haloxylon*. Based on Deblase (1980) it is part of the Baluchestan zoogeographic zone and Sahari-Sindi flora is the main vegetation cover of the region (Misonne, 1959). Madjdzadeh (2012) proposed the presence of three different zones in the region (desert and marginal desert, tropical zones and temperate mountainous zone). In fact, low plains reaching high mountainous range together provide magnificent paradoxical landscapes which can be seen in the region.

### Sampling

The study was conducted in the Jaz Murian depression, southeast Iran (parts of Sistan & Baluchestan beside Kerman Provinces) from January 2014 to July 2015. Attributed geographical coordinates were recorded using GPS and ArcGIS ver. 9.3 software was applied for preparing the map of sampling localities (Fig. 1).

Rodents were collected using live-traps and snack or sausage bates. Since, jerboas are not trap-pable in live traps so we caught them with a hand net, using a searchlight at night and motorcycle. Collected specimens were subjected and prepared based on mammalogical procedure established by the American Society of mammalogists Animal Care and Use Committee (1998). Standard vouchers (skull, skin, tissues and karyotype idiograms) were preserved in Zoology Museum of Ferdowsi University (ZMFUM). In addition, specimens were identified based on identification keys (Corbet, 1978) with consideration to new revisions on rodent species of Iran (Musser & Carleton, 2005; Darvish et al., 2006b, Darvish, 2009; Dianat et al., 2010; Darvish et al., 2014; Darvish et al., 2015). Taxonomic arrangement followed Musser and Carleton (2005). Four external (Table 2) and eight cranial characters were measured (Table 4) applying a digital caliper to the nearest 0.01 mm (Instar Inc., Hangzhou, China). Fourteen dental characters (Table 3) were taken using a measuring microscope accurate to 0.001 mm. Mean and standard deviation of characters were estimated using SPSS 16 (SPSS Inc., Chicago, IL, USA).

ABBREVIATIONS. BL: body length, TL: tail length, FL: foot length, EL: ear length, M1/L: length of first upper molar, M2/L: length of second upper molar, M3/L: length of third upper molar, M1/W:

width of first upper molar, M2/W: width of second upper molar, M3/W: width of third upper molar, M/1L: length of first lower molar, M/2L: length of second lower molar, M/3L: length of third lower molar, M/1W: width of first lower molar, M/2W: width of second lower molar, M/3W: width of third lower molar, UML: length of upper tooth row, LML: length of lower tooth row, BCH: braincase height, RH: rostral height, ZYGW: zygomatic breadth, RW: rostral width (maximum distance), IOW: interorbital constriction, BB: Breadth of braincase, CL: condylobasal length, BL: bulla length.

### RESULTS

Totally, 127 specimens belonging to 5 families, 14 genera and 15 species were captured.

Family MURIDAE

Subfamily MURINAE

#### 1. *Mus musculus* Linnaeus, 1758

TYPE LOCALITY. Uppsala, Sweden (Musser & Carleton, 2005).

DISTRIBUTION. Worldwide distribution (except Antarctica) and commensally introduced by human to islands (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Sardasht, Biskove; Fariab; Bazman, Sefid Abad; Dalgan; Hudian; Bampur, Jafar Abad, Ali Abad; Iranshahr, Tigh Abad; Nikshahr; Fariab, Sardak-i-Sargorich; Kahnooj; Anbar Abad, Amjaz.

DIAGNOSTIC CHARACTERS. The inner tubercle of the first loop of the first and second upper molars is markedly curved backwards; incisors with a denticle (Bonhomme et al., 1994; Din et al., 1996; Darvish et al., 2006b; Darvish, 2015).

#### 2. *Apodemus witherbyi* Thomas, 1902

TYPE LOCALITY. Iran, Fars Province, Shul (Musser & Carleton, 2005).

DISTRIBUTION. Plains, mountain and plateau steppes, and highland semi-deserts (not found in desert depressions) from southern Europe, Anatolia, the Middle East except Arabia, probably also occurs in Afghanistan (Musser & Carleton, 2005), Darvish et al. (2015) revealed its distributional range in Iran.

MATERIAL LOCALITIES. AnbarAbad, Amjaz.

DIAGNOSTIC CHARACTERS. Pectoral spot; stephanodont first upper molar; cusp-like t7 on 2nd upper molar; U-shaped fronto-parietal suture; posterior edge of the palatine is straight; large t7 on the first upper molar (Darvish et al., 2006a; Darvish et al., 2014).

TYPE LOCALITY. Sweden, Uppsala County, Uppsala (Musser & Carleton, 2005).

DISTRIBUTION. Native to Indian Peninsula, and introduced worldwide in the temperate zone and parts of the tropical and subantarctic zones (Musser & Carleton, 2005).

### 3. *Rattus rattus* Linneaus, 1758

MATERIAL LOCALITIES. Minab, Tarom.

SPECIES	PREVIOUS REPORTS	THIS STUDY	NO.
<i>Jaculus blanfordi</i>	Jaz Murian (1)	Bazman, Shandak; Bampur, Jafar Abad; Kahnnoj, Avaz Abad; Maskutan	5, 7, 11, 13
<i>Mus musculus</i>	IranShahr (4); Jaz Murian, Nikshahr, Kahnnoj (3, 14); Jiroft, Anbar Abad (2, 9)	Sardasht, Biskove; Fariab; Bazman; Bazman, Sefid Abad; Dalgan; Hudian; Bampur, Jafar Abad, Ali Abad; Iranshahr, Tigh Abad; Nikshahr; Fariab, Sardak-i-Sargorich; Kahnnoj; Anbar Abad, Amjaz	1, 4, 5, 6, 7, 8, 10, 12, 13
<i>Apodemus witherbyi</i>	Anbar Abad, Amjaz (2)	AnbarAbad, Amjaz	16
<i>Nesokia indica</i>	Iran Shahr (1); Bampur (5)	Bampur, Ali Abad; Kahnnoj; Anbar Abad, Kesht-o-Sanat	7, 13, 17
<i>Rattus rattus</i>	Jiroft (2)	Minab, Tarom	3
<i>Golunda ellioti</i>	Jiroft, Kahnnoj (11), (12); Anbar Abad, Amjaz (2, 10, 12)	AnbarAbad, Amjaz	16
<i>Acomys dimidiatus</i>	Jiroft (2, 13)	Sardasht, Biskove; Kohe Hidar village; Fanuj; Fariab	1, 2, 4, 11
<i>Meriones persicus</i>	Iran Shahr, Nikshahr (6); Jiroft (2); Amjaz (2)	Amjaz	16
<i>Meriones libycus</i>	Iran Shahr, Jaz Murian (1, 3)	Bazman, Kargokan, Cheshm-i-Abegarm; Hudian; Iranshahr, Tigh Abad; Maskutan	5, 6, 8, 11
<i>Meriones hurrianae</i>	Nik Shahr, Ghasreghand (7)	-	
<i>Gerbillus nanus</i>	Jaz Murian (1)	Minab, Tarom; Bazman, Kalgande; Jolgechah-i-Hashem; Bampur, Jafar Abad, Ali Abad; Iranshahr, TighAbad; Maskutan	3, 5, 6, 7, 8, 11
<i>Tatera indica</i>	Chah-i-Dadkhoda (7), Iranshahr; Jaz Murian, Nikshahr, Kahnnoj (3, 14); Jiroft, Anbar Abad (2, 13)	Minab, Tarom; Roodan; Bazman; Dalgan; Jolgechah-i-Hashem; Hudian; Bampur, JafarAbad; Roodbar	3, 4, 5, 6, 7, 14
<i>Calomyscus hotsoni</i>	-	Kohe Hidar village; Fanuj; Anbar Abad	2, 9, 17
<i>Cricetulus migratorius</i>	Anbar Abad, Amjaz (2)	Anbar Abad	16
<i>Micotus kermanesis</i>	-	Anbar Abad	16
<i>Ellobius fuscocapillus</i>	Bashagerd (8)	-	
<i>Hystrix indica</i>	Jaz Murian (7); Iranshahr (3, 13)	Observed and collected its spines in Kohe Heidar village by the first author	2

Table 1. Sampling localities of previous reports and present study of rodents from the Jaz Murian depression. 1: Lay, 1967; 2: Amir Afzali et al., 2010; 3: Etemad, 1978; 4: Darvish, 2006c; 5: Zaree, 2013; 6: Missone, 1959; 7: Heptner, 1940; 8: Shenbrot & Krosnov, 2005; 9. Haddadian Shad et al., 2016.; 10: Darvish, 2012; 11: Nazari & Farid, 1991; 12: Madjzadeh, 2012; 13: Firouz, 1999; 14: Ziaie, 2008.

DIAGNOSTIC CHARACTERS. Tail length longer than head and body length; ear reaches eye if pulled down; supraorbital ridges of the skull not parallel (Darvish, 2015).

#### 4. *Nesokia indica* (Gray, 1830 in 1830–1835)

TYPE LOCALITY. India (Musser & Carleton, 2005).

DISTRIBUTION. Modern range covers Bangladesh, N-India, Pakistan, Afghanistan, Iran, Iraq, Syria, Saudi Arabia, Israel-Jordan, NE-Egypt, NW-China, and Central Asia (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Bampur, Ali Abad; Kahnooj; Anbar Abad, Kesht-o-Sanat.

DIAGNOSTIC CHARACTERS. Incisors are broad; breadth of zygomatic arcs is more than a half of the skull length; skull is with well developed crests (Darvish, 2015).

#### 5. *Acomys dimidiatus* Cretzschmar, 1826

TYPE LOCALITY. Egypt, Sinai.

DISTRIBUTION. Sinai Peninsula of Egypt, Levant, Arabian Peninsula, S-Iraq, S-Iran, and S-Pakistan (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Sardasht, Biskove; Kohe Hidar village; Fanuj; Fariab.

DIAGNOSTIC CHARACTERS. Dorsal pledge is spiny; Tma is incorporated into the prelobe; on upper first molar t3 is posterior to t2; cusps linked with crests (Volobouev et al., 2007).

#### 6. *Golunda ellioti* Gray, 1837

TYPE LOCALITY. India, Dharwar (Musser & Carleton, 2005).

DISTRIBUTION. SE-Iran, Pakistan, Nepal, N- and NE-India south through Indian peninsula to Sri Lanka (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Anbar Abad, Amjaz.

DIAGNOSTIC CHARACTERS. Upper incisors is grooved and upper molars have special columnar structure with high separated cusps (Darvish et al., 2012)

Taxa	N	BL	TL	FL	EL
<b>MURIDAE</b>					
<i>Apodemus whiterbyi</i>	6	88.50±7.81	102.00±3.84	21.00±1.09	16.16±0.75
<i>Mus musculus</i>	32	72.40±8.13	74.62±8.95	16.23±1.85	12.63±1.18
<i>Meriones libycus</i>	13	128.53±16.19	149.54±22.67	34.23±2.52	18.07±2.01
<i>Meriones persicus</i>	1	155.10	180.60	31.20	17.00
<i>Tatera indica</i>	13	151.80±13.64	173.22±12.44	37.10±2.99	25.30±3.59
<i>Gerbillus nanus</i>	15	75.53±4.35	118.00±8.67	23.23±1.09	12.07±0.86
<i>Golunda ellioti</i>	2	135±00	110.00±2.82	26.50±0.70	18.00±00
<i>Nesokia indica</i>	8	157.25±41.37	109.12±26.68	31.62±4.43	18.16±3.86
<i>Rattus rattus</i>	2	115.00±00	199.00±33.94	32.00±2.82	22.50±3.53
<i>Acomys dimidiatus</i>	21	90.50±10.24	106.18±9.80	19.38±0.50	20.00±1.60
<b>CALOMYSCIDAE</b>					
<i>Calomyscus hotsoni</i>	6	72.83±4.26	82.50±8.36	18.83±0.75	17.33±1.03
<b>DIPODIDAE</b>					
<i>Jaculus blanfordi</i>	6	123.16±7.73	205.33±49.57	67.16±3.18	25.33±1.36
<b>CRICETIDAE</b>					
<i>Micotus kermanesis</i>	1	140	54	23	16
<i>Cricetulus migratorius</i>	1	119	21	14	21

Table 2. Standard external measurements (Mean ± SD, in mm) of different species of rodents in southeast of Iran (see the text for abbreviations). BL: body length, TL: tail length, FL: foot length, EL: ear length.

Family MURIDAE

Subfamily GERBILINAE

7. *Meriones persicus* Blanford, 1875

TYPE LOCALITY. Iran, Kohrud, 116 km North of Isfahan (Musser & Carleton, 2005).

DISTRIBUTION. Iran, adjacent regions of Transcaucasia, Turkey (E-Anatolia), Iraq, Turkmenistan, Afghanistan and Pakistan (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Anbar Abad, Amjaz.

DIAGNOSTIC CHARACTERS. Each incisor have a groove; bullae enlarged; hind soles are bare; tail is longer than head and body (Corbet, 1978; Darvish, 2015).

8. *Meriones libycus* Lichtenstein, 1823

TYPE LOCALITY. Egypt, Alexandria (Musser & Carleton, 2005).

Taxa	N	M1/L	M2/L	M3/L	M1/W	M2/W	M3/W	M/1L	M/2L	M/3L	M/1W	M/2W	M/3W	LML	UML
<b>Muridae</b>															
<i>Apodemus whiterbyi</i>	6	1.81± 0.07	1.20± 0.04	0.93± 0.06	1.15± 0.06	1.06± 0.08	0.79± 0.03	1.56± 0.19	1.17± 0.03	1.05± 0.23	1.07± 0.07	1.04± 0.13	0.90± 0.06	4.12± 0.83	3.68± 0.06
<i>Mus musculus</i>	32	1.83± 0.8	1.03± 0.05	0.64± 0.05	1.11± 0.04	0.92± 0.06	0.63± 0.15	1.43± 0.11	0.94± 0.09	0.69± 0.09	1.04± 0.07	0.93± 0.08	0.59± 0.05	3.30± 0.17	3.07± 0.15
<i>Meriones libycus</i>	13	2.68± 0.41	1.50± 0.14	0.77± 0.08	1.75± 0.19	1.55± 0.18	0.86± 0.12	2.42± 0.24	1.56± 0.24	0.91± 0.20	1.80± 0.13	1.74± 0.11	1.02± 0.14	5.43± 0.50	5.39± 0.39
<i>Meriones persicus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Tatera indica</i>	13	3.18± 0.26	1.75± 0.11	1.11± 0.12	2.39± 0.09	2.06± 0.19	1.42± 0.10	2.99± 0.13	1.92± 0.13	1.29± 0.18	2.27± 0.13	2.23± 0.15	1.40± 0.12	6.44± 0.26	6.19± 0.24
<i>Gerbillus nanus</i>	15	1.85± 0.10	1.00± 0.06	0.48± 0.04	1.27± 0.06	1.07± 0.07	0.61± 0.05	1.74± 0.09	1.15± 0.05	0.69± 0.09	1.23± 0.07	1.22± 0.07	0.67± 0.05	3.51± 0.31	3.48± 0.13
<i>Golunda ellioti</i>	12	2.68± 0.09	2.57± 0.06	2.39± 0.07	2.11± 0.00	2.28± 0.05	1.64± 0.04	2.95± 0.00	2.17± 0.32	1.73± 0.14	1.74± 0.12	1.76± 0.17	1.50± 0.24	6.80± 0.02	6.73± 0.11
<i>Nesokia indica</i>	8	3.41± 0.35	2.34± 0.29	2.00± 0.31	3.00± 0.27	2.79± 0.34	2.28± 0.30	3.51± 0.30	2.48± 0.30	2.13± 0.51	2.48± 0.22	2.67± 0.18	2.06± 0.24	8.64± 0.96	8.42± 0.71
<i>Rattus rattus</i>	2	3.08± 0.00	2.34± 0.24	1.60± 0.09	1.95± 0.14	1.83± 0.09	1.40± 0.12	2.68± 0.16	1.90± 0.11	1.84± 0.04	1.71± 0.06	1.79± 0.13	1.61± 0.14	6.44± 0.77	6.26± 0.73
<i>Acomys dimidiatus</i>	21	2.24± 0.04	1.51± 0.05	1.01± 0.04	1.53± 0.04	1.45± 0.07	0.92± 0.05	1.93± 0.05	1.39± 0.06	1.04± 0.05	1.37± 0.06	1.38± 0.06	0.99± 0.06	4.5± 0.09	4.1± 0.09
<b>Calomyscidae</b>															
<i>Calomyscus hotsoni</i>	6	1.55± 0.06	1.22± 0.08	0.60± 0.04	1.10± 0.05	1.05± 0.03	0.67± 0.03	1.46± 0.06	1.24± 0.05	0.78± 0.03	1.03± 0.02	1.13± 0.02	0.69± 0.02	3.39± 0.12	3.26± 0.15
<b>Dipodidae</b>															
<i>Jaculus blanfordi</i>	6	1.83± 0.10	1.72± 0.09	1.39± 0.08	1.76± 0.10	1.78± 0.04	1.31± 0.10	2.03± 0.10	2.05± 0.11	1.68± 0.16	1.67± 0.05	1.91± 0.09	1.40± 0.04	5.26± 0.19	5.46± 0.13
<b>Cricetidae</b>															
<i>Micotus kermanesis</i>	1	2.67	2.17	2.53	1.67	1.37	1.28	3.70	2.01	2.02	1.62	1.01	1.22	7.94	8.05
<i>Cricetulus migratorius</i>	1	1.91	1.42	-	1.40	1.27	-	1.73	1.41	1.39	1.24	1.26	0.96	4.23	4.40

Table 3. Dental measurements (Mean ± SD, in mm) of different species of rodents from the Jaz Murian depression, southeast Iran. (Data were not prepared for *Meriones persicus*). M1/L: length of first upper molar, M2/L: length of second upper molar, M3/L: length of third upper molar, M1/W: width of first upper molar, M2/W: width of second upper molar, M3/W: width of third upper molar, M/1L: length of first lower molar, M/2L: length of second lower molar, M/3L: length of third lower molar, M/1W: width of first lower molar, M/2W: width of second lower molar, M/3W: width of third lower molar, UML: length of upper tooth row, LML: length of lower tooth row.

DISTRIBUTION. North Africa through Saudi Arabia, Jordan, Iraq, Syria, Iran, Afghanistan, Central Asia to W-China; probably Anatolia (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Bazman, Kargokan, Cheshm-i-Abegarm; Hudian; Iranshahr, Tigh Abad; Maskutan.

DIAGNOSTIC CHARACTERS. Soles are not bare; claws are black (Darvish et al., 2006b).

#### 9. *Tatera indica* Hardwicke, 1807

TYPE LOCALITY. Between Benares and Hardwar, north of India (Musser & Carleton, 2005).

DISTRIBUTION. An extensive range from SE-Anatolia in Syria, Iraq, and Kuwait through Iran, Afghanistan, and Pakistan into most of Indian Peninsula north to S-Nepal; also Sri Lanka (Musser & Carleton, 2005).

Taxa	N	BCH	RH	ZYGW	RW	IOW	BB	CL	BL
<b>Muridae</b>									
<i>Apodemus whiterbyi</i>	6	7.92±0.35	6.21±0.45	12.70±0.35	4.32±0.22	4.26±0.15	11.55±0.20	23.30±0.92	4.97±0.65
<i>Mus musculus</i>	32	7.01±0.31	4.84±0.38	10.97±0.59	3.24±0.24	3.48±0.16	9.33±0.27	19.49±1.23	3.56±0.32
<i>Meriones libycus</i>	13	13.31±0.97	8.77±0.67	20.56±0.96	4.90±0.26	6.64±0.59	17.97±0.80	33.74±2.43	15.04±0.87
<i>Meriones persicus</i>	-	-	-	-	-	-	-	-	-
<i>Tatera indica</i>	13	14.33±0.88	10.38±1.87	21.68±1.78	4.49±0.30	6.75±0.33	17.77±0.53	36.70±2.79	13.82±0.97
<i>Gerbillus nanus</i>	15	9.11±0.37	6.02±0.73	13.48±0.58	3.26±0.15	4.68±0.30	12.36±0.40	22.41±0.76	10.04±0.27
<i>Golunda ellioti</i>	2	10.00±0.24	8.30±0.24	15.98±0.07	5.23±0.16	4.41±0.32	12.84±0.27	30.73±0.38	6.52±0.12
<i>Nesokia indica</i>	8	14.59±1.85	12.59±2.16	25.00±3.96	7.29±1.08	6.20±0.66	17.04±1.31	40.05±6.84	7.86±0.99
<i>Rattus rattus</i>	2	11.31±0.43	8.86±1.39	18.03±1.95	5.71±0.65	5.65±0.77	15.44±1.51	35.18±4.76	6.25±0.51
<i>Acomys dimidiatus</i>	21	8.97±0.26	5.65±0.23	13.91±0.55	3.69±0.14	4.71±0.12	12.45±0.26	26.50±1.30	5.28±0.28
<b>Calomyscidae</b>									
<i>Calomyscus hotsoni</i>	6	7.42±0.31	5.01±0.21	12.16±0.39	3.83±0.18	4.05±0.24	10.89±0.44	20.78±1.22	5.44±0.32
<b>Dipodidae</b>									
<i>Jaculus blanfordi</i>	6	14.17±0.45	8.40±0.48	23.44±0.68	5.27±0.18	12.51±0.41	22.64±0.57	31.39±1.00	15.62±0.64
<b>Cricetidae</b>									
<i>Micotus kermanesis</i>	1	8.66	8.23	17.55	5.03	4.70	15.02	32.76	9.39
<i>Cricetulus migratorius</i>	1	9.18	7.37	15.10	5.53	4.58	11.77	22.07	5.50

Table 4. Cranial measurements (Mean ± SD, in mm) of different species of rodents from The Jaz Murian depression, southeast Iran. (Data were not prepared for *Meriones persicus*). BCH: braincase height, RH: rostral height, ZYGW: zygomatic breadth, RW: rostral width (maximum distance), IOW: interorbital constriction, BB: Breadth of braincase, CL: condylobasal length, BL: bulla length.

MATERIAL LOCALITIES. Minab, Tarom; Roodan; Bazman; Dalgan; Jolgechah-i-Hashem; Hudian; Bampur, Jafar Abad; Roodbar.

DIAGNOSTIC CHARACTERS. Bullae is rather small; transvers bands of molars are separate (Corbet, 1967; Mirshamsi et al., 2007; Darvish, 2015).

10. *Gerbillus nanus* Blanford, 1875

TYPE LOCALITY. Pakistan, Gedrosia (Musser & Carleton, 2005).

DISTRIBUTION. An extensive range from the Baluchistan region of NW-India, Pakistan, S-Afghanistan, and Iran through the Arabian Peninsula, Iraq, Levant, North Africa to Morocco, south in the Sahara to at least and NE-Mali (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Minab, Tarom; Bazman, Kalgande; Jolgechah-i-Hashem; Bampur, Jafar Abad, Ali Abad; Iranshahr, Tigh Abad; Maskutan.

DIAGNOSTIC CHARACTERS. Tail is longer than head and body; auditory meatus with anterodorsal rim inflated; no curtain within the meatus (Corbet, 1978; Darvish, 2015).

Family DIPODIDAE

11. *Jaculus blanfordi* Murray, 1884

TYPE LOCALITY. Bushire, Iran (Musser & Carleton, 2005).

DISTRIBUTION. SE coast of Caspian Sea through Turkmenistan to the Kyzylkum Desert, C-Uzbekistan, E- and S-Iran (Lay, 1967), S- and W-Afghanistan and SW Pakistan (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Bazman, Shandak; Bampur, Jafar Abad; Kahnooj, Avaz Abad; Maskutan.

DIAGNOSTIC CHARACTERS. Maxillary tooth row usually under 5 mm (Corbet, 1978; Darvish, 2015).

Family CALOMYSCIDAE

12. *Calomyscus hotsoni* Thomas, 1920

TYPE LOCALITY. W-Pakistan, W-Balochistan, Makran Dist., Gwambuk Kaul, 50 km SW-Panjgur.

DISTRIBUTION. Recorded from vicinity of type locality and Baluchistan Province of SE-Iran (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Kohe Heidar; Fanuj; Anbar Abad.

DIAGNOSTIC CHARACTERS. Nasal width is narrow; skull is high; diastema is long; intarorbital is narrow.

Family CRICETIDAE

Subfamily CRICETINAE

13. *Cricetulus migratorius* (Pallas, 1773)

TYPE LOCALITY. West Kazakhstan, Lower Ural River (Musser & Carleton, 2005).

DISTRIBUTION. SE-Europe to Romania and Bulgaria eastwards through Kazakhstan to S-Mongolia and N-China southwards through Turkey and Transcaucasia to Levant, Iraq, Iran (Lay, 1967), Afghanistan, Pakistan and N-India (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Anbar Abad, Amjaz.

DIAGNOSTIC CHARACTERS. Teeth are no-prismatic and with two rows; antero external angles of parietal is rounded (Corbet, 1978; Darvish, 2015).

Family CRICETIDAE

Subfamily ARVICOLLINAE

14. *Micotus kermanesis*

TYPE LOCALITY.

DISTRIBUTION. Dry montane steppe habitats on isolated mountains from N slopes of Kopet-Dag Mtns in S-Turkmenistan (Meyer et al., 1996), mountains in E-Iran in the NE (Khorassan Prov., 5 km N-Kashmar, USNM) and S (Kuh-e Laleh-Zar and Kuh-e Hazar Mtns south of Kerman; Roguin, 1988), and the Hindu Kush of N-Afghanistan (Ellerman, 1948; Parvan Province, Shibar Pass, FMNH).

MATERIAL LOCALITIES. Anbar Abad.

Family HYSTRICIDAE

15. *Hystrix indica* Kerr, 1792

TYPE LOCALITY. India

DISTRIBUTION. Transcaucasus, Asia Minor, Israel, Arabia to S Kazakhstan and India, Sri Lanka, Tibet (China) (Musser & Carleton, 2005).

MATERIAL LOCALITIES. Kohe Heidar

**DISCUSSION**

The Jaz Murian depression was formed from the Early Tertiary during the southward movement of Makran, between continental margin of Makran and Lut basin (Berberian & King, 1981). It was part of Gondwana land mass possibly an extension of the Afro-Arabian continental platform (Stocklin, 1968; Berberian, 1976). From the biogeographic aspects, south of Iran was known as a bridge between oriental realm and African-Arabian region (known as Ethiopian realm; Frey & Probst, 1986; Coad & Vhlenkin, 2004; Madjnoonian et al., 2005). This dry land surrounded by mountains and desert range lacks endemic Iranian elements (Misonne, 1959) and was considered as a unique zoogeographic zone (Zarudny, 1911). Frey & Probst (1986) in their synopsis of the vegetation of Iran accounted the region as a Nubo-Sindian zone which was excluded from Palaeartic parts of Iran from the phytogeographic view. Conversely, the depression enjoys Oriental and Ethiopian elements which could pass the Sindian plains and Arabian deserts penetrating Iran from northern shores of Persian Gulf (Misonne, 1959; Frey & Probst, 1986). In fact, during the late Early Miocene, decline in the sea level may have resulted in faunal exchange via some emerging islands (Wessels, 1955).

The penetration route of African (Ethiopian) elements (*Acomys* I. Geoffroy, 1838, *Gerbillus* Desmarest, 1804 and *Meriones* Illiger, 1811) into the region is not clear but Madjnoonian et al. (2005) proposed Bandar Abbas through Hormoz Strait as a paleo-corridor during Quaternary. Eastern spiny mouse (*Acomys dimidiatus*) was blocked in the southeast Iran while *Tatera indica* could pass the barriers into the central Plateau of Iran (Madjnoonian et al., 2005). *Acomys dimidiatus* entered south Iran from the west and passing northern margin of Persian Gulf (Fars, Bushehr, Hormozgan, Sistan and Baluchestan provinces) reaching southern

Pakistan (Etemad, 1978; Firouz, 1999; Frynta et al., 2010). This study provided new records of the Eastern spiny mice from Kerman province. Mean value of tail length of the Jaz Murian specimens of *A. dimidiatus* is nearly similar to the Arabian specimens (Harrison, 1972).

Steppe field mouse (*A. witherbyi*) was previously reported from different localities of Iran (Hossein-pour Feizi et al., 2009; Darvish et al., 2015). Comparing to the specimens from northwest of Iran, mean value of head and body and tail length of the Jaz Murian specimens is longer (Darvish et al., 2014). Considering the fact that genus *Apodemus* Kaup, 1829 is a Palaeartic element (Michaux et al., 2002), the Jaz Murian depression can be interpreted as a boundary between Palaeartic and Oriental realms. It is supposed that the Jaz Murian depression is the southernmost boundary of distributional range of *A. witherbyi* in the world. The region might have also played a role as a corridor for entering *Mus musculus* from its origin (north Indian) to central Iranian Plateau (Bonhomme et al., 1994).

In *Mus musculus* and *Tatera indica* the head and body and tail length of the Jaz murian specimens were smaller than that of Pakistan specimens but tail length is longer than that of *Mus musculus* from northwest of Iran (Roberts, 1997; Darvish et al., 2014). The head and the body length of *Jaculus blanfordi* from the region are smaller than that of Pakistan and Turkmenistan specimens but the average tail length of the Jaz Murian specimens is longer than the tail length of Pakistan and Turkmenistan specimens (Shenbrot et al., 2008). The head and body length of *Cricetulus migratorius* from Jaz Murian is longer than the mean value of the head and body length of Pakistan, but the tail length is smaller. Also, it shows smaller head and body and tail length compared to specimens from the northwest of Iran and Arabia (Harrison, 1972; Roberts, 1997; Darvish et al., 2014). Mean value of head and body length of *Merion libycus* is smaller than that of Pakistan, but mean value of tail length is longer. Libyan jirds of the Jaz Murian show longer mean value of head and body and tail length comparing to the specimens from northwest of Iran (Roberts, 1997; Darvish et al., 2014). The head and body and tail length of the Jaz Murian specimens of *Nesokia indica* is smaller than the Pakistan and Arabian specimens (Harrison, 1972; Roberts, 1997). Also, the Jaz Murian specimens of *Calomy-*

*scus hotsoni* show smaller head and body length, but longer tail length comparing to the Pakistan specimens (Roberts, 1997).

Indian bush rat *Golunda ellioti* has been recorded from the Jaz Murian depression (Jiroft, Kerman) by different authors (Misonne, 1990; Nazari & Farid, 1991; Madjdzadeh 2012; Darvish et al., 2012). Actually, the genus *Golunda* occupied oriental realm from early Pliocene (Cheema et al., 1997, 2003) and it seems that the Jaz Murian is the westernmost boundary of this oriental species (Ziaie, 2008). The head and body and tail length of *Golunda ellioti* from Jaz Murian is longer than that of Pakistan specimens (Roberts, 1997).

Corbet (1978) mentioned that *Meriones hurrianae* (Jerdon, 1867) (Baluchestan, southeast Iran) and *Rattus niviventer* (Hodgson, 1836) (northern Pakistan) are oriental species which can be found in the boundary of Palaearctic realm; however, they were not captured in this study. The total head and body and the tail length of *Rattus rattus* from Jaz Murian specimens were smaller than that of Pakistan specimens (Roberts, 1997).

For most specimens, except *Gerbillus nanus*, and *Apodemus whiterbyi*, total length of the body is small, compared to that of their counterparts from northeast and northwest Iran (Darvish et al., 2006; Darvish et al., 2014). This pattern of nanism may be a response to lower precipitation and sparse vegetation cover in the region. In fact, high temperature and drought resulting in lower primary productivity and decline in food level, which in turn cause body size decline (Sheridan & Bickford, 2011).

## CONCLUSION

The Jaz Murian depression is a crossroad between Palaearctic, Ethiopian and Oriental realms. Because of the conspicuous geographic and topographic features of this transition zone, a complex mixture of rodent species such as Oriental species i.e. *Golunda ellioti*, *Meriones hurrianae*, *Mus musculus*, *Tatera indica*, *Hystrix indica* and Ethiopian elements such as *Gerbillus nanus*, *Meriones libycus* and *Acomys dimidiatus* beside Palaearctic species i.e. *Apodemus whiterbyi*, *Rattus rattus*, *Cricetulus migratorius*, *Microtus* sp. can be found in the region. Although, the region is characterized by a low plains surrounded by high mountains, it is not strictly isolated. Thus, it can be considered as a corridor between three

realms. The specific geographical condition and the unique topography and climatic situation of the Jaz Murian depression made the region favorite destination for zoogeographic and phylogeography studies. This study was just a preliminary investigation on the rodent's fauna of the Jaz Murian depression carried out to contribute to other studies aimed at revealing specific aspects of the region.

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## Diversity and seasonal appearance of aquatic fungi in three streams of Western Ghat forests of Goa, India

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### ABSTRACT

In the absence of any detailed and intensive investigation on the mycota of freshwater streams of the northern part of Western Ghats, in the present paper an effort was made to study the diversity and seasonal appearance of aquatic fungi of this region. It has been observed, from the study made among the three seasonal samplings, that monsoon season is the best for recovery of this group of fungi.

### KEY WORDS

Aquatic fungi; Biodiversity; Freshwater streams; Western Ghats.

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### INTRODUCTION

Aquatic fungi in freshwater habitats are represented by two major groups namely Saprolegniales (watermoulds) and Aquatic Hyphomycetes. A number of fungi belonging to Ascomycotina and Mastigomycotina (zoosporic fungi) and a few Basidiomycetes also occur in freshwater habitats but in the dynamics of freshwater stream ecosystem, hyphomycetous fungi are considered as the most significant participants in view of their ability to digest a variety of submerged organic matter (Koushik & Hynes, 1971; Barlocher & Kendrick, 1976; Barlocher, 1992; Graca et al., 1993). Growing on submerged leaves and twigs, these fungi abound in fast flowing tree lined streams and well aerated rivers. The streams contain sufficient runoff organic material which, in the living or dead state, serve as a constant source of nutrients for the fungi living in water. The production of characteristic conidial-shape-like sigmoid, tetra- or radiate, helicoids and branched spores are the significant feature of this group of fungi.

The aquatic fungi of the streams of Western Ghat forests of Goa (India) have been a subject of study since the publication of a preliminary survey of 11 streams of the region carried out by Subramanian and Bhat in 1981 where *Anguillospora longissima*, *Tetracladium setigerum* (Grove) Ingold and *Triscelophorus monosporus* were reported for the first time from Dudhsagar falls in Goa State. Since then, a number of publications appeared on these fungi from the forest streams of Western Ghats in Karnataka and Kerala and have been reviewed in detail by Sridhar & Barlocher (1992).

The present work aims at the study of occurrence and abundance of aquatic fungi on submerged leaf litter in different seasons i.e., the monsoon, post-monsoon and the summer seasons in Goa state. Studies were carried out in one stream each in three wildlife sanctuaries of Goa - i.e., Bondla, Cotigao and Molem (Fig. 1). All the three sites have dense riparian canopy and have fast running water streams during monsoons which dry up during the summer seasons. An attempt was made to discover the diversity and number of species present in each season.

## MATERIAL AND METHODS

### *Sampling sites*

For the study of aquatic fungi occurring in different seasons, sampling was done at regular intervals in one stream each in three wild life sanctuaries, Bondla, Cotigao and Mollem. Assuming that the tree canopy may play a decisive role on the ecology of aquatic fungi by providing organic matter input, only those streams in the sanctuaries with dense riparian tree cover were chosen for the study. Besides abundance and frequency of occurrence, diversity of aquatic fungi was also studied from these sites. The sampling sites are described below:

**Stream-1.** A seasonal moderately fast flowing stream originated at a slightly high altitude in the ghats and flown down through Bondla wildlife sanctuary (120 m asl), in Pondataluka was considered as stream 1. The collecting site was about 2 km before the entry gate to the sanctuary and 60 km north-west of Goa University campus. The stream bed at the site was rocky. Banks of the stream on either sides were lined mainly by *Calamus thwaitesii* Becc. and *Dendrocalamus strictus* (Roxb.) Hook. and *Bambusa arundinaceae* (Retz.) Willd, besides

tree species such as *Adina cordifolia* (Roxb.) Hook., *Bauhinia tomentosa* L., *Dillenia indica* L., *Grewia hirsuta* Vahl., *Hydnocarpus laurifolia* (Dennst.) Sleumer, *Indigo feradalzeli* Cooke., *Stephania japonica* Thunb Miers. and *Terminalia tomentosa* Wt. et Arn.

**Stream-2.** A fast flowing seasonal stream originated at Anmod Ghat and flown down into Bhagavan Mahavir sanctuary (230 m asl) was chosen as stream 2. The collection site was located about 4 km west of Mollem in Sanguem Taluka, 65 km west of Goa University campus. The stream bed had soft soil at the collecting site. Even though a variety of tree species was present in the sanctuary, riparian vegetation along the stream mainly composed of *Hopea ponga* (Dennst.) Mabb, the roots of which extend into the flowing waters along the sides of the stream. The other dominant tree species in the catchment area included evergreen types such as *Careya arborea* (Roxb.) De Wilde and *Tinospora cardifolia* Miers.

**Stream-3.** A moderately fast flowing seasonal stream, originated above in the ghat and flown down near Tree-top point of Cotigao wild life sanctuary (280 m asl) in Canacona Taluka, was considered as stream 3 for the study. The stream had lateritic soft soil in the bottom and good run off in monsoon season but gradually dried up during the late post monsoon and summer months. The site was 75 km south-east of Goa University campus. The catchment area was covered by dense vegetation of semi-evergreen and evergreen tree species, and some of the dominant riverine trees found in the area were *Careya arborea* (Roxb.), *Calycopteris floribunda* (Roxb) Lamk., *Dillenia indica* L., *Grewia hirsuta* Vahl., *Kandelia candel* (L.) Druce., *Lagerstoemia lanceolata* Wall. Ex Wt. et Arn., *Terminalia paniculata* Roth. and *Xylia xylocarpa* Taub.

### *Sampling seasons and intervals*

Sampling of aquatic hyphomycetes was done during three sampling seasons namely monsoon, post-monsoon and summer season. During monsoon, from June to September every year, the windward western slopes of the Western Ghats receive a total rainfall of 250–350 cm. The mean annual temperature varies between 22–36 °C, the minimum seldom falling below 18 °C. Humidity ranges between 60–90%. All along the Western Ghats, in



Figure 1. Study area: Western Ghat forests of Goa, India.

monsoon the streams are usually gorgeous with flowing water. During post-monsoon (October to January), the streams either have little flowing water or mostly at many places exhibit pools of stagnant water bodies. In the summer months (February to May), the streams are practically dry and without water, except those perennial ones where flow of water is very slow.

While raining, fallen leaves from the trees lining the stream and river banks and adjoining forests get washed into the streams, the leaf litter in the stream either remains submerged or gets parked against rock crevices, fallen logs or any obstacles. These samples were carefully collected and brought to the laboratory, assuming that aquatic fungi colonise on submerged leaf litter.

#### *Samples for floristic study*

Spores of Deuteromycotina, Ascomycotina and Basidiomycotina get trapped in foam of freshwater streams. If a drop of foam is examined under a light microscope, spores and hyphal fragments of a variety of aquatic fungi can be seen.

**Fixed foam.** Foam accumulated on the surface of stream water was gathered by gently and repeatedly scooping a wide-mouth glass jar or glass petri plate lid over the foam. The collected foam was fixed by adding few drops of FAA fixative (a mixture of Formaldehyde 40% (5 ml), Glacial Acetic Acid (5 ml) and 70% Ethyl alcohol). The foam bubbles break into a cream coloured or slightly turbid liquid at the bottom of the container. The sample was maintained in 10 ml screw-capped vials. The vials were appropriately labelled in the field indicating the sample number, location and date of collection.

**Dried foam.** A drop of fresh foam was directly placed and spread over a clean slide and air-dried at the collection site. The slides were appropriately labelled indicating the sample number, location and date of collection and brought to the laboratory by arranging them vertically and in rows in a slide box. These slides were observed under the microscope by placing a drop of lactophenol-cotton blue mountant over the fixed foam dried area. Examination of FAA-fixed or air-dried foam under a microscope revealed the floristics of aquatic fungi of the catchment region. The slides examined were deposited as specimens at the Herbarium of Botany Department, Goa University (GUBH).

**Leaf litter.** Leaves of trees lining the stream and rivers on senescence fall into water. The fallen leaves act as substrate for growth and colonisation of aquatic fungi (Ingold, 1975). The submerged and partially to fully decayed leaf litter and twigs thus form excellent source for recovery of aquatic fungi. These leaves were hand-picked, thoroughly washed in water and placed in clean polythene bags. These were transported to the laboratory in ice-pack container. Of the decayed and well-skeletonised leaf litter brought to the laboratory, 2–3 leaves were washed thoroughly with de-ionized tap water and placed in large specimen jars containing 1L of sterile distilled water. The jars were aerated continuously for 5–7 days using a fish tank aerator. The aerated water was filtered through a Millipore filter (8 µl pore size) and the aquatic spora on the filter were counted (Iqbal & Webster, 1973).

#### *Statistical Analysis*

Data collected during the 24 month study period were subjected to statistical analysis. Margaliff's and Shanon's index were used for analysis of diversity of fungi. Analysis of Variance (ANOVA) Test was carried out to analyse the variations in occurrence of fungi in different seasons. The following formulas were used for statistically analysing the data obtained during the seasonal study of aquatic fungi.

$$\text{Percentage Frequency (\% F)} = \frac{\text{Total no. of quadrats in which species occurred}}{\text{Total no. of quadrants sampled}} \times 100$$

$$\text{Relative Frequency (R.F.)} = \frac{\text{No. of occurrence of a species}}{\text{No. of occurrence of all species}} \times 100$$

$$\text{Density (D)} = \frac{\text{Total number of individuals of the species}}{\text{Total number of quadrants taken}}$$

$$\text{Abundance (A)} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occurred}}$$

The density of fungi on leaf litter, as expressed in water by aquatic spora, during the three different seasons and their significance of occurrence was analysed using 'Analysis of Variance' (ANOVA) test.

## RESULTS

In all, conidia of 62 species of aquatic fungi were recorded in varying concentration in the aerated water. Fungal taxa seen as conidia in water and their average relative abundance (%) are given in Table 1. The relative abundance of species of fungi in 3 different seasons at three sites, namely Cotigao, Bondla and Molem indicates that during monsoon, highest number of species were at Bondla (54). Followed by Cotigao (51) and Molem (45). During post monsoon, the species richness remained in the same order of abundance in three sites i.e., Bondla (41), Cotigao (37) and Molem (31). However, the abundance was in different order in summer, showing highest number of species at Cotigao (19), followed by Bondla (15) and Molem (16).

Analysis of variance test (ANOVA) (Table 2) on seasonal sampling carried out during the year showed a highly significant variation in the species richness in three different seasons at three sites and the order of significance was as follows: Cotigao (4.47), Bondla (3.31) and Molem (2.45). Less significant variation was observed between the sites during the same seasons: Monsoon (1.69), post-monsoon (1.18) and summer (0.92). The significant level tested between the places during same seasons did not show much variation. The F ratio obtained in monsoon, post-monsoon and summer from the three sampling sites was 1.84, 1.37 and 0.44, respectively. This similarity in significance may be attributed to the similar type of vegetation composition seen at the three sites.

Among the three different seasons chosen for the collection of freshwater fungi encountered on randomly sampled leaves, highest number of species were observed during monsoon (June to September) and the lowest during the summer (February to May). The results also indicated that the density and number of species recorded did not show a significant correlation with the pH and temperature, which was noted on the sampling sites. As an overall analysis, it may be said that occurrence and species density of fungi of a given stream ecosystem is largely dependent on factors such as rainfall, substrate availability and leaf deposition.

## DISCUSSION AND CONCLUSIONS

The results showed that there is no much differ-

ence amongst the 3 sites considered for seasonal study in their fungal wealth (Fig. 2). This is because all the three sites had dense riparian canopy and good flow of water in the streams during monsoon and post monsoon. Of the fungi recovered, 75.5% were foam trapped and 56.3% associated with submerged leaf litter (Fig. 3). This clearly showed that aquatic foam from natural streams will continue to be the best source of diverse fungi as described by Descals (1997).

It may be seen from figure 4 that fungi with blastic type of conidiogenesis were of higher percentage (89.65) than phialidic (10.35) type. It may be said that from the evolutionary stand point (Hawksworth et al., 1995), the fungi of aquatic ecosystem need not to possess phialidic conidiogenesis. This is an instrument largely used for conidiogenesis by fungi in terrestrial environment.

The study also revealed (Fig. 5) that aquatic spora of branched and appendaged type were of higher percentage (29.31) followed by tetra- radiate (24.14), sigmoid (15.52) and helicoids (1.72). These are adaptations for aquatic environment where the spora can remain afloat and get disseminated to a much larger distance. It has been realised that fungi that are taxonomically unrelated while converging into water, during the course of evolution exhibited similar morphology as an adaptation to aquatic system (Ingold, 1975; Dix & Webster, 1995). As can be seen from the study, there is no such significance in the abundance of different types of conidia. All the three to four types of conidia, i.e., appendaged, branched, sigmoid and tetra- radiate were found in abundance in aquatic systems. It is also clear from the study that natural foam accumulated on the surface of water was the best source of aquatic fungi (75.5%) for isolation. However, when aerated, significantly high percentage was recovered from submerged leaves (56.3%). This justified our taking of submerged leaves as a substrate to evaluate the aquatic flora in the stream ecosystem. Twigs with a very low percentage (8.8%) occurrence of aquatic fungi proved to be a poor substrate for isolation.

From the investigation it is clear that monsoon and post monsoon seasons are the best for recovery of freshwater fungi from the streams of forests of Western Ghats, and that those streams with dense riparian tree canopy and abundant substrate availability would yield higher diversity of aquatic fungi.

Sl.	Name of fungus	BONDLA			COTIGAO			MOLEM		
		M	PM	S	M	PM	S	M	PM	S
1	<i>Actinospora megalospora</i> Ingold	0.46	0.09	-	0.19	0.05	-	0.17	-	-
2	<i>Alatospora acuminata</i> Ingold	0.93	0.49	-	0.47	0.39	0.05	1.15	0.39	-
3	<i>Anguillospora crassa</i> Ingold	3.17	1.22	0.59	3.12	0.74	0.29	1.82	1.24	-
4	<i>Cylindrocarpon</i> sp.	1.05	0.46	-	1.38	0.92	0.42	-	-	-
5	<i>Cylindrocladium</i> sp.1	1.75	0.95	0.16	2.30	2.20	0.49	1.02	0.53	0.22
6	<i>Cylindrocladium</i> sp.2	3.89	2.24	1.88	3.41	1.36	1.19	11.23	7.73	3.46
7	<i>Anguillospora longissima</i> (Sacc. et P. Syd.) Ingold	0.39	-	-	1.09	0.57	-	-	-	-
8	<i>Ardhachandra solenoides</i> (de Hoog) Subram et Sudha	0.19	0.03	-	0.29	0.12	-	0.39	0.18	-
9	<i>Ardhachandra</i> sp.	0.82	0.63	-	0.17	-	-	-	-	-
10	<i>Articulospora tetracladia</i> Ingold	0.19	0.19	-	2.13	1.04	0.59	0.79	0.75	0.35
11	<i>Bahusutrabeeja angularis</i> V. Rao et de Hoog	1.45	0.59	0.19	1.83	0.92	0.62	1.24	0.04	-
12	<i>Beltrania rhombica</i> Penz.	0.75	0.33	-	3.54	1.86	-	3.24	0.62	-
13	<i>Scutisporus brunneus</i> K.Ando et Tubaki	0.93	0.36	-	3.19	1.31	0.42	3.46	1.11	0.44
14	<i>Articulospora</i> sp.	0.53	0.06	-	-	-	-	-	-	-
15	<i>Camposporium pellucidum</i> (Grove) S. Hughes	0.63	0.29	-	-	-	-	-	-	-
16	<i>Campylospora chaetocladia</i> Ranzoni	1.92	0.85	0.29	1.61	1.04	0.29	3.06	0.84	0.13
17	<i>Lunulospora curvula</i> Ingold	1.78	0.59	-	3.04	0.64	-	1.28	1.06	-
18	<i>Centrospora acerina</i> (R. Hartig) A.G. Newhall	0.56	0.06	-	-	-	-	-	-	-
19	<i>Lemonniera aquatica</i> De Wild.	-	-	-	0.47	0.29	0.19	0.53	0.08	-
20	<i>Chaetendophragma triseptata</i> Matsush.	0.53	0.16	-	0.42	0.17	-	0.44	0.13	-
21	<i>Diplocladiella scalaroides</i> G. Arnaud ex M.B. Ellis.	-	-	-	-	-	-	1.99	0.79	-
22	<i>Condylospora spumigia</i> Nawawi	4.36	-	-	5.25	1.78	1.38	8.21	1.55	0.75
23	<i>Dactylella ellipsospora</i> (Preuss) Grov.	2.47	0.76	0.29	4.16	2.03	0.82	2.39	0.88	-
24.	<i>Dactylaria</i> sp.	0.49	-	-	0.59	-	-	0.53	0.35	0.26
25	<i>Dactylaria aquatica</i> Udaiyan	1.25	0.69	-	1.53	0.67	-	0.84	0.35	0.22
26	<i>Dendrospora erecta</i> Ingold	0.92	-	-	2.15	1.06	0.37	0.53	-	-
27	<i>Ceratosporium</i> sp.	0.46	0.56	-	0.69	-	0.39	0.75	0.35	0.22
28	<i>Tripospermum myrti</i> (Lind) Hughes	0.86	0.69	-	0.29	0.19	0.12	0.48	-	-
29	<i>Lateriramulosa uni-inflata</i> Matsush.	0.89	0.06	0.09	0.05	0.19	0.09	0.62	0.22	-
30	<i>Dendrosporium lobatum</i> Plakidas et Edgerton ex J.L. Crane	0.16	0.06	-	0.07	-	-	0.39	-	-
31	<i>Dichotomophthoropsis aquatica</i> Sreekala et Bhat	0.49	-	-	0.12	0.27	-	-	-	-

Table 1/1. Fungal taxa seen as conidia in water and their average relative abundance (%).

Sl.	Name of fungus	BONDLA			COTIGAO			MOLEM		
		M	PM	S	M	PM	S	M	PM	S
32	<i>Dictyochaeta assamica</i> (Agnihothr.) Aramb., Cabello et Mengasc	-	-	-	-	-	-	1.19	0.57	0.09
33	<i>Endophragma inaequiseptata</i> Matsush.	-	-	-	0.12	0.09	-	-	-	-
34	<i>Flabellospora crassa</i> Alas.	2.84	1.88	-	1.46	0.29	-	1.24	0.66	0.08
35	<i>Flagellospora curvula</i> Ingold	0.96	0.33	-	-	-	-	-	-	-
36	<i>Beltraniella odineae</i> Subram.	0.86	0.36	0.16	0.32	0.05	-	0.35	0.13	-
37	<i>Flabellospora verticillata</i> Alas.	0.43	0.29	0.19	0.22	-	-	0.66	0.35	0.08
38	<i>Flabellospora multiradiata</i> Nawawi	0.49	0.39	0.09	0.72	0.12	-	0.35	-	-
39	<i>Helicomycetes roseus</i> Link	0.56	0.26	-	0.05	-	-	-	-	-
40	<i>Helicosporium</i> sp.1	8.45	6.97	0.92	6.23	2.87	-	2.57	-	-
41	<i>Helicosporium</i> sp.2	1.75	0.36	0.26	0.77	0.29	-	0.84	0.53	0.18
42	<i>Helicosporium</i> sp.3	3.23	1.92	-	2.00	-	-	0.22	-	-
43	<i>Ingoldiella hamata</i> Shaw	2.08	1.16	-	1.68	1.26	-	0.93	-	-
44	<i>Isthmotricladia laeensis</i> Matsush.	0.56	0.26	-	0.05	0.12	-	1.99	1.15	-
45	<i>Isthmotricladia britanica</i> Descals	-	-	-	1.46	-	0.05	-	-	-
46	<i>Nawawia filiformis</i> (Nawawi) Marvanová	0.53	0.49	0.36	0.69	0.29	0.19	0.84	0.44	0.13
47	<i>Phalangispora constricta</i> Nawawi et J. Webster	0.66	0.36	-	0.29	0.19	-	-	-	-
48.	<i>Mycocleptodiscus indicus</i> (V.P. Sahni) B. Sutton	0.19	0.19	-	0.22	0.05	-	0.13	0.04	-
49	<i>Tetrachaetum elegans</i> Ingold	0.49	-	-	0.54	0.35	-	0.26	-	-
50	<i>Sopagraha sibika</i> Subram. et Sudha	0.69	0.39	0.26	0.72	0.37	-	0.44	0.04	-
51	<i>Speiropsis hyalospora</i> Subram. et Lodha	0.46	0.16	-	0.07	-	-	0.35	0.31	0.08
52	<i>Speiropsis pedatospora</i> Tubaki	0.65	-	-	-	-	-	-	-	-
53	<i>Subulispora</i> sp.1	0.39	-	-	0.42	-	-	0.84	-	-
54	<i>Subulispora</i> sp.2	0.23	-	-	0.05	-	-	0.79	-	-
55	<i>Tetraploa aristata</i> Berk. et Broome	0.63	-	-	0.39	-	-	-	-	-
56	<i>Tetracladium</i> sp.	0.23	-	-	-	-	-	0.53	-	-
57	<i>Tetracladium angulatum</i> Ingold	3.17	0.63	0.36	1.28	0.64	0.17	3.86	0.66	0.26
58	<i>Triscelophorus acuminatus</i> Nawawi	-	-	-	0.29	-	-	0.62	-	-
59	<i>Triscelophorus konajensis</i> K.R. Sridhar et Kaver.	-	-	-	0.39	-	-	-	-	-
60	<i>Triscelophorus monosporus</i> Ingold	0.39	-	-	-	-	-	-	-	-
61	<i>Seimatosporium</i> sp.	-	-	-	-	-	-	0.22	-	-
62	<i>Robillarda phragmitis</i> Cunnell	0.26	-	-	-	-	-	-	-	-
	<b>Total (no. of species)</b>	<b>54</b>	<b>42</b>	<b>15</b>	<b>51</b>	<b>37</b>	<b>19</b>	<b>45</b>	<b>31</b>	<b>16</b>

Table 1/2. Fungal taxa seen as conidia in water and their average relative abundance (%).

Places	Seasons	Experimental Method				
		Sum of squares	Degree of Freedom	Mean square	F ratio	Significance
Bondla	Between seasons	8604.65	2	4302.33	3.13	Yes
	Residual	148591.24	108	1375.84		
Cotigao	Between seasons	16697.25	2	8348.63	4.47	Yes
	Residual	199862.1	107	1867.87		
Molem	Between seasons	6875.37	2	3437.69	2.45	Yes
	Residual		91	1402.71		
Monsoons	Between places	127646.46	2	3989.72	1.69	No
	Residual	361992.46	154	2350.60		
Post-Monsoons	Between places	2281.51	2	1140.79	1.18	No
	Residual	102324.58	106	965.33		
Summer	Between places	469.65	2	234.83	0.92	No
	Residual	11782.76	46	256.15		

Table 2. Analysis of Variance (ANOVA) for the three sampling sites.

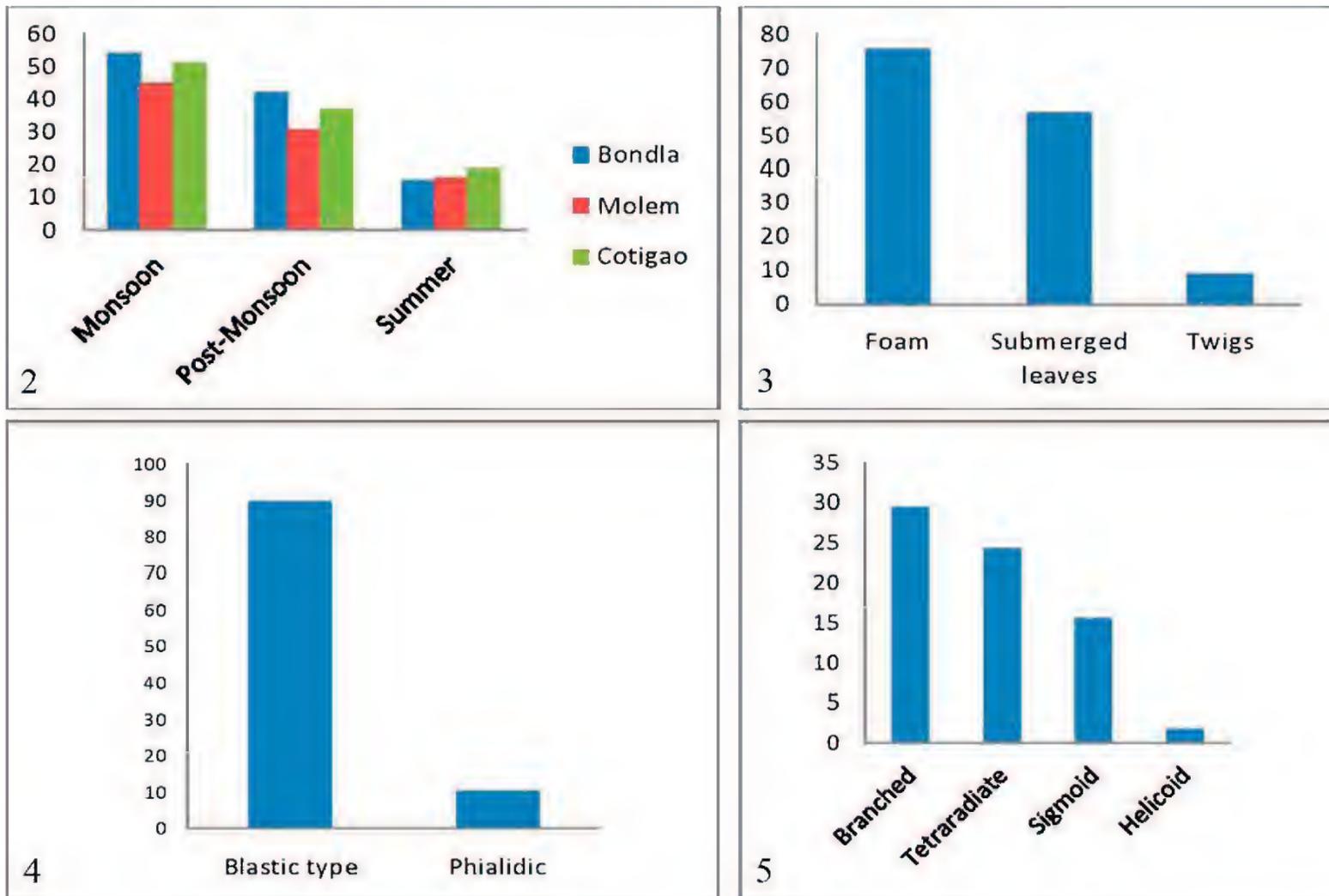


Figure 2. Seasonal occurrence of aquatic fungi in different seasons. Figure 3. Substrate specificity of aquatic fungi. Figure 4. Percentage occurrence of conidia based on its conidiogenesis. Figure 5. Percentage appearance of different types of conidia.

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## Contribution to the flora of United Arab Emirates: *Glinus lotoides* L. (Molluginaceae) and *Senna occidentalis* L. (Fabaceae) two new records

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### ABSTRACT

This paper reports *Glinus lotoides* L. (Molluginaceae) and *Senna occidentalis* L. (Fabaceae) as two new records to the flora of the United Arab Emirates (UAE). In the UAE, *G. lotoides* grows in the seasonally inundated land when the water recedes and soils have high clay contents. This is the only representative species of the genus *Glinus* in the UAE. Hence, we added a new genus to the country's flora. *Senna occidentalis* was recorded from Wadi Al-Ain with ca. 15 individuals in its population. This species is considered as a weed elsewhere, so, there should be further assessments in order to monitor naturalization potential in its new localities in the UAE. The general distribution of the newly recorded species, habitat preferences and taxonomy with a map of localities in the UAE are presented. The occurrence of both species in different places in the UAE calls for further investigation and more extensive field studies to explore the country's genetic resources.

### KEY WORDS

Floristic survey; *Glinus lotoides*; *Senna occidentalis*; new record; UAE.

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### INTRODUCTION

The United Arab Emirates (UAE) is characterized by a wide variety of habitats (i.e., mountainous, coastal lowlands, desert and alluvial plains) that support unique diversity of plant genetic resources. Despite the UAE is regarded as floristically poor, it harbors unique plants with remarkable morphological, physiological and anatomical adaptations strategies that enable them tolerating the very harsh climatic conditions prevailing in the country (Tourenq & Launay, 2008).

The UAE supports varying amounts of sparse seasonal vegetation. The flora of the UAE accounts for ca. 750 species of vascular plants including important native plant species and is affected by

alien invasive species (El-Keblawy & Abdel Fatah, 2014).

Although it might be regarded that there is a reasonable knowledge on the general distribution of vascular plants in the UAE, recent studies showed new regular discoveries that enriching the flora of the country (e.g., Gairola et al., 2015; Mahmoud et al., 2015a, b; Shahid & Rao, 2015). There are some potentially very interesting remote areas (e.g., mountainous regions) thus have not been fully explored floristically. In such areas, certain new plant records or new species to the UAE are waiting to be recorded. For example, in a recent survey for the flora of the remote area of Wadi Helo, El-Keblawy et al. (2016) recorded 6 species new to the UAE flora.

Since 2009, the research team of the Sharjah Seed Bank & Herbarium (SSBH) is extensively exploring plant diversity of the country. It was realized that the exploration of non-recorded species is vital in assessing the genetic resources, especially in the more vulnerable and remote high mountains in this harsh part of the world. As a continuation of such explorations, some taxa have been recently collected from the region and added as new records to the flora of the UAE. The recent contributions to the flora of the UAE include a series of joint botanical collecting trips involving the staff of Kew Herbarium and SSBH (e.g., Heller & El-Keblawy, 2013; Gairola et al., 2015; Mahmoud et al., 2015a, b) and various other researchers (e.g., Feulner, 1997; Böer & Chaudhary, 1999.; Brown et al., 2006; Shahid, 2014; Shahid & Rao, 2014a, b; Shahid & Rao, 2015) have revealed the presence of some spontaneously occurring plant species new to the UAE. The recently published new records from the UAE are important additions to Jongbloed (2003) and Karim & Fawzi (2007). However, a few non-indigenous invasive or weedy elements that have been recorded for the first time among the flora of the UAE need critical monitoring to assess their future distribution. The climatic and environmental harshness of the Arabian deserts might hinder the invasion of alien plant species. However, the increasing human impacts, such as habitat fragmentation, encroachment of natural habitats through farmland and expansion of residential areas are threatening the natural flora. Some of the unre-

corded species of the UAE flora might extinct before being discovered. Present article sheds light on the distribution, habitats preferences, and taxonomy of two newly recorded plant species in the UAE.

## MATERIAL AND METHODS

During the years 2015-2016, floristic surveys were undertaken in different parts of the UAE and samples of a particular plant species were collected for observation and identification. The digital photos of plants in their natural habitat were also taken to facilitate the identification process. Preliminary identification of *Glinus lotoides* L. (Molluginaceae) and *Senna occidentalis* L. (Fabaceae) was done using taxonomic keys in different flora books, including Flora of Arabian Peninsula and Socotra (Miller & Cope, 1996). The identification of *G. lotoides* was confirmed by Dr. Jacob Thomas, a key taxonomist in the Arabian flora. Once the species was identified, the collected material with voucher numbers, family, species and collection details was kept at the Sharjah Seed Bank & Herbarium, Sharjah Research Academy, Sharjah. Flora of UAE (Karim & Fawzi, 2007) and other available literature (e.g., Jongbloed, 2003) were thoroughly checked and have been found that there were no previous records for *G. lotoides* and *S. occidentalis* from the country.

Therefore, we consider these plants are a new addition to the flora of UAE. For each species, synonyms, general distribution, habitat preferences, and taxonomy as well as a list of localities recorded are presented.

## RESULTS AND DISCUSSION

During our recent floristic surveys, it became apparent that *G. lotoides* was recorded for the first time from UAE. Another newly recorded species *S. occidentalis* was found growing in a moist habitat of wadi Al Ain bed. Furthermore, after going through the literatures, it has been confirmed that *G. lotoides* and *S. occidentalis* are new records to the UAE flora.

*Glinus lotoides* is recorded from the adjacent countries including Saudi Arabia and Oman (Miller & Cope, 1996). Figure 1 and Table 1 present the



Figure 1. Map showing the sites where *G. lotoides* and *S. occidentalis* was found in UAE.

Locality/ Species	Latitude	Longitude	Alt. (m)	Phenology	Local status
<i>Glinus lotoides</i>					
Wadi Ham Dam, Fujairah	25.13311	56.28102	80	Vegetative	Not common
Wadi Al Quor Dam, Ras Al Khaimah	24.90565	56.15346	238	Flowering and Fruiting	Co-dominant
Wadi Al Mansab Dam, Ras Al Khaimah	25.06022	55.99275	255	Flowering	Common
Wadi Al Mudaynah Dam, Ras Al Khaimah	25.03348	56.02315	300	Flowering	Not common
Wadi Shawkah Dam, Ras Al Khaimah	25.10585	56.04448	295	Flowering	Common
Wadi Al Qasheesh Dam, Ras Al Khaimah	25.13964	56.01296	240	Vegetative	Common
Wadi Sfini Dam, Ras Al Khaimah	25.17176	56.10849	320	Vegetative	Rare
<i>Senna occidentalis</i>					
Wadi Al Ain (upstream)	24.20895	55.77321	290	Fruiting	Not Common
Wadi Al Ain (upstream)	24.20232	55.72448	260	Flowering and Fruiting	Not Common

Table 1. Recording site details, phenology and local status of *Glinus lotoides* and *Senna occidentalis* populations in UAE.

collection localities of *G. lotoides* and *S. occidentalis* in the UAE. The population of *G. lotoides* was recorded repeatedly in different seasonally inundated areas, especially in the front of dams (Figs. 2, 3). In a few sites, *G. lotoides* occurs in large numbers and establishes a viable population. It is worth mentioning that *G. lotoides* is the only representative of the genus *Glinus* in the UAE flora.

The population of *S. occidentalis* consists of ca. 15 individuals and was found in moist, sandy areas in Wadi Al Ain (Figs. 4, 5). It is important to mention here that *S. occidentalis* is regarded as an alien weed elsewhere (Holm et al., 1997; Wu et al., 2003). Therefore, the population of *S. occidentalis* should be monitored for its naturalization potential and long-term observations need to be conducted to prove the future weedy status of this species in the UAE.

The brief below descriptions of the two newly recorded species are based on various flora books. In addition, we relied on the description of our collected specimens from the UAE.

### *Glinus lotoides* L.

SYNONYMS. *Mollugo hirta* Thunb., *Mollugo lotoides* (Linn.) O. Kuntze, *Glinus dictamnoides* Burman f. and *Mollugo glinus* A. Richard.

DESCRIPTION. Prostrate to spreading annual or short-lived perennial, up to 50 cm high. Stems procumbent or decumbent, stellate-tomentose throughout. Leaves elliptic to obovate and obcordate, to 20 mm long, acute to obtuse, hairy; petiolate. Flowers in axillary clusters of 3–15, subsessile, shortly pedicellate; pedicel up to 1.5 mm long. Capsule sub-globose or oblong, ca. 6 mm long, membranous, enclosed in the sepals. Seeds, many tuberculate, strophiolate, less than 1 mm long, orange-brown in colour.

DISTRIBUTION. *Glinus lotoides* is native to Eurasia and Africa and has become widespread in tropical, subtropical and warm-temperate areas worldwide (El-Hamidi et al., 1967). Regionally, it is recorded in Saudi Arabia, Oman, Yemen and Socotra. In the UAE, it was reported from Fujairah and Ras Al Khaimah.

FLOWERING AND FRUITING. January–March. In the UAE, it was recorded in flowering and fruiting stage in some sites, but in vegetative phase in other sites.

HABITAT. *Glinus lotoides* was found growing in occasionally inundated areas in wet clay soils. It was recorded in seven sites in the front of dams and water breakers.

ASSOCIATE SPECIES. *Asphodelus tenuifolius* Cav., *Erucaria hispanica* (L.) Druce, *Launaea capitata* (Spreng.) Dandy, *Physorhynchus chamaerapistrum* Boiss., *Sisymbrium erysimoides* Desf.

MEDICINAL USES. *Glinus lotoides* serves a variety of medicinal purposes. This species is used as treatment for diarrhea, boils and abdominal diseases as well as weakness in children (Kirtikar & Basu, 1935; Qureshi et al., 2010). Antihelmintic properties are reported for *G. lotoides* from several African studies (Abegaz & Tecle, 1980; Broberg, 1980).

### *Senna occidentalis* (Linnaeus) Link

SYNONYMS. *Cassia occidentalis* L.

DESCRIPTION. *Senna occidentalis* is an annual or perennial undershrub, erect, up to 1.5 m high. Leaves ca. 20 cm; stipules caducous, triangular to lanceolate, petiole 3–4 cm, with a large, brown, ovoid gland near the petiole base. Leaflets 3–5 (or 6) pairs, ovate to ovate-oblong; mucronate, opposite, petiolule ca. 1 mm. Inflorescence pedunculate, axillary or terminal, corymbose raceme forming terminal panicles. Flowers ca. 2 cm. Sepals unequal, outer ones suborbicular, ca. 6 mm in diam., inner ones ovate, 8–9 mm. Petals yellow, purplish veined, 2 outer slightly larger, shortly clawed. Legume 9–12 cm long, brown, with pale thick margins, strap-shaped, falcate, flattened, 10–13 × ca. 1 cm with septa between seeds. Seeds flat, orbicular, pale-brown.

DISTRIBUTION. Wadi Al-Ain in the UAE. A circumtropical weed, possibly native to tropical America; widely introduced and naturalized in the tropics and subtropics elsewhere (Wu & Raven, 1994).

FLOWERING AND FRUITING. November–June. In the UAE, flowering and fruiting were recorded during May.

HABITAT. Wadis in shady moist places.

ASSOCIATE SPECIES. *Cenchrus ciliaris* L., *Cynodon dactylon* (L.) Pers., *Senna italica* Mill., *Sesbania sesban* (L.) Merr, *Tephrosia apollinea* (Delile) DC., *Ziziphus spina-christi* (L.) Desf.

WAY OF INTRODUCTION IN UAE. Unknown. The recorded locations of *S. occidentalis* in Wadi Al Ain

basin are adjacent to the territory of the neighboring country Oman from where the wadi originates. So, the seeds might have been introduced through this corridor of the Wadi bed from Oman to the UAE. *Senna occidentalis* also might have been introduced with transported agricultural materials to many farms present on both sides of the Wadi.

INVASIVE/WEEDY STATUS. Casual in the UAE but need further assessment as this species is listed among the world's worst weeds (Hsu, 1975; Holm et al., 1997; Wu et al., 2003).

MEDICINAL USES. *Senna occidentalis* has been known to possess antibacterial, antifungal, antidiabetic, anti-inflammatory and hepatoprotective activity (Yadav et al., 2010). Leaves and seeds are externally applied as antiperiodic to be useful in the cure of itch and other cutaneous diseases. A decoction of the root is said to be diuretic. Seeds are roasted and used as a substitute for coffee in French Africa and Argentina.

## CONCLUSIONS

*Glinus lotoides*, a therophyte, was found in seasonally inundated areas. It is obvious that due to the cryptic nature and seasonal growth cycles of certain plants, especially in unpredictable desert environments, ecological surveys are sometimes unable to detect all species present at particular sites, such as flooded habitats. Therefore, floristic surveys following natural flooding would help to document full floristic diversity of the temporarily inundated areas. On the other hand, *S. occidentalis* is likely to be found in the early stages of its naturalization in the UAE. Consequently, regular field assessments of *S. occidentalis* should be undertaken to monitor its population dynamics and naturalization potential.

From the literatures, it is evident that most of the newly recorded species for the country are desert annuals. In fact, many desert annuals characteristically form persistence seed banks and can be absent for many years and only appear in particularly wet seasons. Therefore, floristic surveys throughout a range of seasons are suggested to fully document the flora present in the country. As the UAE, like most of the other Arab Gulf countries, is experiencing a fast growth and development, particularly in the agricultural exchange, there is a



Figures 2, 3. *Glinus lotoides*: habitat (Fig. 2); flowering twig with fruit capsules (Fig. 3).  
Figures 4, 5. *Senna occidentalis*: flowering twig (Fig. 4); pods (Fig. 5).

possibility of spontaneous occurrence of new vascular plants to the country's flora. The increased knowledge of the existence of newly recorded species and their habitats can assist to detect, monitor, measure and predict changes in biological diversity and its conservation.

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## Quality of swimming waters in the Gulf of Skikda (Algeria)

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### ABSTRACT

The purpose of this study is to determine the bacteriological and physico-chemical quality of swimming waters in the region of Skikda (Algeria), a popular tourist area known for its many beaches, through the water analysis of ten sites. This monitoring program was carried out for a period of five months.

### KEY WORDS

swimming waters; bacteriological pollution, physico-chemical parameters; Gulf of Skikda.

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### INTRODUCTION

The sea is an essential element of our life, source of food and of leisures; it represents, in most Mediterranean countries, a significant part in the economy, thanks to tourism, it concentrates in fact over 30% of international tourism (UNEP/MAP, 2012); its quality has therefore a major importance. These last years, strong urbanization, tourism and democratization of aquatic activities involved an increase in frequentation of the Mediterranean coastline and therefore a degradation of the quality of coastal waters.

In this study, we will try to determine the microbiological and physico-chemical quality of the swimming waters of the Gulf of Skikda through the water analysis of a ten station thus covering the entire Gulf.

### MATERIAL AND METHODS

The wilaya of Skikda is located in north-eastern Algeria bordering the Mediterranean Sea and has a coastline of over 140 km long. Our study area

gathers two villages and extends over twenty kilometers, it includes, east beaches Filfila and Ben M'hidi about 15 Km and to the west, a road about 3 Km beaches (Fig. 1). In addition the Gulf of Skikda is a discharge point for many wadis: Wadi Safsaf the main one, flowing in the center of the Gulf, and two secondary wadis at Filfila.

The samples, transport and analysis of seawater samples were conducted according to guidelines for the monitoring of the quality of swimming waters. This monitoring program was carried out for a period of five months (December 2013–April 2013). The collected data were measured in each seawater sample taken per month per site. The analysis focuses on the quantification of faecal indicator bacteria (total coliforms, faecal and faecal streptococci) using the method of the enumeration in liquid medium by determining the most probable number (MPN); as well as determining certain physicochemical parameters (electrical conductivity, pH, dissolved oxygen, ...).

The health status of swimming water is assessed based on the results obtained and compared to thresholds, quality bacteriological and physico-chemical criteria present in the Executive Decree No. 93-164.

Moreover, in order to compare the averages of the different physico-chemical parameters measured between the ten sites, we used the test of the analysis of variance in a criterion of classification (ANOVA), fixed pattern.

## RESULTS AND DISCUSSION

Regarding the average results recorded for the various physico-chemical parameters, we note that those are in adequacy with the quality standards required for swimming waters by the standards in force (Table 1). The temporal variation of the concentrations of different germs sought shows that they fluctuate in the same way showing their dominance during the month of December (Fig. 2). This can be justified by climatic conditions recorded during this month which resulted in the discharge of rainwater directly into the sea without treatments, the high flows of urban waste and wadis, the agitation of the water, etc. (Mazières, 1963).

Moreover, presence of enteric bacteria in the sea water can be justified by several phenomena and is conditioned by a number of specific parameters including:

- Physical factors: temperature, absorption / adsorption, dispersion, dilution, sedimentation, light (bactericidal radiation at shallow depths only) (see Carlucci & Pramer, 1959; Brisou, 1968; UNEP / WHO, 1983; Pommepuy et al., 1991; Gourmelon, 1995);

- Chemical factors: salinity (selection factor), and dietary deficiencies in vitamins, fasting, dissolved oxygen (Carlucci & Pramer, 1959; Brisou, 1968);

- Biological factors: microphage plankton or adsorbent, benthos and nekton (macrophage-plankton), vital competition, bacteriophages (Brisou, 1968; Oger et al., 1983; Gourmelon., 1995).

All these factors act together; either simultaneously or in successive steps in time and in space, to reduce the number of bacteria or eliminate them.

The spatial variation of the concentrations of different germs sought allows us to see that as, a whole, the average results recorded are in adequacy with the quality standards for swimming waters except for the fourth site where registered rates are significantly higher than the limit values required for fecal coliforms and fecal streptococci (Fig. 3). The results obtained at the fourth site, namely the "Beach la jetée" shows a fecal contamination and,

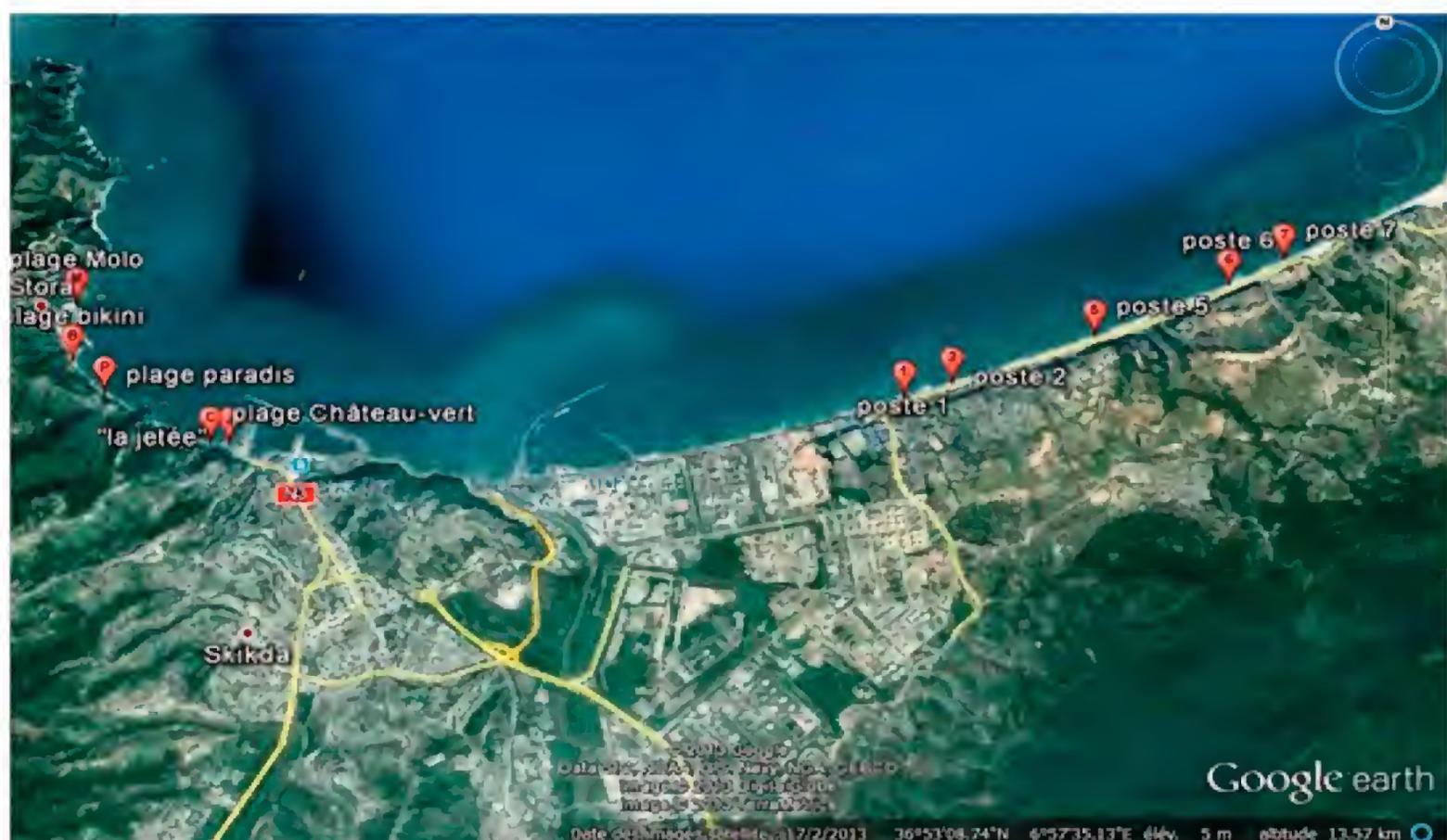


Figure 1. Location of the study area and sampling sites, Gulf of Skikda, Algeria.

therefore, its poor bacteriological quality. The presence of an urban emissary explains these results and justifies its permanent closure for swimming.

Moreover, analysis of total coliforms does not allow to assess the quality of water because a great heterogeneity of species is grouped under this term. In fact, some of them are certainly of fecal origin and may reflect a fecal pollution of water, but others are found naturally in the soil or vegetation (Rodier et al., 2005); Today, only the detection of fecal coliforms, specifically *Escherichia coli* and intestinal enterococci, in water must seriously let suspect fecal contamination, since they are the most reliable enteric pathogens, and therefore the best way to detect recent fecal contaminations (Payment & Hartmann, 1998; Scientific Group on Water, 2003).

The results of the univariate analysis of variance (ANOVA) for the five physicochemical variables measured, allow us to note the lack of significant differences between the waters of the ten sites studied (Table 2), which confirms our previous observations as to the equivalence of swimming waters sites studied from the physico-chemical point of view.

	T (°C)	pH	Salinity	Conductivity (mS/cm)	Saturation dissolved O <sub>2</sub> (%)
Site 1 «château-vert »	13.82	7.62	36.40	54.72	106.68
Site 2 «paradis »	13.88	7,7	36.42	54.74	106.62
Site 3 « molo »	14.24	7.60	36.46	54.70	104.88
Site 4 «la jetée »	13.76	7.61	36.04	54.22	98.18
Site 5 «poste 1 »	14.76	7.72	36.24	54.82	106.90
Site 6 «bikini »	13.78	7.62	36.32	54.80	104.62
Site 7 «poste 2 »	14.66	7.75	36.24	54.92	108.08
Site 8 «poste 5 »	14.58	7.74	36.22	54.84	107.90
Site 9 «poste 6 »	14.84	7.67	36.16	54.94	108.88
Site 10 «poste 7 »	14.78	7.67	36.34	54.96	108.84

Table 1. Average results of physico-chemical parameters measured.

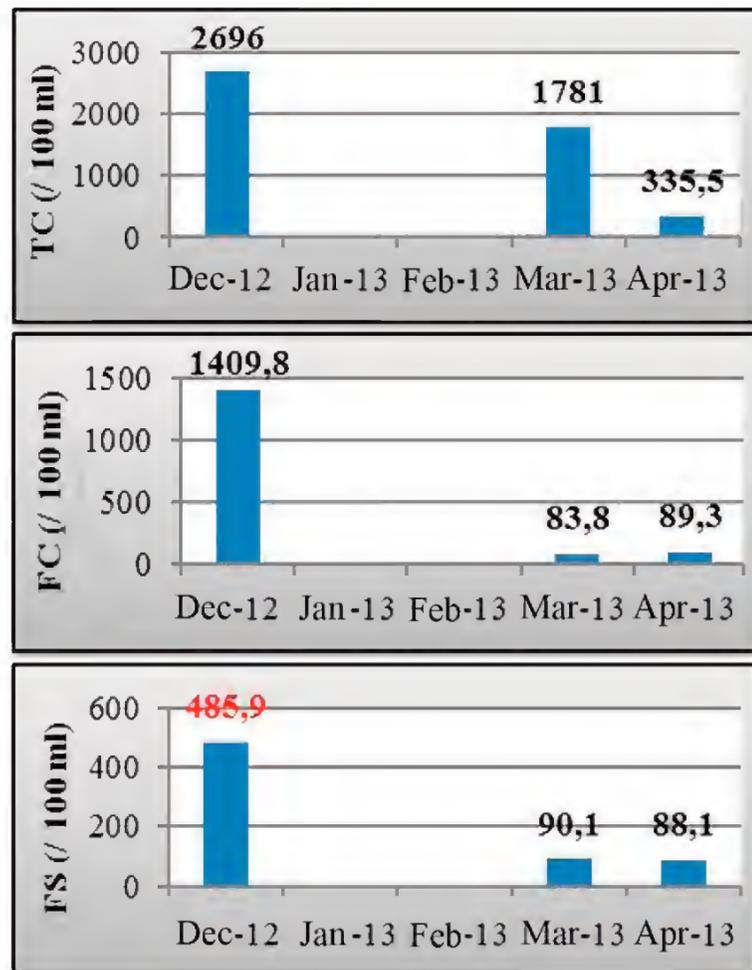


Figure 2. Temporal variation of germs recorded during the study period.

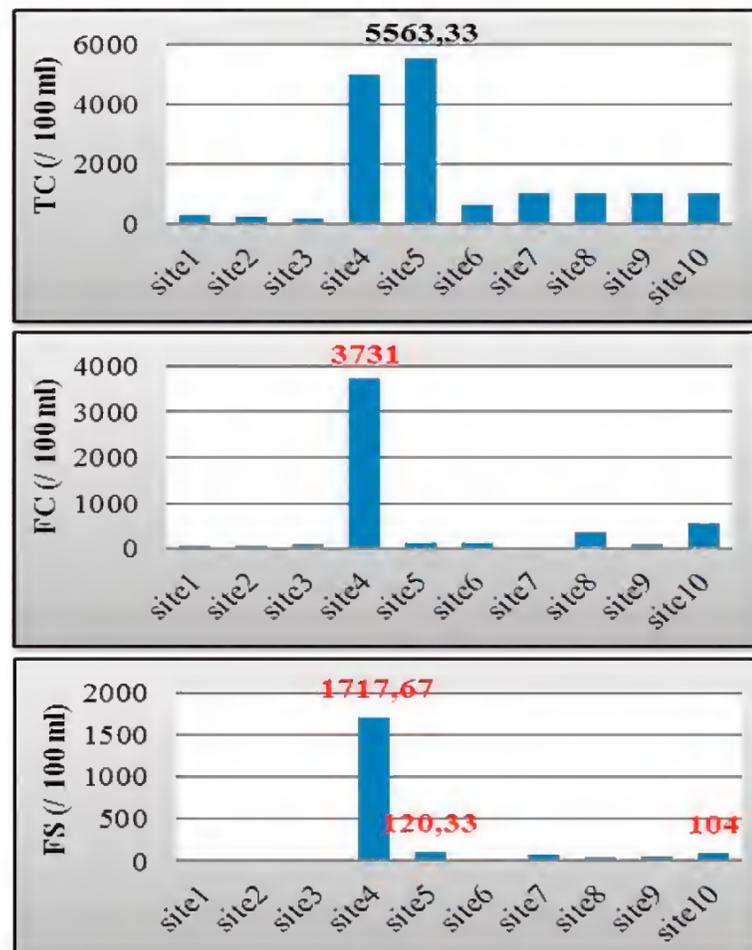


Figure 3. Spatial variation of germs recorded during the study period.

Variables	Sources of variation	ddl	SCE	CM	F <sub>obs</sub>
T (°C)	Sites	9	9.55	1.062	0.096 ns
pH	Sites	9	0.142	0.016	0.108 ns
S (‰)	Sites	9	0.751	0.083	1.203 ns
Conductivity (mS/cm)	Sites	9	2.032	0.226	0.236 ns
O <sub>2</sub> (%)	Sites	9	450.074	50.008	1.285 ns

Table 2. Results of the analysis of variance (ANOVA) of fixed patterns in comparisons between the sites; for each of the five physicochemical variables, average values were considered. Abbreviations: ddl = degrees of freedom; SCE = sum of squared deviations; CM = mean square; Fobs = F value Fischer.

## CONCLUSION

So, in the light of the results of physico-chemical analysis, the swimming waters of the different study sites are good given the Algerian standards, since results are not above the normal values for swimming waters.

However when considering bacteriological analyses such waters show, depending on the months and the sites, although in the standards, a relatively high rate of coliforms and streptococci, thus allowing us to suggest the existence of a kind of pollution of various origins (mainly urban waste and stormwater runoff flowing into the sea without treatment), observed especially at site 4, but present at all other sites, even if less obvious.

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## First records of digenean trematodes of two fishes (Teleostei Sparidae) from the West Algerian coast and comparative study with Tunisian coast (Mediterranean Sea)

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### ABSTRACT

Two species of the Teleostean *Diplodus* Rafinesque, 1810 Sparidae fish, *Diplodus sargus* (Linnaeus, 1758) (n = 134) and *D. annularis* (Linnaeus, 1758) (n = 60), from the Algerian west coast were examined with regards to Digenea parasites occurrence between March 2013 and December 2014. This investigation led to inventory 12 species of Digenea (*Lepidauchen stenostoma*, *Arnola microcirrus*, *Magnibursatus bartolii*, *Proctoeces maculatus*, *Holorchis pycnopus*, *Lepocreadium album*, *Wardula sarguicola*, *Monorchis* sp., *Macvicaria crassigula*, *Pseudopycnadena fischtali*, *Diptherostomum brusinae* and *Zoogonus rubellus*). These species are reported in the selected locality situated in Oran bay for the first time. Furthermore, *Lepidauchen stenostoma* in *D. annularis* is reported for the first time in the western Mediterranean. The majority of the recorded digeneans colonize one or two parts of the host digestive tract, the intestine being the most parasitized site. The calculation of epidemiologic indices provides information on the occurrence of digeneans identified in these two hosts. The diversity of Digenea is compared with that of the Gulf of Tunis, the Bizerte lagoon and another locality in the western Mediterranean. The Algerian west coast shows the highest value in the species richness of digeneans as compared to that of all the Mediterranean coasts.

### KEY WORDS

Digenea; *Diplodus*; Diversity; Epidemiologic indices; Oran bay.

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### INTRODUCTION

The Sparidae form the most representative fishing family in Algeria. This is one of the largest currently recognized families that the perciforms order counts (Tortonese, 1973). Their importance is related to their specific richness and high commercial value (Fischer et al., 1987). Indeed, during these last decades the digenean parasites of the Sparidae

family from the northern shores of the Mediterranean sea have been the subject of numerous studies (Bartoli, 1987a, 1987b; Bartoli & Gibson, 1989; Bartoli & Bray, 1996; Bartoli et al., 1989a, 1989b; 2005; Sasal et al., 1999; Ternengo et al., 2005a; Pérez -del Olmo et al., 2006, 2007a, 2008; Kostadinova & Gibson, 2009; Sanchez et al., 2013, 2014). Whereas, on the southern Mediterranean, little work has been done (Gargouri & Maamouri,

2008; Gargouri et al., 2011; Derbel et al., 2012; Bayoumy & Abu-Taweel, 2012; Antar & Gargouri, 2013; Antar et al., 2015). In particular, along the Algerian coasts the digenean fauna of sparid fishes is poorly known (Merzoug et al., 2012 and Abid Kachour et al., 2013) and no study has been carried out on the genus *Diplodus* Rafinesque, 1810. The purpose of this work is to establish a database of these Trematodes as collected in these fishes from the Oran bay (north western Algeria). Among the Sparidae family representatives, the *Diplodus sargus* (Linnaeus, 1758) and *D. annularis* (Linnaeus, 1758) species were selected for this study. The results obtained are compared with those of the Gulf of Tunis and the Bizerte lagoon. The species richness is appraised with respect to that of the Scandola nature reserve (Corsica) in the northern Mediterranean.

## MATERIAL AND METHODS

From March 2013 to December 2014, a total of 194 sparid fishes of *D. sargus* and *D. annularis* were caught in the Oran bay. The fish nomenclature is taken from Fischer et al. (1987). The investigated sample of *D. sargus* comprised 134 individuals while that of *D. annularis* was constituted of 60 individuals. The trematodes were collected from fresh fish, fixed by being pipetted into nearly boiling saline, stained with iron acetocarmine, dehydrated through a graded alcohol series, cleared in dimethyl phthalate and finally examined as permanent mounts in Canada balsam. The population descriptors, namely, prevalence, mean intensity and abundance were calculated as described by Buch et al. (1997).

## RESULTS

A total of 12 digenean species belonging to 8 distinct families were found in the two sparid fishes studied. As seen on the Table 1 where the main results are assembled, they are: Acanthocolpidae Luhe, 1906; Derogenidae Nicoll, 1910; Fellodistomidae Nicoll, 1909; Lepocreadiidae Odhner, 1905; Mesometridae Poche, 1926; Monorchidae Odhner, 1911; Opecoelidae Ozaki, 1925 and Zoogonidae Odhner, 1902. Most recorded di-

geneans colonize one or two parts of the host digestive tract. It should be noted that *Lepidauchen stenostoma* Nicoll, 1913, *Holorchis pycnopus* Stossich, 1901 and *Diptherostomum brusinae* Stossich, 1889, seem to show clear ecological preferences and limit their distribution to only one niche, in this case the intestine. Moreover, all parasites in both hosts revealed that the majority of the parasitic species occupies the intestine. Hosting 12 trematodes, *D. sargus* has the most diverse fauna whereas only 8 species were found in *D. annularis*. The distribution of the parasitic indices of the different digenean species vary from one host species to another. The most striking gap is observed for the prevalence of *Arnola microcirrus* (Vlasenko, 1931) between that in *D. sargus* and that in *D. annularis*, being equal respectively to 18.65% and 1.33%. Very similar cases are registered for *Lepocreadium album* Stossich, 1904 and *Zoogonus rubellus* Looss, 1901.

The calculation of epidemiologic indices shows that the highest rates of infestation are found for *Macvicaria crassigula* (Linton, 1910) in *D. sargus* and for the species *Monorchis* sp. in *D. annularis* at the level of 33.58% and 40%, respectively. *Lepidauchen stenostoma*, *Proctoeces maculatus* (Looss, 1901), *Wardula sarguicola* Bartoli et Gibson, 1989 and *Pseudopycnadena fischali* Saad-Fares et Maillard, 1986 in *D. sargus* and *Arnola microcirrus* in *D. annularis* infest less than 5% of the population of their respective hosts. The other species recorded a prevalence ranging from 5 to 36.66%. The highest mean intensity of infestation exceeds 5 parasites per fish for *D. annularis* by *Diptherostomum brusinae* and abundance value is recorded by *Diptherostomum brusinae* (1.93) in *D. annularis*.

## DISCUSSION

As already mentioned, this investigation showed that the *Lepidauchen stenostoma*, *Diptherostomum brusinae* and *Holorchis pycnopus* collected within the digestive systems of *D. sargus* and *D. annularis* are limited to the intestine. Various authors have discussed the factors that can influence the processes that lead to niche restriction in helminthes species and have proposed hypotheses regarding the adaptive value of this restriction.

Species	Families	Present Work			Gulf of Tunis - Gargouri & Maamouri (2008)			Bizerte Lagoon - Antar & Gargouri (2013)					
		Site	P(%)	A	MI	Site	P(%)	A	MI	Site	P(%)	A	MI
<b><i>Diplodus sargus</i> n= 134</b>													
<i>Lepidauchen stenostoma</i>	Acanthocolpidae	E	1.49	0.01	1								
<i>Arnola microcirrus</i>	Derogenidae	BC	18.65	0.25	1.36	B	1.42	0.01	1				
<i>Magnibursatus bartolii</i>	Derogenidae	AI	14.92	0.34	2.3								
<i>Proctoeces maculatus</i>	Fellodistomidae	E	2.98	0.02	1	GH	8.57	0.19	2.17	GH	15.8	0.10	1.0
<i>Holorchis pycnopus</i>	Lepocreadiidae	E	11.19	0.20	1.86	DF	7.14	0.11	1.6				
<i>Lepocreadium album</i>	Lepocreadiidae	CE	20.14	0.56	2.81	D	2.86	0.06	2				
<i>Lepocreadium pegorchis</i>	Lepocreadiidae									CD	10.5	0.10	1.5
<i>Wardula sarguicola</i>	Mesometridae	B	2.23	0.02	1	H	4.29	0.07	1.66				
<i>Monorchis parvus</i>	Monorchiiidae					C	1.43	0.04	3				
<i>Monorchis</i> sp.	Monorchiiidae	CE	13.43	0.53	4								
<i>Macvicaria crassigula</i>	Opecoelidae	CE	33.58	0.58	1.73	DF	18.57	0.34	1.87	F	5.3	0.05	1.0
<i>Peracreadium characis</i>	Opecoelidae					DF	1.43	0.17	12				
<i>Pseudopycnadena fisch tali</i>	Opecoelidae	E	1.49	0.02	2	F	4.29	0.04	1				
<i>Diptherostomum brusinae</i>	Zoogonidae	E	17.91	0.59	3.33	H	12.86	0.50	3.89	G	5.3	0.10	3.0
<i>Zoogonus rubellus</i>	Zoogonidae	E	5.97	0.08	1.37	H	7.14	0.11	1.6				
<b><i>Diplodus annularis</i> n= 60</b>													
<i>Lepidauchen stenostoma</i>	Acanthocolpidae	E	5	0.05	1								
<i>Arnola microcirrus</i>	Derogenidae	B	1.33	0.16	1.25					B	0.8	0.01	1.0
<i>Steringotrema pagelli</i>	Fellodistomidae									D	0.8	0.01	1.0
<i>Lecithocladium excisum</i>	Hemiuridae					B	2.94	0.04	1.5				
<i>Holorchis pycnopus</i>	Lepocreadiidae	E	15	0.25	1.66					DG	3.8	0.08	2.2
<i>Lepocreadium album</i>	Lepocreadiidae	E	5	0.06	1.33	DF	2.94	0.07	2.5	ACG	11.5	0.40	3.8
<i>Lepocreadium pegorchis</i>	Lepocreadiidae					C	4.41	0.10	2.33	CD	2.3	0.03	1.7
<i>Prodistomum polonii</i>	Lepocreadiidae									G	0.8	0.02	3.0
<i>Monorchis parvus</i>	Monorchiiidae					CD	44.12	4.11	9.63	CD	8.5	0.30	3.9
<i>Monorchis</i> sp.	Monorchiiidae	CE	40	1.81	4.54								
<i>Macvicaria crassigula</i>	Opecoelidae	CE	21.66	0.38	1.76	DF	10.29	0.19	1.85	DFG	13.1	0.4	3.3
<i>Pseudopycnadena fisch tali</i>	Opecoelidae					F	2.94	0.07	2.5				
<i>Diptherostomum brusinae</i>	Zoogonidae	E	36.66	1.93	5.27	H	16.17	0.51	3.18	DGH	14.6	0.50	3.5
<i>Zoogonus rubellus</i>	Zoogonidae	EH	11.66	0.11	1	H	1.47	0.01	1	H	0.8	0.01	2.0

Table 1. Epidemiologic parameters: prevalence (P), abundance (A) and mean intensity (MI) of Digenea in sparid fishes from the Oran bay and Gulf of Tunis (Gargouri & Maamouri, 2008) and from the Bizerte Lagoon (Antar & Gargouri 2013) for the esophagus (A), stomach (B), pyloric caeca (C), duodenum (D), intestine (E), mid-intestine (F), posterior intestine (G), rectum (H) and Gills (I) sites.

According to Holmes (1990), apart from the physicochemical gradient in the intestine, factors as specialization, reproductive efficiency, competition and host immune mechanisms influence the selection site. The study of Ricklefs & Schluter (1993) suggested that the fact that some parasites are limited to a single microbiotope generates the presence of a physical or chemical barrier that prevents other digeneans to cross it. Indeed, a key factor in niche restriction processes is intra- and inter-specific competition (Holmes, 1990; Sukhdeo & Sukhdeo, 1994; Dezfuli et al., 2002). Rohde (1994) reported that competition, probability of finding mates, reinforcement of reproductive barriers and adaptation to environmental complexity are selective pressures causing niche restriction. On the other hand, the data shown on the Table indicate that the stomach is among the sites that are very little parasitized. This is explained by the inhospitality of the physical and chemical conditions in the stomach towards the parasites (Crompton, 1973). It could also be invoked that this absence of parasites at this site results from the lack of niche saturation (Stock & Holmes, 1988).

The distribution of parasitic species shows that *Lepocreadium album* does not occupy the same microbiotope in the two host species. Indeed, this parasite colonizes the intestine and pyloric caeca in *D. sargus* whereas it is limited to intestine in *D. annularis*. This fact is probably related to the digestive tube polymorphism of the hosts and their differential resistance to parasites (Crompton, 1973). The same situation is observed for the species *Arnola microcirrus* and *Zoogonus rubellus*.

It is also noted that the intestine is the most parasitized site by *Lepidauchen stenostoma*, *Holorchis pycnopus*, *Lepocreadium album*, *Proctoeces maculatus*, *Monorchis* sp., *Macvicaria crassigula* and *Pseudopycnadena fischali*. In fact, the intestine is the nutrient-richest site and seems to influence the parasite specificity towards the host. Holmes (1990) also stated that the use of nutrients by parasites is an important factor which regulates competition among the intestine parasites. According to Sasal et al. (1999) each parasite species which shows this tolerance is generalist.

The distributions of digeneans parasitic indices in both hosts show inequality towards parasitism. Indeed, important differences appear with regards

to the prevalence of some parasites: *Arnola microcirrus* (18.65–1.33%), *Lepocreadium album* (20.14–5%) and *Zoogonus rubellus* (5.97–11.66%). However, these epidemiological values are generally higher in the Sparidae from the Oran bay than those from the Gulf of Tunis (Gargouri Ben Abdallah & Maamouri, 2008) and Bizerte lagoon (Antar & Gargouri Ben Abdallah, 2013) (Table 1). The causes of these variations according to Combes (1995) and Khan (2012) are numerous and may be related to the genetics, life environment, energy consumption, age of the host, potential host proximity, presence of other parasites, biogeography, environmental changes, host ethology and immune system. Ternengo et al. (2005b) suggested that each fish species has a characteristic parasitic fauna and particular levels of infestation. Some parasites recorded in the Oran bay in *D. sargus* (*Lepidauchen stenostoma*, *Magnibursatus bartolii* Kostadinova, Power, Fernandez, Balbuena, Raga et Gibson, 2003 and *Monorchis* sp.) and *D. annularis* (*Lepidauchen stenostoma*, *Arnola microcirrus*, *Holorchis pycnopus* and *Monorchis* sp.) were not collected in either one of these two fishes in the Gulf of Tunis (Gargouri Ben Abdallah & Maamouri, 2008) (Table 1). However, *Lepidauchen stenostoma* was described as a parasite of *D. annularis* in the Adriatic Sea off the coast of Montenegro (Bray & Bartoli, 1996) and reported in *D. sargus* from Scandola nature reserve (Corsica) by Bartoli et al. (2005). Hence, we report it for the first time in the western Mediterranean in *D. annularis*. Similarly, *Magnibursatus bartolii* was encountered in another sparid species, *Boops boops* (Linnaeus, 1758), from the North-east Atlantic coast, Spain (Kostadinova et al., 2003), in *Oblada melanura* (Linnaeus, 1758) (Gargouri Ben Abdallah & Maamouri, 2008) in the Gulf of Tunis, in *Sparus aurata* Linnaeus, 1758 from the Bizerte Lagoon (Gargouri Ben Abdallah et al., 2011) and in *D. sargus* off the coast of Buriana, Spain (Kostadinova & Gibson, 2009). *Arnola microcirrus* was described as a parasite of *D. annularis* in the Black Sea (Gaevskaya & Korniyuchuk, 2003) and reported in Corsica (Kostadinova et al., 2004). *Holorchis pycnopus* was recorded in many different regions of the Mediterranean (Bray & Cribb, 1997). By contrast, some parasite species as *Peracreadium characis* Bartoli, Gibson et Bray,

1989, *Lecithocladium excisum* (Rudolphi, 1819) Lühe, 1901, *Lepocreadium pegorchis* (Stossich, 1901), *Monorchis parvus* Looss, 1902 and *Pseudopycnadena fischali* that were found in the Gulf of Tunis were not collected during this research in the Oran bay. Several factors may influence the parasite community. One is probably related to the low frequency of intermediate hosts in the biotope due to a harmful effect of pollution on them and parasite free stages. Others are linked to environmental parameters (MacKenzie 1999, Khan 2012), the geographical distance (Pérez-Del Olmo, 2008) and the sampling site (Ternengo et al., 2009). Pérez-Del Olmo (2007) demonstrated that significant changes were noted in the structure of parasite communities in *Boops boops* after the Prestige oil spill in 2002. However, it should be noted that *Lecithocladium excisum* and *Lepocreadium pegorchis* were reported respectively in *Boops boops* (Merzoug et al., 2012) and in *Pagellus erythrinus* Linnaeus, 1758 from the in Oran bay (Abid Kachour, 2014).

Our results compared to those from the Bizerte Lagoon (Antar et al., 2013) show variations with respect to the diversity of the digenean (Table 1). Indeed, in *D. sargus*, nine species of Trematodes (*Lepidauchen stenostoma*, *Arnola microcirrus*, *Magnibursatus bartolii*, *Holorchis pycnopus*, *Lepocreadium album*, *Wardula sarguicola*, *Monorchis* sp., *Pseudopycnadena fischali* and *Zoogonus rubellus*) are recorded only in the present study, although their absence of representation in the Bizerte lagoon could be explained by the small number of hosts studied (n = 19). It should be noted that *Lepocreadium album* was found for the first time in the Oran bay in *Boops boops* (Merzoug et al., 2012). Furthermore, *Lepidauchen stenostoma* and *Monorchis* sp. are observed only among *D. annularis* from the Oran bay. On the other hand, *Steringotrema pagelli* (Van Beneden, 1871) Odhner, 1911, *Lepocreadium pegorchis*, *Prodistomum polonii* Bray et Gibson, 1990 and *Monorchis parvus* are recorded in the Bizerte lagoon but absent in the Oran bay. And more recently, Antar et al. (2015) revealed the presence of *Macvicaria bartolii* Antar, Gorgieva, Gargouri Ben Abdallah et Kostadinova, 2015 in *D. annularis* from the Bay of Bizerte whereas this parasite was not collected in this investigation. This fact might be connected with the successful

completion of life cycles of these parasites in the Bizerte Lagoon, a confined environment limiting the dispersal of the larval stages. Indeed, Maillard (1976) showed that a digenean which completes its life cycle in the ponds and the lagoons has a higher chance of completion than that having a marine life cycle.

As compared to the data of digenean species in the sparid fishes from Scandola nature reserve (Corsica) in the western Mediterranean (Bartoli et al., 2005), our results show a significant richness in *D. sargus* and *D. annularis* from the Oran bay. Altogether, seven species of digenean parasites were not mentioned in Corsica: *Lepidauchen stenostoma*, *Arnola microcirrus*, *Holorchis pycnopus*, *Lepocreadium album*, *Monorchis* sp., *Zoogonus rubellus* and *Magnibursatus bartolii*. In the Oran bay, the first six ones were found in *D. sargus* and the last three in *D. annularis*. Similarly, in the Tunisian coast as well as the Bizerte Lagoon, *Lepidauchen stenostoma*, *Magnibursatus bartolii*, and *Monorchis* sp. were not reported in *D. sargus*, whereas *Lepidauchen stenostoma* and *Monorchis* sp. were not found in *D. annularis* (Table 1).

The causes of this species diversity may be related to the passage of the Atlantic waters. Indeed, the Oran bay is undoubtedly under the influence of these Atlantic currents through the Straits of Gibraltar which can periodically convey nutrients (fish, invertebrates, etc ...) between the Mediterranean and the Atlantic. This mixing process increases the probability of intermediate hosts transfer. Consequently, the life cycle of various taxa may explain this parasite biodiversity in the two investigated hosts in the Western Algerian coast. The wider digenean diversity observed in the Scandola Nature reserve is probably related to the equilibrium stability of the ecosystem that is devoid of major pollutants and opens directly to the Western Mediterranean basin (Bartoli et al., 2005). Thus, the Digenea diversity is related to the high general level of biodiversity reported in that region (Miniconi et al., 1990; Verlaque, 1990; Merella, 1991; Verlaque et al., 1999). On the other hand, Gargouri Ben Abdallah & Maamouri (2008) suggested that the relatively important digenean diversity of sparidae off the Tunisian coasts is related to the geographical situation of Tunisia. The latter, representing also a

transition zone between the Western and Eastern Mediterranean, undergoes the influence of both the Atlantic through the Straits of Gibraltar and the Red Sea via the Suez Canal. Furthermore, Thieltges et al. (2008) mentioned that the origin of this differential distribution of digenean frequencies between the different Mediterranean environments may be related to the frequency of the intermediate hosts and the variation in physical and chemical parameters of the biotope that can influence the host as well as the free-living larval stages of parasites.

Finally, in this study, all the parasites exposed in Table 1 are recorded for the first time in *D. sargus* and *D. annularis* from the Oran bay although they were already described in the same hosts in other regions of western Mediterranean (Bartoli et al., 1989a; Bartoli et al., 1989b; Bartoli & Gibson, 1989; Bartoli & Bray, 1996; Bray & Bartoli, 1996; Lepommel et al., 1997; Jousson et al., 1998; Jousson et al., 1999; Sasal et al., 1999; Jousson et al., 2000; Kostadinova et al., 2004; Bartoli et al., 2005; Ternengo et al., 2005a; D'Amico et al., 2006; Gargouri Ben Abdallah & Maamouri, 2008; Kostadinova & Gibson, 2009; Derbel et al., 2012; Antar & Gargouri, 2013).

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# Preliminary survey of hill stream fishes in Upper Cyber Stream, outside Huai Kha Khaeng Wildlife Sanctuary, West Thailand

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## ABSTRACT

Fields survey of freshwater fish in Cyber Stream, outside Huai Kha Khaeng Wildlife Sanctuary, at Ban Cyber, Khok Khwai Subdistrict, Hui Kod District, Uthai Thani Province, West Thailand were carried out in December 2015. We found 10 families and 22 species of hill stream fishes. *Schistura desmotes* (Fowler, 1934) and *Homalopteroides smithi* (Hora 1932) (Cypriniformes Balitoridae) are dominant in transparent and running fast stream ecosystem and *Neolissochilus stracheyi* (Day, 1871) and *Mystacoleucus marginatus* (Valenciennes, 1842) (Cypriniformes Cyprinidae) are dominant in running slowly stream and pool of the headwater stream ecosystem. One alien species in this area is *Poecilia reticulata* Peters, 1859 (Cyprinodontiformes Poeciliidae). Two species, *Pseudohomaloptera* cf. *leonardi* (Hora, 1941) (Cypriniformes Balitoridae) and *Channa* cf. *gachua* (Hamilton, 1822) (Perciformes Channidae), still have an unclear taxonomic status. The Thai local names, habitat and distribution data of hill stream fishes are provided.

## KEY WORDS

hill stream fishes; Cyber Stream; Huai Kha Khaeng; Wildlife Sanctuary; Thailand.

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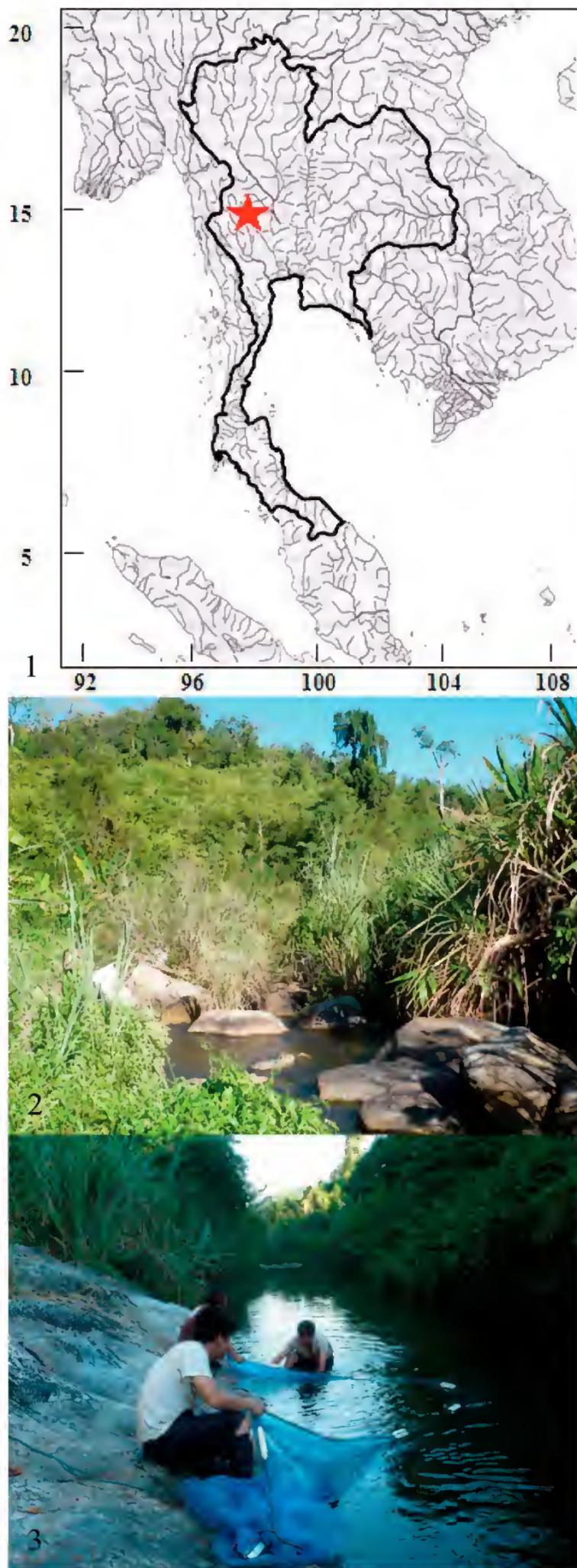
## INTRODUCTION

Huai Kha Khaeng Wildlife Sanctuary (HKKWS) is a 278,000 ha (2,780.14 km<sup>2</sup>) world heritage (Southeast-Asia, Uthai Thani Province of Thailand) (Sukmasuang, 2009; Simcharoen et al., 2014). Climate of HKKWS is classified as tropical savanna, with six forest type categories: hill ever green (13%), moist ever green, dry ever green (25%), mixed ever green (48%), dry dipterocarps (7%) and a small successional community (The Faculty of Forestry, 1989; WEFKOM, 2004).

The Sanctuary is important as in-situ conservation for the diversity of flora and fauna, and ecosys-

tem. According to a Forest Research Center report (1997), HKKWS consists of 130 mammals, 360 birds, 81 reptiles, 37 amphibians and 105 fish.

Cyber Stream is part of the Huai Khun Kaew Basin and the West Thailand Watershed. The geography of Upper Cyber Stream is a hill and a little flat land, but the lower area is relatively flat (Royal Irrigation Department, 2012). Upper Cyber Stream is characterized by its own ecological features which differentiate it from the other hill stream ecosystem systems of Thailand. Although it is certainly of interest, nevertheless is poorly investigated and little is known about hill stream fishes occurring in this area. In order to obtain a more detailed know-



Figures 1–3. Study area, Upper Cyber Stream, outside Huai Kha Khaeng Wildlife Sanctuary, Uthai Thani Province, West Thailand.

ledge on this item, we carried out this survey project on Cyber Stream fishes, outside HKKWS area but near to Cyber forest (a protect station of HKKWS) at Ban Cyber, Khok Khwai Subdistrict, Hui Kod District, Uthai Thani Province, West Thailand (Figs. 1–3) in December 2015. The area was separated into 3 regions in accordance to the ecosystems; namely:

1. Transparent running fast stream ecosystem (Fig. 2). The average width of the stream is about 10 m, average depth is less than 1 m, the bottom is a combination of sand, gravel and large rock.

2. Transparent running slow stream ecosystem (Fig. 3). The average width of the stream is about 15 m, average depth is about 1–2 m, the bottom is a combination of sand, large rock, clay and sandy mud, the stream is transparent and running slowly.

3. Pool of the headwater stream ecosystem. The average width of the stream is about 10–15 m, average depth is about 1–1.5 m, the bottom is a combination of clay and sandy mud, the area is transparent to turbid.

ACRONYMS. Standard length (SL)

## RESULTS

Order CYPRINIFORMES Bleeker, 1859  
Family CYPRINIDAE Cuvier, 1817

*Danio albolineatus* (Blyth, 1860)  
Pearl danio

HABITAT. This species (Fig. 4) was found in the pool of the headwater stream and transparent running fast stream.

DISTRIBUTION. This species is known from Irrawaddy Basin and Salween Basin in Myanmar; Sumatra, Indonesia; Indochina, Laos, Mekong Basin and Maeklong drainages in Thailand.

THAI LOCAL NAME. Pla sel bai pai lek.

*Rasbora paviana* Tirant 1885  
Sidestripe rasbora

HABITAT. This species (Fig. 5) was found in the pool of the headwater stream, transparent running fast stream and the main stream.

DISTRIBUTION. This species is known from Indonesia; Malaysia; Indochina, Mekong Basin, Chao

Phraya Basin and Maeklong Basins, northern Malay Peninsula in Thailand.

THAI LOCAL NAME. Pla sel kruiy.

***Rasbora borapetensis*** Smith 1934

Blackline rasbora

HABITAT. This species was found in the pool of the headwater stream and transparent running fast stream.

DISTRIBUTION. This species is known from Indochina, Mekong Basin, Chao Phraya Basin and Maeklong Basins, northern Malay Peninsula in Thailand.

THAI LOCAL NAME. Pla sel hang dang.

***Mystacoleucus marginatus*** (Valenciennes, 1842)

Indian river barb

HABITAT. This species (Fig. 6) was found in transparent slowly stream and pool of the headwater stream ecosystem.

DISTRIBUTION. This species is known from Myanmar to Indonesia.

THAI LOCAL NAME. Pla kee yok or Pla num lung.

REMARKS. This species is dominant in transparent slowly stream and pool of the headwater. In Thailand, *M. marginatus* can be found in many ecosystems such as reservoir and large running fast rivers (Kottelat, 1998; Petsut & Kulabong, 2015).

***Barbodes rhombeus*** (Kottelat, 2000)

Waterfall barb

HABITAT. This species (Fig. 7) was found in transparent and running fast stream ecosystem.

DISTRIBUTION. This species is known from Mekong Basin, Chao Phraya Basin, Maeklong Basins, eastern Gulf of Thailand Drainages and peninsular Thailand.

THAI LOCAL NAME. Pla Ta pean num tok.

***Neolissochilus stracheyi*** (Day, 1871)

Mahseer

HABITAT. This species (Fig. 8) was found in the

pool of the headwater stream and transparent running slow stream.

DISTRIBUTION. This species is known from Maeklong River, Chao Phraya River, Southeast Basin and Peninsular Thailand; Mekong Basin in Thailand, Laos, Cambodia and Viet Nam; Salween Basin, Thailand and Myanmar.

THAI LOCAL NAME. Pla plong.

REMARKS. This species is dominant in pool and slow stream. In nature, adult Mahseer groups inhabit pools and runs over gravel and cobble in slow hill stream but juveniles commonly can be found in or near rapids (Rainboth, 1996; Kottelat, 2001; Kunlapapuk & Kulabong, 2011).

***Osteochilus vittatus*** (Valenciennes, 1842)

Bonylip barb

HABITAT. This species was found in transparent running fast stream to main stream.

DISTRIBUTION. This species is known from Myanmar; China; Sumatra, Java, Borneo in Indonesia; Mekong Basin, Chao Phraya Basin, Maeklong Basin, eastern Gulf of Thailand Drainages; Malay Peninsula.

THAI LOCAL NAME. Soi nok kaw.

***Garra cambodgiensis*** (Tirant 1884)

Stonelapping minnow

HABITAT. This species (Fig. 9) was found in the transparent running fast stream.

DISTRIBUTION. This species is known from Mekong Basin, Chao Phraya Basin, Peninsula Thailand; Cambodia; Vietnam.

THAI LOCAL NAME. Pla lia hin

***Garra nasuta*** (McClelland, 1838)

Stonelapping minnow

HABITAT. This species (Fig. 10) was found in the transparent running fast stream.

DISTRIBUTION. This species is known from India; Myanmar; South China and Indochina.

THAI LOCAL NAME. Pla mood

Family BALITORIDAE Swainson, 1839

***Schistura desmotes*** (Fowler, 1934)  
Loach

HABITAT. This species (Fig. 11) was found in the transparent running fast stream.

DISTRIBUTION. This species is known from Chao Phraya Basin, MaeKlong Basin in Thailand; Malay Peninsula, India; Myanmar; South China and Indochina.

THAI LOCAL NAME. Pla mood

REMARKS. This species is dominant in this study area. In Thailand, can predominantly be found in fast flowing streams over gravel substrate and, sometimes, in pools of hill areas.

***Homalopteroides smithi*** (Hora, 1932)  
Gecko fish

HABITAT. This species (Fig. 12) was found in the transparent running fast stream.

DISTRIBUTION. This species is known from Indochina to Malaysia Peninsula; Indonesia.

THAI LOCAL NAME. Pla jing jok.

REMARKS. This species is dominant in rapid stream ecosystem.

***Pseudohomaloptera cf. leonardi*** (Hora, 1941)  
Gecko fish

HABITAT. This species (Fig. 13) was found in the transparent running fast stream.

DISTRIBUTION. This species is known from Central, East, South Thailand; Malaysia

THAI LOCAL NAME. Pla jing jok.

REMARKS. In Thailand, the taxonomic status of this taxon is still unclear.

Family COBITIDAE Swainson, 1838

***Lepidocephalichthys berdmorei*** (Blyth, 1860)  
Burmese loach

HABITAT. In this study, only one specimen was found in the transparent running fast stream and the pool of the headwater stream.

DISTRIBUTION. This species is known from India;

Bangladesh; Myanmar; China; Thailand; Laos; Peninsular Malaysia.

THAI LOCAL NAME. Pla eed.

Order SILURIFORMES Cuvier, 1817  
Family BAGRIDAE Bleeker, 1858

***Batasio tigrinus*** Ng et Kottelat, 2001  
Hill stream bagrid catfish

HABITAT. In this study, only one specimen was found in the transparent running fast stream over gravel substrate.

DISTRIBUTION. This species is known from MaeKlong Basin and West Thailand.

THAI LOCAL NAME. Pla ka yang pu kao

***Pseudomystus siamensis*** (Regan, 1913)  
Asian Bumblebee Catfish

HABITAT. In this study, only one specimen was found in the transparent running fast stream over gravel substrate.

DISTRIBUTION. This species is known from Mekong Basin, Chao Phraya Basin, MaeKlong Basins, eastern Gulf of Thailand Drainages and peninsular Thailand.

THAI LOCAL NAME. Pla ka yang hin.

***Hemibagrus nemurus*** (Valenciennes, 1840)  
Yellow Catfish

HABITAT. In this study, only one specimen was found in the transparent slow stream.

DISTRIBUTION. This species is known from Indochina to Indonesia.

THAI LOCAL NAME. Pla kod luang.

Order BELONIFORMES L.S. Berg, 1937  
Family BELONIDAE Bonaparte, 1835

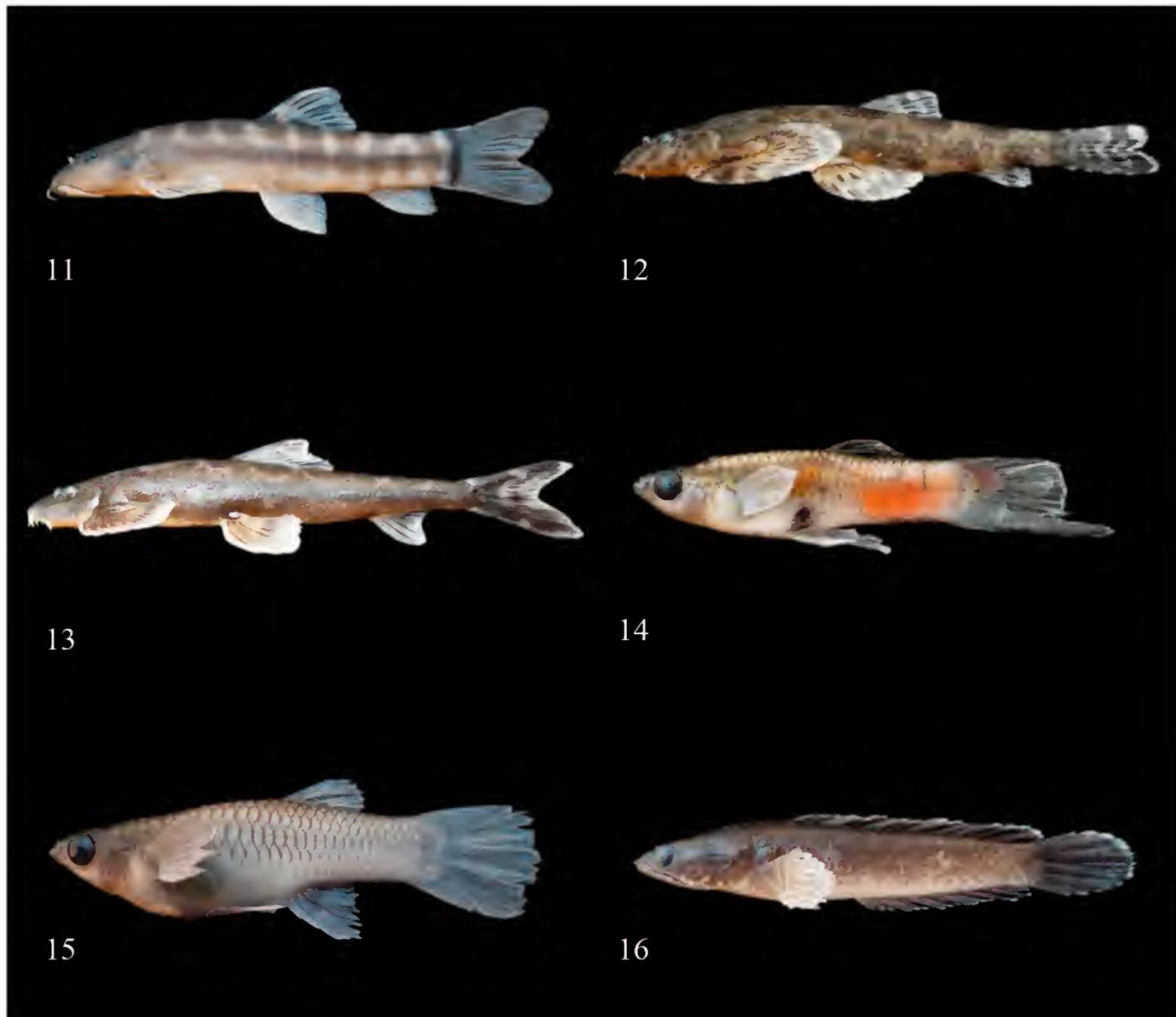
***Xenentodon cancila*** (F. Hamilton, 1822)  
Freshwater garfish

HABITAT. In this study, only one specimen was found in the transparent slow stream.

DISTRIBUTION. This species is known from India



Figures 4–10. Freshwater fish in Cyber Stream, outside Huai Kha Khaeng Wildlife Sanctuary, West Thailand. Figure 4. *Danio albolineatus*, 31 mm SL. Figure 5. *Rasbora paviana*, 51 mm SL. Figure 6. *Mystacoleucus marginatus*, 63 mm SL. Figure . *Puntius rhombeus*, 25 mm SL. Figure 8. *Neolissochilus stracheyi*, 78 mm SL. Figure 9. *Garra cambodgiensis*, 38 mm SL. Figure 10. *Garra nasuta*, 73 mm SL and mouth of *Garra nasuta*.



Figures 11–16. Freshwater fish in Cyber Stream, outside Huai Kha Khaeng Wildlife Sanctuary, West Thailand. Figure 13. *Schistura desmotes*, 63 mm SL. Figure 14. *Homalopteroides smithi*, 35 mm SL. Figure 15. *Pseudohomaloptera* cf. *leonardi*, 70 mm SL. Figure 16. *Poecilia reticulata*, male, 23 mm SL. Figure 17. *Poecilia reticulata*, female, 26 mm SL. Figure 18. *Channa* cf. *gachua*, 133 mm SL.

Sub-continent to Southeast Asia. Introduced in America.

THAI LOCAL NAME. Pla kra tung hav.

Order SYNBRANCHIFORMES Bonaparte, 1838  
Family MASTACEMBELIDAE Bleeker, 1870

*Mastacembelus favus* Hora, 1924  
Tire track eel

HABITAT. This species was found in the pool of the headwater stream and transparent running slow stream.

DISTRIBUTION. This species is known from Thailand to Malay Peninsula.

THAI LOCAL NAME. Pla kra ting.

Order CYPRINODONTIFORMES L.S. Berg, 1940  
Family POECILIIDAE Bloch et Schneider, 1801

*Poecilia reticulata* Peters, 1859  
Guppies

HABITAT. This species (Figs. 14, 15) was found in the pool of the headwater stream.

DISTRIBUTION. This species is native to South America; introduced to many different countries in the world.

THAI LOCAL NAME. Pla hang nok yung.

REMARKS. Alien species in Thailand.

Order PERCIFORMES Bleeker, 1859  
Family AMBASSIDAE Klunzinger, 1870

*Parambassis siamensis* (Fowler, 1937)  
Siamese glassfish

HABITAT. This species was found in the pool of the headwater stream and transparent running slow stream.

DISTRIBUTION. This species is known from Indochina to Malay Peninsula; introduced in Singapore and Indonesia.

THAI LOCAL NAME. Pla pan ghav.

Family NANDIDAE Bleeker, 1852

*Pristolepis fasciata* (Bleeker, 1851)  
Malayan leaffish

HABITAT. This species was found in the pool of the headwater stream and transparent running slow stream.

DISTRIBUTION. This species is known from Myanmar to Indonesia.

THAI LOCAL NAME. Pla mor chang yab.

*Channa cf. gachua* (Hamilton, 1822)  
Dwarf snakehead

HABITAT. This species (Fig. 16) was found in running slow stream and the pool of the headwater stream.

DISTRIBUTION. This species is known from Indian Sub-continent to Southeast Asia.

THAI LOCAL NAME. Pla gung.

REMARKS. In Thailand, the taxonomic status of this taxon is still unclear, being reported from time to time as *C. gachua* or *C. limbata*.

## CONCLUSIONS

In this work a total of 10 families and 22 species of hill stream fishes were recorded from Upper Cyber Stream, outside Huai Kha Khaeng Wildlife Sanctuary, West Thailand. In particular, 1 alien species, *Poecilia reticulata* is reported for Upper Cyber Stream and two species, *Pseudohomaloptera cf. leonardi* and *Channa cf. gachua* still have an unclear taxonomic status.

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## ***Principidium (Testedium) laetum* (Brullé, 1836) new to Italian fauna (Coleoptera Carabidae Trechinae Bembidiini)**

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### **ABSTRACT**

The Mediterranean ground beetle *Principidium (Testedium) laetum* (Brullé, 1836) (Coleoptera Carabidae Trechinae Bembidiini) is herewith first recorded for Italy, on Favignana Island (Egadi Archipelago). The site of the species is a small complex of coastal temporary pools. Notes on the species and considerations on the significance of its local occurrence are given.

### **KEY WORDS**

Egadi Islands; new species to Italy; *Principidium (Testedium) laetum*; Carabidae.

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### **INTRODUCTION**

Favignana, with an area of about 20 km<sup>2</sup>, is the larger island of Egadi Archipelago, west of Sicily (Trapani province). It is about 9 km in length and 4.8 km in maximum width, situated less than 10 km from the major island. The sea between the two is shallow, the depth not exceeding 13 m, so that even during minor marine regressions in the past they have been connected to each other by an emerged land bridge.

The island is crossed in its widest point by the “Montagna Grossa” range, running from North to South, reaching 302 m a.s.l. with the Mount Santa Caterina (302 m). East and west of the range there are two plains, “la Piana” (= “the Plain”) and “il Bosco” (= “the Wood”) respectively. The formerly existing woodlands have been almost completely destroyed; the landscape is at present rather bare, largely dominated by grasslands and garrigues with some typical elements of the Mediterranean maquis, such as wild olive (*Olea europaea* L.), mastic (*Pistacia lentiscus* L.), arboreal euphorbia

(*Euphorbia dendroides* L.). Nevertheless, flora includes many elements of great phytogeographic interest, as well as a number of endemic ones. A floristic survey, dating to sixties of XX century, on Egadi islands records for Favignana about 570 species (Di Martino & Trapani, 1967). Recent surveys are expected to result in increase of this number (La Rosa, pers. comm.).

The first zoological surveys on Favignana date to sixties of XX century, within the CNR “Piccole Isole” (= small islands) project. Results refer mainly to Amphibia and Reptilia (Bruno, 1970; Lanza, 1973) and to some Arthropoda groups, namely Coleoptera Tenebrionidae (Focarile, 1969; Marcuzzi, 1970), Carabidae (Magistretti, 1971), Staphylinidae (Bordoni, 1973), Curculionidae (Magnano & Osella, 1973; Osella, 1973), Chrysomelidae (Daccordi & Ruffo, 1975); Chilopoda (Matic, 1968); Diplopoda (Strasser, 1969); Araneae Dysderidae (Alicata, 1973); terrestrial Isopoda (Caruso, 1973). Since then, further contributions resulted in increased knowledge for Coleoptera Tenebrionidae (Aliquò, 1993, 1995), Rhynchota (= Hemiptera)

Heteroptera (Carapezza, 1993) and terrestrial Mollusca (Riedel, 1973; Beckmann, 2002; Fiorentino et al., 2004).

*Princidium (Testedium) laetum* Brullé, 1836 is a Mediterranean (extending to Macaronesia) species, whose recorded range includes Iberian peninsula, Canary Islands (type locality), North Africa, Greece and Turkey (Marggi et al., 2003), though not recorded for the latter in Casale & Vigna Taglianti (1999). It lives in warm areas, where it inhabits borders of standing, often temporary waters, including artificial basins, and also damp soils not close to open water.

In April and May 2016 one of us (CM), during a field trip in Favignana Island (Egadi Archipelago, Sicily), noticed a population of *P. laetum* in a small coastal wetland. The present record is the first one for Italy.

## MATERIAL AND METHODS

### *Study area*

The biotope where *P. laetum* was discovered (37°56'58"N - 12°18'05"E) is situated close to Punta Faraglione, on the north-western coast of the Favignana Island (Figs. 1, 2). It is a small complex of Mediterranean temporary pools on brown soils with calcarenite and dolomite outcrops (Abate et al., 1994). It is an extremely significant environment, from biologic and conservation viewpoint, recognized by the Habitats Directive (92/43/EEC) as Site

of Community Importance (Genovesi et al., 2014). Several rare plants, *Aristolochia navicularis* Nardi, *Limonium dubium* (Guss.), *L. hyblaeum* Brullo, *L. virgatum* (Willd.), *L. bocconeii* (Lojac.) Litard., *L. lojaconoii* Brullo e.g., are found here (La Rosa, pers. comm.).

### *Sampling*

On 5–6.IV.2016 and 13.V.2016, several *P. laetum* individuals were observed and photographed (Fig. 3) by one of us (CM), close to one single pool within the said area; some of them were collected in order to confirm determination and are now housed in the authors' collections. Beetles were found on damp soil, not far from the water edge, under stones or hidden into the crevices. No other hygrophilous Coleoptera were found to co-occur with them, and no individual was seen at the remaining pools of the area, despite of seemingly quite similar conditions.

## DISCUSSION AND CONCLUSIONS

It looks quite surprising that none of the entomologists that previously collected on Favignana ever noticed such a conspicuous and unmistakable insect as *P. laetum*, no doubt one of the most handsome among European and Mediterranean ground beetles; even more because in this kind of small islands, aquatic habitats are rare, and when existing are hardly overlooked by researchers. According to



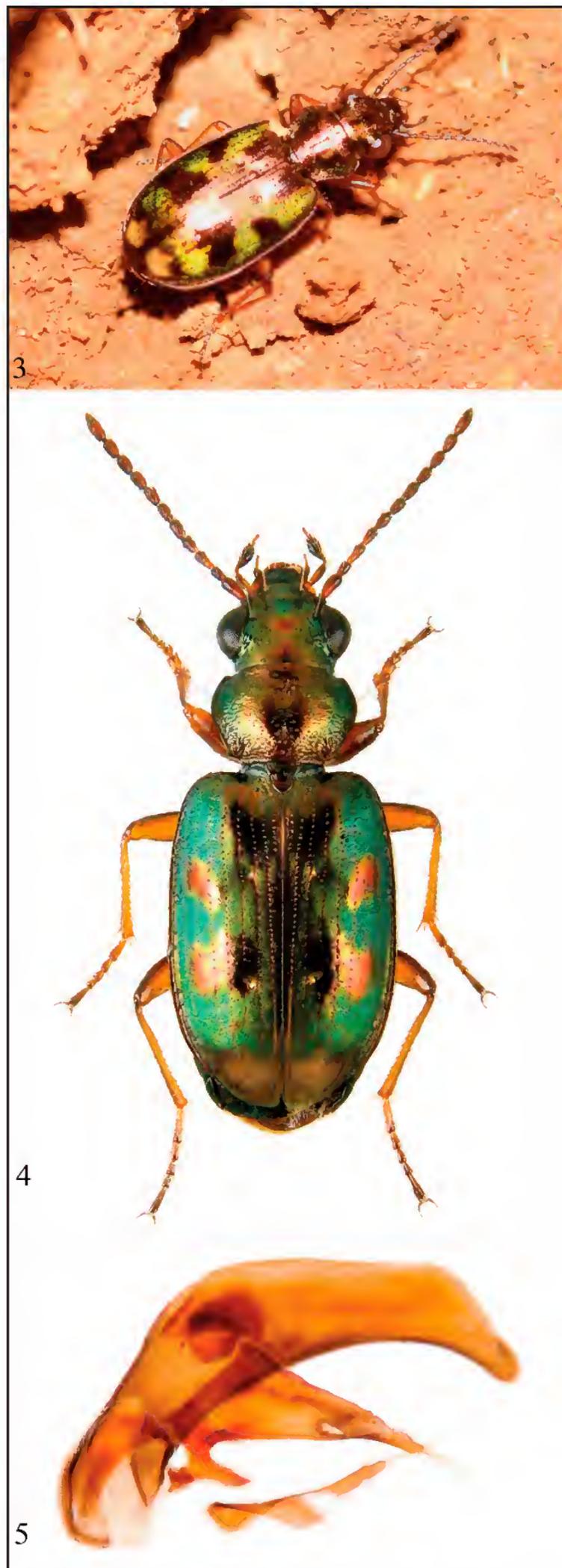
Figures 1, 2. Favignana Island: temporary pool west of Punta Faraglione, habitat of *Princidium (Testedium) laetum*.

Focarile (1969) and Osella (1973), Favignana was visited in March, May-June and October, i.e. in periods at least partly suitable for findings of this species. At least the former author should have visited this or some such habitat, since Magistretti (1970), upon Focarile's materials, records for Favignana (sub *Bembidion tethys* Net.) *Phyla tethys* (Netolitzky, 1926), a hygrophilous ground beetle. Incidentally, with possible exception of *Distichus planus* (Bonelli, 1813), listed sub *Scarites planus* Bon., that may be found either at the pools (more likely) or at seashore, no other hygrophilous ground beetles (*Dyschiriodes* Jeannel, 1941 s.l., *Bembidion* Latreille, 1802 s.l., *Tachys* Dejean, 1821 s.l., *Pogonus* Dejean, 1821 s.l., *Chlaenius* Bonelli, 1810 s.l., e.g.) are recorded for the island.

In our opinion it seems not unlikely that at the time *P. laetum* simply did not exist there, and that its occurrence may result from a recent colonisation from airborne individuals (aeroplankton). In genera related to (and by several authors treated as subgenera of) *Bembidion*, most species are good fliers, probably unable to fly actively over very long distances, yet no doubt able to stay on flight for several hours, reaching even quite far areas when supported by southern winds. The minimum distance between Tunisian coast, where *P. laetum* occurs, and Favignana is less than 150 km, clearly at reach of such fliers. Anyway, the fair number of individuals seen together, only in a small spot, excludes that all of them may have come from overseas, and proves at least occasional local breeding. The local absence of potential competitors may have favoured the subsequent settlement. It is at present unknown whether the species permanently occurs on Favignana, or only does so as a temporary occurrence, not to persist in the next future.

#### ACKNOWLEDGEMENTS

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Figures 3–5. *Principidium (Testedium) laetum*, from Favignana. Fig. 3. Living animal in situ. Fig. 4. Idem, habitus. Fig. 5. Idem, aedeagus.

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## Biological data of Burmese carplet *Amblypharyngodon atkinsonii* (Blyth, 1860) in South Myanmar (Cypriniformes Cyprinidae): a preliminary report

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### ABSTRACT

The present paper reports on biological data of Burmese carplet, *Amblypharyngodon atkinsonii* (Blyth, 1860) in Tanintharyi River, Tavoy, Tanintharyi Division, South Myanmar. The study indicated that this fish is a surface and mid-water feeder. According to stomach content, it can be considered as planktivorous and insectivorous. Food items can be separated into five groups, namely phytoplanktons, zooplanktons, aquatic insects, plant materials and organic matters, the first two being the main items. Females of *A. atkinsonii* were found to be predominant. The length-weight relationship was related by the equation,  $W = 0.0000031SL^{3.5221}$ ; ( $R^2 = 0.94$ ). Fecundity ranged from 1,548–4,020 eggs. Fecundity-length relationship was related by the equation,  $Fe = 0.88046SL^{1.9560}$ ; ( $R^2 = 0.87$ ) and Fecundity-weight by  $Fe = 914.4292W^{0.6182}$ ; ( $R^2 = 0.88$ ).

### KEY WORDS

*Amblypharyngodon atkinsonii*; feeding habit; fecundity; Myanmar.

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### INTRODUCTION

The Tanintharyi River originates at Tanow Sri mountain range, frontier of Thailand and Myanmar at an altitude of 2,074 m. This river system runs through Tanintharyi Division, Southern Myanmar after passing by several towns, including Tagu, Banlaw, Wunna, Thamihla, Tharapon and Kahan and flows into the Andaman Sea at the Tanintharyi Estuary, Myeik City with a total length of about 250 kilometers. Tanintharyi River is a major river of southern Myanmar and a very important river basin (Grosberg, 2005), but very little is known about aquatic resources in this area, including biological data of fish populations.

The freshwater cyprinid fish genus, *Amblypharyngodon* Bleeker, 1860, order Cypriniformes Bleeker, 1859, family Cyprinidae Cuvier, 1817, has been reported from Indian Subcontinent to South-east Asia (Blyth, 1860; Talwar & Jhingran, 1991 Kottelat, 2013; Doi, 1997).

In Myanmar, it comprises two valid species: *Amblypharyngodon mola* (Hamilton, 1822) reported from West to Central Myanmar and *A. atkinsonii* (Blyth, 1860) (Fig. 1) reported from Central to South Myanmar (Vidthayanon et al., 2005). In Myanmar it is poorly known, on the contrary, in India *A. mola* is a popular food, particularly in the Indian sub-continent. *Amblypharyngodon mola* is a species, mostly planktivorous, inhabiting in

ponds, reservoirs, slow-moving streams or main stream. The spawning season is all year round and fecundity was found to range from 1,021–13,812 eggs (Suresh et al., 2007; Gupta & Banerjee, 2013, 2014; Mondal & Kaviraj, 2013). At present, nothing is known on *A. atkinsonii*.

A survey project aimed at studying freshwater fishes in Tanintharyi River, Tavoy, Tanintharyi Division, South Myanmar was carried out in August 2014. Specimens of *A. atkinsonii* were collected by beach seine along with other fish including *Esomus ahli* Hora et Mukerji 1928, *Puntius chola* (Hamilton, 1822), *Mystus pulcher* (Chaudhuri, 1911), *Parambassis ranga* (Hamilton, 1822), *Trichogaster labiosa* Day, 1877, *Pseudopocryptes elongatus* (Cuvier, 1816), *Odontamblyopus rubicundus* (Hamilton, 1822) and others. The purpose of this study is provide new preliminary data on biology of *A. atkinsonii*.

ACRONYMS AND ABBREVIATIONS. Standard length = SL; head length = HL.

## MATERIAL AND METHODS

Field study was carried out in August 2014. Fifteen specimens of Burmese carplet were collected by beach seine (1x1 mm). Feeding morphology was investigated according to Nakabo (2002); stomach content analysis was performed as in Hyslop (1980); sex, length-weight relationship and fecundity were studied as reported by Krebs (1998).

## RESULTS

### *Feeding habit*

Feeding morphology of Burmese carplet (Fig. 2) showed that the position of the mouth is in the upper part of the head (superior mouth), this character indicated that this fish is a surface and mid-water feeder. Average values of intestinal length (compared to standard length) is  $300.77 \pm 6.57$ . Gill rakers are short, sparse, pointed in shape, average number of first gill rakers is  $12 \pm 3$ . Particularly, *A. atkinsonii* is compressed, body length is about 42–54 mm, body depth is 33.6–35.5% SL. Head

length is 26.6–26.8% SL. Eye is large, eye diameter is 25.7–27.3% HL (7.3–7.6% SL). Post orbital length is 66.7–67.1% HL (17.7–18.6% SL), snout length is short, 12.1–14.9% HL (3.2–4.6% SL) and interorbital width is 37.3–39.2% HL (10.2–10.8% SL). Based on stomach content analysis, the fish can be considered as planktivorous and benthivorous. Food items can be separated into five groups, i.e. phytoplanktons, zooplanktons, aquatic insects, plant materials and organic matters. Phytoplanktons and zooplanktons were the main ones.

### *Sex*

The number of female specimens we found was higher than males, namely 11 females and 5 males. This finding is in line with other papers reporting on sex ration in *A. mola* (see Afroze et al., 1991; Mondal & Kaviraj, 2013; Gupta & Banerjee, 2013; 2014).

### *Length-Weight relationship*

Total length ranged from 42 mm to 54 mm and weight from 1.63 to 3.9 grams. The length-weight relationship equation (sexes combined) was:

$$W = 0.0000031SL^{3.5221}$$

$$(R^2 = 0.94)$$

Where

W = weight of specimens (g)  
SL = standard length of specimens (mm)

### *Fecundity*

Fecundity ranged from 1,548–4,020 eggs. Linear relationships were estimated between fecundity and standard length and weight, respectively.

### *Fecundity - Length relationship*

$$Fe = 0.88046SL^{1.9560}$$

$$(R^2 = 0.87)$$

Where

Fe = fecundity of specimens (eggs)  
SL = standard length of specimens (cm)

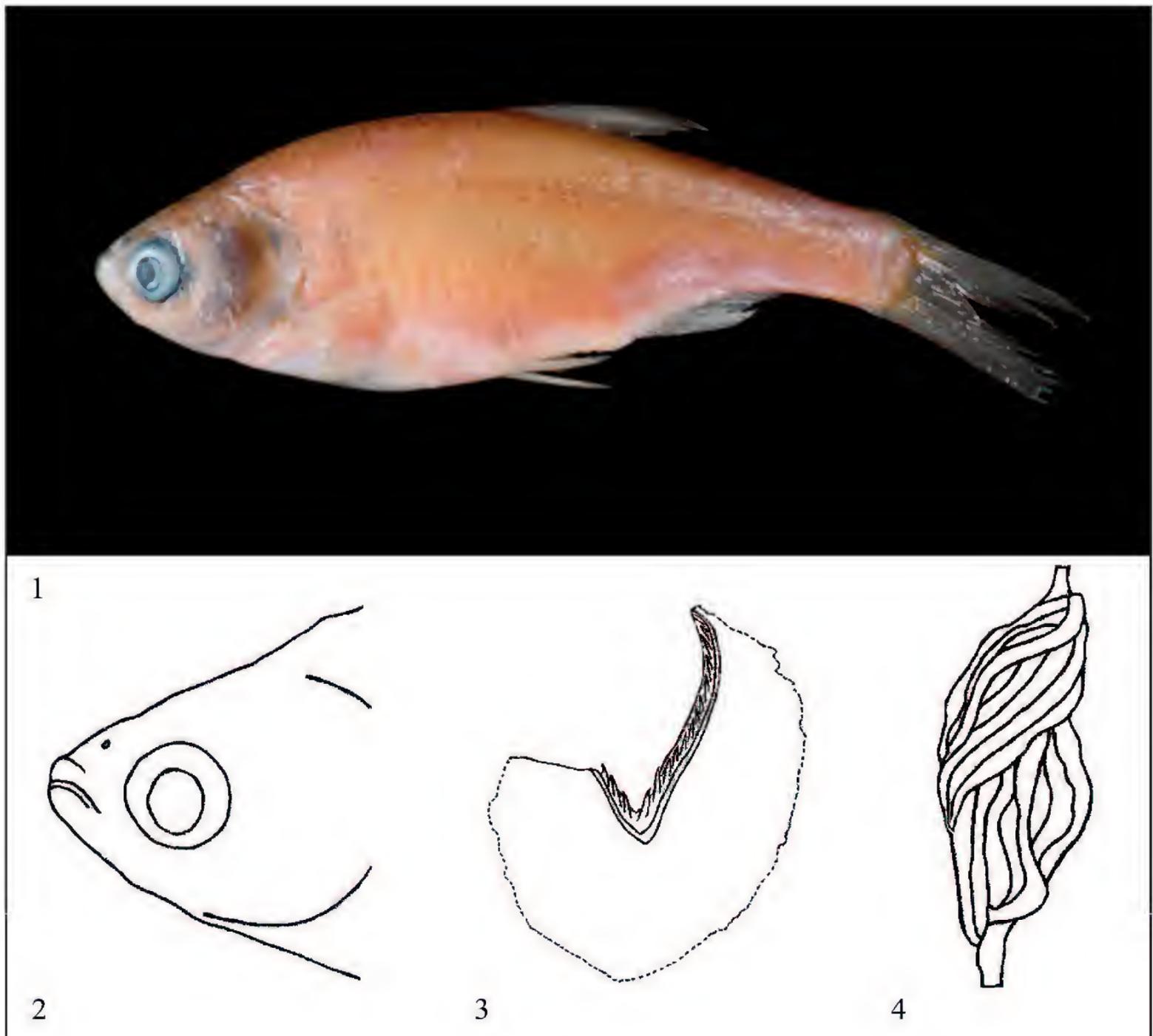


Figure 1. *Amblypharyngodon atkinsonii*, 54 mm SL, from South Myanmar. Figures 2–4. Feeding morphology of *Amblypharyngodon atkinsonii*; Figure 2. The position of the mouth, Figure 3. Gill rakers, Figure 4. Intestine.

Fecundity - Weight relationship

$$Fe = 914.4292W^{0.6182}$$

( $R^2 = 0.88$ )

Where

Fe = fecundity of specimens (eggs)  
 W = weight of specimens (g)

**CONCLUSIONS**

Very preliminary data discussed herein suggest

that Burmese carplet in South Myanmar is planktivorous and benthivorous; fecundity (1,548–4,020 eggs) was found to be related to body length and weight.

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## About the wide Mediterranean distribution of the “geographically localized” *Clelandella myriamae* (Gofas, 2005) (Gastropoda Trochidae)

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### ABSTRACT

Almost one thousands of empty shells recognized as *Clelandella myriamae* (Gofas, 2005) (Gastropoda Trochidae) have been collected from the Gioia Basin (South Tyrrhenian) and, in minor number, from the Strait of Messina. The records remarkably increase the areal known for this bathyal species, previous known only from Levantine Basin.

### KEY WORDS

bathyal; *Clelandella*; first record; gastropod; Mediterranean.

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### INTRODUCTION

Before Gofas (2005), who described five new species from northeastern Atlantic and Mediterranean, the genus *Clelandella* Winckworth, 1932 (Gastropoda Trochidae), was only known for *C. miliaris* (Brocchi, 1814), whose areal extends from Norway to West Africa and Mediterranean Sea. A further species has been added by Vilvens et al. (2011) for Western Sahara. All such new species appeared geographically localized, as an effect of insular segregation, as suggested for the endemic Mediterranean *C. myriamae* (Gofas, 2005). This latter species, that has been first collected south of Crete, broadly sympatric with *C. miliaris* (Gofas, 2005), has been later recorded in the Nile Deep-Sea Fan, both located in the eastern Mediterranean (Gaudron et al., 2010).

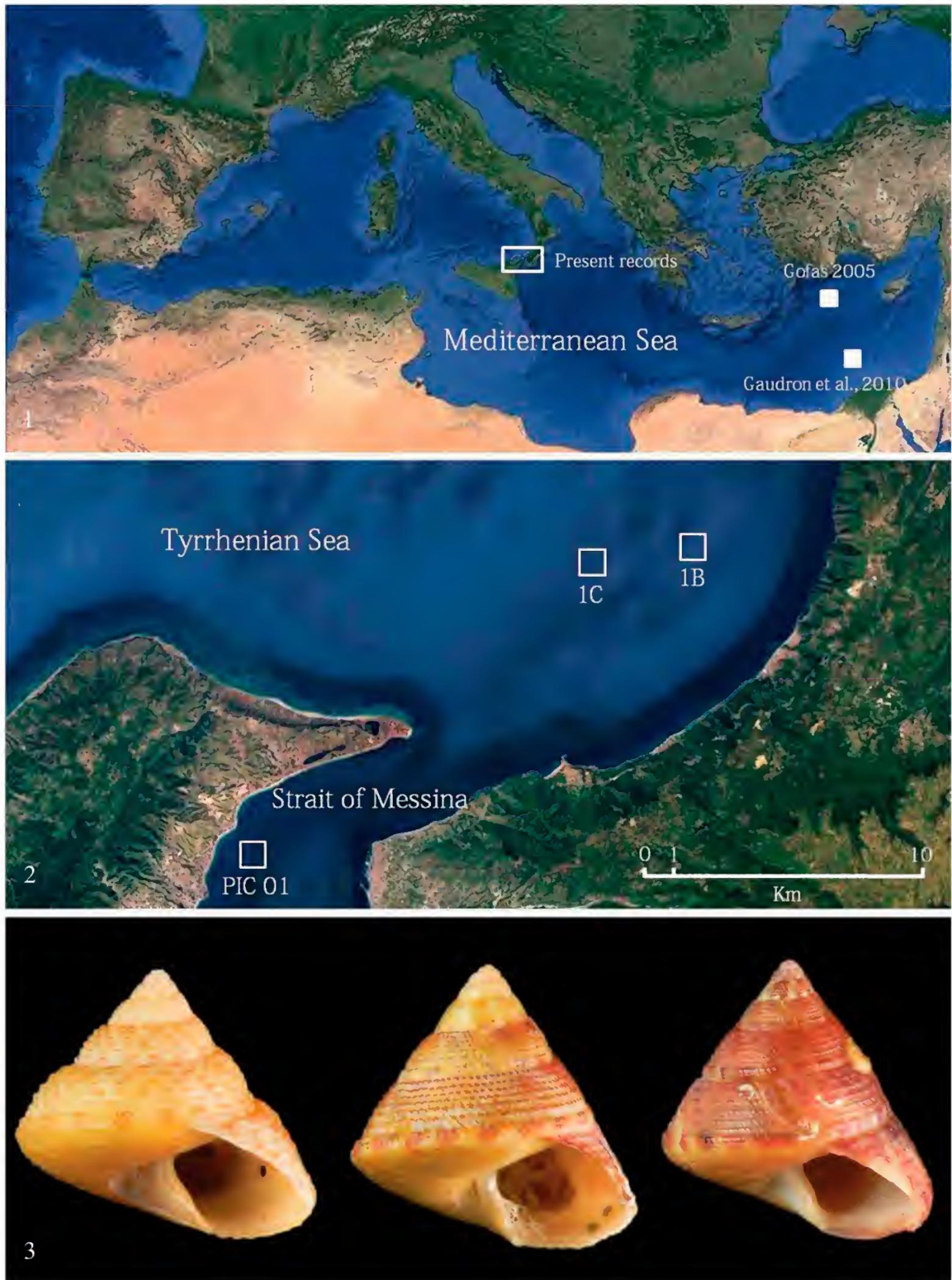
In this paper, the finding of numerous *C. myriamae* dead specimens from the Messina Strait and

close Tyrrhenian sea, is reported, testifying of a wider areal than previous known.

### MATERIAL AND METHODS

The Strait of Messina and Tyrrhenian coasts of Calabrian (Fig. 1) have been respectively explored in the framework of the projects POP '95 and POR Calabria 2005. Seafloor sediments, in both investigations, have been sampled by means of a modified van Veen grab covering 0.25 square meter surface (75 dm<sup>3</sup> in volume).

Samples have been washed on board with seawater, by means of sieve series of 8 mm, 4 mm, 1 mm, 0.5 mm meshes, and fixed in ethylene 75%. In laboratory, after removing of benthic fauna, sediments have been washed with fresh water and dried at 45°C. From dried sediments, all shell remains have been extracted and classified at the



Figures 1–3. *Clelandella myriamae*. Mediterranean distribution (Fig. 1) and new findings (Fig. 2). The shell-shape variability (Fig. 3).

species level, as far as possible. All *C. myriamae* specimens have been counted and set aside for further investigation.

## RESULTS AND DISCUSSION

From the investigated death assemblages, nearly a thousand of empty shells were recognized as *C. myriamae*. Most specimens have been collected in the Gioia Basin, south Tyrrhenian (Fig. 2), by two sampling stations located 371 m (St. 1B) and 335 m depth (St. 1C). Both stations were characterized by a mixture of coarse sand (80–90%) and gravel (9–10%), rich in bioclastic fragments. A further dozen specimens, sampled inside the Messina Strait (Fig. 2), were found at lower depth (-185 m: St. PIC01), in a coarse bioclastic substrate.

The sampled shells showed a remarkable morphological variability (Fig. 3), ranging between the two “typical” and “aberrant” forms cited by Gofas (2005). Such variability has been recently investigated by Sanfilippo et al. (in press) on the specimens collected in the 1C station. The present samplings of *C. myriamae* testify of a wider distribution of this species rather than the Levantine Basin only, overcoming the eastern-western Mediterranean boundary (Bianchi, 2007). Furthermore, the two records from Tyrrhenian and Messina should be considered as bio-geographically distinct, although separate by twenty kilometers only.

The Strait of Messina, in fact, is interposed between two basins, Tyrrhenian at north, and Ionian at south, with different oceanographic characteristics. Moreover, the Strait of Messina itself is quite different from both the close Tyrrhenian and Ionian basins, due to the peculiar tidal regime and related upwelling phenomena, and for this reason is considered a biogeographically distinct “micro-sector” (Bianchi et al., 2010).

The bathymetric range of the species is also wider than known, extending at least from the upper (present records) to the deeper bathyal zone (first records). In terms of habitat, the peculiar environment of mud volcanoes which provided the first specimens of *C. myriamae* (Carlier et al., 2010) does not involve a specialized adaptation towards

extreme habitats supported by chemosynthetic production.

In fact, the finding of juveniles in different devices with organic and inorganic substrate, according to Gaudron et al. (2010), might indicate *C. myriamae* a sulphide tolerant species that opportunistically colonizes locally enriched substrates in oligotrophic areas. Such an opportunistic behavior might explain the relevant number of dead specimens (very higher than each other associated mollusc species) that have been found in a relatively small sediment volume, thus suggesting *C. myriamae* may reach high population densities. Nevertheless, is unclear what food source might support a high population density in the Strait, lacking any evidence of present hydrothermal activity as well as of massive organic matter deposition. In this respect, records of alive specimens from the same area (Vazzana, pers. comm.), if confirmed, might provide useful indications about the population dynamics and life strategy of such scarcely known species.

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## Second contribution to the knowledge of Longhorn Beetles of the Syrian Coastal Region (Coleoptera Cerambycidae)

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### ABSTRACT

Knowledge relating to the Longhorn Beetles of Syria was extended in this study, with special emphasis on the Coastal Region (SCR), which was the focal point of a previous study we published last year (2015). This contribution provides a detailed account about additional species and subspecies that were collected from different areas and localities of the SCR, in as much as reporting two new species to be recorded for the first time from the Syrian territory, namely: *Stenopterus atricornis* Pic, 1891 and *Pogonocherus barbarae* Rapuzzi et Sama, 2012. Among the examined catches, one specimen was identified down to the genus level, but its species status is doubtful and its validity still needs further examination. All available faunistics, biogeographies and bionomics of all the reported species and subspecies are given. Moreover, a complete, refined and annotated checklist of the Syrian Cerambycidae was introduced, with special reference to all taxa recorded from SCR up to the time of publication of this work.

### KEY WORDS

Syria; Syrian Coastal Region; Longhorn Beetles; Cerambycidae; new data; faunistics.

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### INTRODUCTION

The biodiversity of the Middle East (ME) is rather unique and might be one of the largest in the world, especially that ME serves as a junction between three major biogeographic regions (i.e. realms) viz. Palearctic, Afro-tropical and Oriental (Krupp et al., 2009). In the grand scheme, entomology in ME is still inchoate, and research endeavors are still hindered by a lingering dearth of resources. However, more effort has been dedicated towards "uncovering" the Middle Eastern fauna of insects (e.g. Cerambycidae) in recent years, which yielded substantial biodiversity data reflected in the notable increase of published work relating to that region (e.g. Sama et al., 2002;

Sama et al., 2010a, b; Özdikmen, 2007, 2008a, b, c; Ali et al., 2015).

Situated at the heart of ME, Syria harbors an outstanding ecological diversity which gives rise to an astounding "biological richness" manifested in overwhelmingly diversified faunae and florae. In reality, the knowledge concerning that richness remains sketchy and not well established. In regards to the scope of this study, the Syrian fauna of Longhorn Beetles (Cerambycidae) is insufficiently documented, and full accounts are - basically - non-existent. Meanwhile, it is worth mentioning that there is only one checklist providing a brief cross-referenced record of species and subspecies reported from the Syrian territory as a whole (Hariri, 1971). Still, given the recent surge in taxonomic

research projects targeting ME, region-wise periodically-updated databases are being issued on a regular basis. Accordingly, Syrian fauna is more likely to encompass more species and subspecies of Cerambycidae than previously reported (Danilevsky, 2012a). Furthermore, taxonomic statuses of taxa are rather dynamic and very liable to change with the course of time, which renders earlier work severely outdated and addresses a crucial need for profound amendments in order for taxonomic databases to be more accurate and attract more validity (Löble & Smetana, 2010).

In line with the novel taxonomic research out-reaches in ME, our endeavor was set out to bridge the gaps inflicting the knowledge of Cerambycidae in Syria. The Syrian Coastal Region (SCR) was under our initial limelight of focus due to the typical Mediterranean climate and heterogenous geography it features, which holds an implication for a significant ecological importance in terms of biodiversity and species richness. Consequently, a detailed study of the Cerambycidae fauna of SCR was published by Ali et al. (2015), accounting for 51 species and subspecies with 9 species (including subspecies) to be recorded for the first time from the Syrian territory.

In this study, we meant to build upon the previous contribution, and provide an account for new species and subspecies collected from Syria, with new taxa to be recorded for the first time as well. In light with recent insecurity situations engulfing vast stretches of the country, a comprehensive survey of Cerambycidae fauna covering the whole land of Syria was technically unfeasible. Nevertheless, we provide an up-to-date checklist of Syrian Cerambycidae with reference to the taxa recorded from the region of concern i.e. SCR.

## MATERIAL AND METHODS

### *Study area*

The study area is a small "strip" of land with a heterogenous geography; ranging from low plains to rocky highlands and mountains reaching more than 1000 m of elevation. The area features a typical Mediterranean climate, with mildly cold winters and relatively hot and wet summers. The clement weather combined with the highly diver-

sified flora provide ideal ecological micro-habitats for many fauna communities to diversify, and insects in this regards are a core component of the Syrian fauna.

### *Collection, preservation, and identification*

Specimens of adult Cerambycidae were collected by the first author (if not mentioned otherwise) from many areas and localities situated across the SCR between early February and late August throughout 2014–2015. Furthermore, collections pertaining to fellow researchers, which included specimens originating from Syria were also examined.

Interested readers can refer to Ali et al. (2015) for a detailed account concerning collection methodology, handling and curation techniques.

Specimens were identified according to: Bense, 1995, Özdikmen & Turgut, 2009, Rapuzzi & Sama, 2012, Rapuzzi & Sama, 2013b.

Each identified specimen was pictured using an Olympus SP 800 UZ digital camera, and all specimens were permanently preserved in the Entomology Laboratory belonging to the Plant Protection Department, Faculty of Agriculture, Tishreen University, Syria.

## RESULTS AND DISCUSSION

During this study a total of 5 species including 2 subspecies belonging to 5 genera in 5 tribes were reported. The species status of one specimen was uncertain and further examination is still needed to determine its validity.

A detailed list of the identified taxa is given below. With the following order:

The classification scheme follows Danilevsky (2012a).

Collection sites and localities with their geographical data (e.g. latitude, longitude, and altitude) are provided in alphabetical order.

Global distribution data are given in alphabetical order, based on Danilevsky (2012a).

Chorotypes were based on the geographic range of distribution based on Danilevsky (2012a); with a further reference where appropriate.

Bionomics, when available, are given, based on:

Hoskovec & Rejzek, 2013, Sama et al., 2010a, b, Rapuzzi & Sama, 2012, 2013b, Özdikmen, 2013.

Remarks, and personal observations were also provided where relevant.

An up-to-date checklist of Syrian Cerambycidae is provided (with special reference to species reported from SCR) based on: Breuning, 1962; Özdikmen, 2008; Löble & Smetana, 2010; Kotán & Sama, 2011; Danilevsky, 2012a, b; Rapuzzi et al., 2011, Rapuzzi & Sama, 2009, 2011, 2012, 2013a, b; Sama & Rapuzzi, 2011; Özdikmen et al., 2012, 2014; Ali et al., 2015, in addition to data obtained from examining collections belonging to some fellow researchers.

Family CERAMBYCIDAE Latreille, 1802

Subfamily PRIONINAE Latreille, 1802

Tribe Prionini Latreille, 1802

Genus *Mesoprionus* Jakovlev, 1887

Type species: *Prionus asiaticus* Faldermann, 1837

### 1. *Mesoprionus lefebvrei* (Marseul, 1856)

EXAMINED MATERIAL. Latakia Province. Latakia Area: Bisnada, 21.0 m, 35°48'14.97"E, 35°32'52.65"N, 23. IX. 2014 (1 female)/ Qismin, 191.0 m, 35°54'18.6"E, 35°38'1.2"N, 17. IX. 2014 (1 male)/ Latakia, 20.0 m, 35°46'51.7"E, 35°31'47.1"N, 3. V. 2015 (1 male)/ Serskieh, 55.0 m, 35°55'10.40"E, 35°42'19.84"N, 10. VIII. 2015 (1 female).

Tartus Province. Baniyas Area: Al-Qadmus, 919.0 m, 36°9'40.13"E, 35°6'6.53"N, 30. XI. 2014 (1 female). Safita Area: Safita: 310.0 m, 36°7'5.14"E, 34°49'1.75"N, 16. X. 2014 (1 male).

CHOROTYPE. Turano-Mediterranean / Balkano-Anatolian (Özdikmen et al., 2012).

DISTRIBUTION. Europe (Albania, Bulgaria, Greece, Macedonia, European-Turkey, Serbia and Montenegro); Asia (Cyprus and Turkey).

BIONOMICS. Polyphagous on deciduous plants (e.g. *Acacia mollissima* Willd., *Ligustrum ovalifolium* Hassk., *Quercus ithaburensis* Decne., *Platanus* sp., *Ficus* sp.); life cycle usually takes 2–3 years; adults are usually encountered between June–August.

REMARKS. Specimens were collected by the

hand from trunk and branches of some deciduous trees, and some specimens were collected from light traps situated near forest sites, and it is considered as a forester species.

Subfamily CERAMBYCINAE Latreille, 1802

Tribe Cerambycini Latreille, 1802

Genus *Cerambyx* Linnaeus, 1758

Type species: *Cerambyx cerdo* Linnaeus, 1758

### 2. *Cerambyx* cfr. *dux* Faldermann, 1837

EXAMINED MATERIAL. Latakia Province. Jableh Area: Qutaolabyah, 215.0 m, 36°1'8.98"E, 35°17'13.14"N, 16. V. 2014 (1 male); 27. VI. 2015 (1 male).

CHOROTYPE. Unknown.

DISTRIBUTION. Unknown.

BIONOMICS. Unknown.

REMARKS. Our first encounter with this species was in 2014, and it is rather rare in SCR. We were unable to verify the species status; therefore, further examination is needed. Specimens were encountered on the branches of oak trees (*Quercus* sp.).

Tribe Purpuricenini J. Thomson, 1861

Genus *Purpuricenus* Dejean, 1821

Type species: *Cerambyx kaehleri* Linnaeus, 1758

### 3. *Purpuricenus interscapillatus interscapillatus* Plavilstshikov, 1937

EXAMINED MATERIAL. Latakia Province. Jableh Area: Mazar Al-Qatria: 142.0 m, 35°55'32.1"E, 35°30'56.0"N, 16. VIII. 2015 (1 male, 1 female).

CHOROTYPE. E-Mediterranean / Palestino-Cyprioto-Taurian (Rapuzzi & Sama, 2013).

DISTRIBUTION. Asia (Syria and Turkey) [Type: "Syria"].

BIONOMICS. Oligophagous on some deciduous trees (e.g. *Quercus calliprinos* Webb., *Rhamnus palaestina* Boiss., *Prunus* sp.); life cycle usually takes 2–3 years; adults are usually encountered between May–August.

REMARKS. Not frequently encountered in SCR, specimens were found on the trunk of an oak tree (*Quercus* sp.).

Subfamily LAMIINAE Latreille, 1825  
Tribe Pogonocherini Mulsant, 1839  
Genus *Pogonocherus* Dejean, 1821  
Type species: *Cerambyx hispidus* Linnaeus, 1758

5. *Pogonocherus barbarae* Rapuzzi et Sama, 2012

EXAMINED MATERIAL. Latakia Province. Latakia Area: Wadi Qandil: 48.0 m, 35°50'28.9"E, 35°43'20.7"N, 13. VI. 2014 (1 male).

CHOROTYPE. Unknown.

DISTRIBUTION. Turkey and Syria.

BIONOMICS. Usually associated with *Pinus nigra* J.F. Arnold.

REMARKS. This is the first record of this species from Syria. It is very rare in SCR; the specimen was found on a branch of the host plant.

Tribe Phytoeciini Mulsant, 1839  
Genus *Phytoecia* Dejean, 1835  
Type species: *Cerambyx cylindricus* Linnaeus, 1758  
Subgenus *Phytoecia* Dejean, 1835  
Type species: *Cerambyx cylindricus* Linnaeus, 1758

4. *Phytoecia caerulea caerulea* (Scopoli, 1772)

EXAMINED MATERIAL. Tartus Province. Baniyas Area: Blawzeh: 462.0 m, 36° 1'5.23"E, 35° 8'59.40"N, 23. V. 2015 (2 males, 1 female).

CHOROTYPE. Turano-European (Özdikmen, 2008).

DISTRIBUTION. Europe, Asia (Azerbaijan, Armenia, Georgia, Iran, Kazakhstan, Syria, Tajikistan, Turkmenistan, Turkey and Uzbekistan).

BIONOMICS. Oligophagous on some herbaceous plants (e.g. *Sinapsis* sp., *Sisymbrium* sp., *Rapistrum* sp.); life cycle usually takes one year; adults are usually encountered between March–June.

REMARKS. Frequently encountered in SCR, especially during early spring (April); specimens were collected by sweeping some herbaceous plants.

## CONCLUSIONS

In total, and in accordance with new data provided in this study, the Cerambycidae fauna of SCR comprises: 139 species including 39 subspecies, belonging to 76 genera, in 35 tribes allocated to 5 subfamilies. The proposed checklist below, and relevant databases will be updated as more progress towards building the complete Cerambycidae fauna of Syria is achieved.

As a final point, the diversity in SCR that has been uncovered up to now is significantly high, which highlights the faunistic importance of the longhorn beetles in Syria. Interestingly, the SCR account for approximately 85% of all species and subspecies reported from Syria (as can be inferred from the checklist), and this further enhances our discussion about the high ecological importance of SCR, but this does not negate the need for further studies to be carried out in order to obtain more data and "excavate" more species that are waiting to be discovered from other regions, especially that SCR represents - roughly speaking - only about 2.5% of the total area of Syria.

## CHECKLIST OF CERAMBYCIDAE OF SYRIA

The species marked by \* are recorded from the area examined in this paper (SCR).

Subfamily PRIONINAE Latreille, 1802  
Tribe Aegosomatini J. Thomson, 1861

Genus *Aegosoma* Audinet-Serville, 1832  
\**scabricorne* (Scopoli, 1763)

Tribe Ergatini Fairmaire, 1864

Genus *Callergates* Lameere, 1904  
\**gaillardoti* (Chevrolat, 1854)

Genus *Ergates* Audinet-Serville, 1832  
\**faber faber* (Linnaeus, 1760)

Tribe Macrotomini J. Thomson, 1861

Genus *Prinobius* Mulsant, 1842  
\**myardi atropos* (Chevrolat, 1854)

Tribe Prionini Latreille, 1802

Genus *Mesoprionus* Jakovlev, 1887

\* *lefebvrei* (Marseul, 1856)

Genus *Prionus* Geoffroy, 1762

[*coriarius* (Linnaeus, 1758)]

\**komiyai* (Lorenc, 1999)

Tribe Remphanini Lacordaire, 1868

Genus *Rhaesus* Motschulsky, 1875

\**serricollis* (Motschulsky, 1838)

Subfamily APATOPHYSEINAE Lacordaire, 1869

Tribe Apatophyseini Lacordaire, 1869

Genus *Apatophysis* Chevrolat, 1860

Subgenus *Apatophysis* Chevrolat, 1860

*katbehi* Rapuzzi et Sama, 2013

Subfamily LEPTURINAE Latreille, 1802

Tribe Lepturini Latreille, 1802

Genus *Anastrangalia* Casey, 1924

\**montana montana* (Mulsant et Rey, 1863)

Genus *Grammoptera* Audinet-Serville, 1835

Subgenus *Grammoptera* Audinet-Serville, 1835

\**baudii pistacivora* Sama, 1996

\**grammopteroides* (Pic, 1892)

Genus *Pachytodes* Pic, 1891

\**erraticus erraticus* (Dalman, 1817)

Genus *Pedostrangalia* Sokolov, 1897

Subgenus *Neosphenalia* Löbl, 2010

\**emmipoda* (Mulsant, 1863)

*riccardoi riccardoi* (Holzschuh, 1984)

Genus *Pseudovadonia* Lobanov, Danilevsky et Murzin, 1981

\**livida livida* (Fabricius, 1777)

Genus *Stenurella* Villiers, 1974

\**bifasciata nigrosuturalis* (Reitter, 1895)

Genus *Stictoleptura* Casey, 1924

Subgenus *Stictoleptura* Casey, 1924

\**benjamini ehdenensis* Sama et Rapuzzi, 2000

\**cordigera cordigera* (Fuessly, 1775)

\**excisipes* (K. Daniel et J. Daniel, 1891)

\**heydeni* (Ganglbauer, 1889)

\**sambucicola* (Holzschuh, 1982)

Genus *Vadonia* Mulsant, 1863

\**unipunctata syriaca* Holzschuh, 1993

Tribe Rhagiini Kirby, 1837

Genus *Anisorus* Mulsant, 1862

\**heterocerus* (Ganglbauer, 1882)

Genus *Cortodera* Mulsant, 1863

\**colchica colchica* Reitter, 1890

\**longipilis* Pic, 1898

\**semilivida* Pic, 1892

*syriaca syriaca* Pic, 1901

Genus *Rhagium* Fabricius, 1775

Subgenus *Megarhagium* Reitter, 1913

\**syriacum* Pic, 1892

Genus *Rhamnusium* Latreille, 1829

\**bicolor praeustum* Reitter, 1895

Subfamily SPONDYLIDINAE Audinet-Serville, 1832

Tribe Anisarthrini Mamaev et Danilevsky, 1973

Genus *Alocerus* Mulsant, 1862

\**moesiacus* (Fivaldszky von Fivald, 1837)

Tribe Asemini J. Thomson, 1861

Genus *Arhopalus* Audinet-Serville, 1834

\**ferus*

\**syriacus* (Reitter, 1895)

Subfamily CERAMBYCINAE Latreille, 1802

Tribe Achrysonini Lacordaire, 1868

Genus *Icosium* P.H. Lucas, 1854

\**tomentosum atticum* Ganglbauer, 1882

Tribe Brachypteromini Sama, 2008

Genus *Brachypteroma* Heyden, 1863

\**holtzi* Pic, 1905

Tribe Callichromatini Swainson, 1840

Genus *Aromia* Audinet-Serville, 1834  
 \**moschata ambrosiaca* (Steven, 1809)

Tribe Callidiini Kirby, 1837

Genus *Callidium* Fabricius, 1775  
 Subgenus *Callidium* Fabricius, 1775  
 \**syriacum* Pic, 1892

Genus *Leioderes* L. Redtenbacher, 1849  
 \**tuerki* (Ganglbauer, 1886)  
 \**fasciatus* Villers, 1789

Genus *Phymatodes* Mulsant, 1839  
 Subgenus *Phymatodellus* Reitter, 1913  
 \**rufipes syriacus* Pic, 1891

Subgenus *Phymatodes* Mulsant, 1839  
 \**testaceus* (Linnaeus, 1758)

Genus *Poecilium* Fairmaire, 1864  
 \**antonini* Rapuzzi, Sama et Tichy, 2011  
 \**fasciatum* (Villers, 1789)  
 \**lividum* (Rossi, 1794)  
 \**wrzecionkoi* Rapuzzi et Sama, 2009

Genus *Pyrrhidium* Fairmaire, 1864  
 \**sanguineum* (Linnaeus, 1758)

Genus *Ropalopus* Mulsant, 1839  
 Subgenus *Ropalopus* Mulsant, 1839  
 \**eleonora* Sama et Rapuzzi, 2002  
*ledereri wittmeri* Demelt, 1970

Genus *Semanotus* Mulsant, 1839  
 \**russicus russicus* (Fabricius, 1777)

Tribe Cerambycini Latreille, 1802

Genus *Cerambyx* Linnaeus, 1758  
 \**cerdo cerdo* Linnaeus, 1758  
 \**dux* (Faldermann, 1837)  
 \**nodulosus* Germar, 1817  
 \**scopolii nitidus* Pic, 1892  
 \**welensii* Küster, 1845

Genus *Neoplocaederus* Sama, 1991  
*laszlokotani* Kotán et Sama, 2011

Tribe Certallini Fairmaire, 1864

Genus *Certallum* Dejean, 1821  
 \**ebulinum* (Linnaeus, 1767)  
*thoracicum* Sharp, 1880

Tribe Clytini Mulsant, 1839

Genus *Chlorophorus* Chevrolat, 1863  
 \**dinae* Rapuzzi et Sama, 1999  
 \**gratiosus gratiosus* (Marseul, 1868)  
*nivipictus* (Kraatz, 1879)  
 \**sartor* (O. F. Müller, 1766)  
 \**trifasciatus* (Fabricius, 1781)  
 \**varius damascenus* (Chevrolat, 1854)

Genus *Clytus* Laicharting, 1784  
*ciliciensis* Chevrolat, 1863  
 \**kabateki* Sama, 1988  
 \**madoni* Pic, 1891  
 \**rhamni* Germar, 1817

Genus *Plagionotus* Mulsant, 1842  
 \**arcuatus* (Linnaeus, 1758)  
 \**bobelayei* (Brullé, 1832)  
 \**detritus africaeseptentrionalis* Tippmann, 1952

Genus *Xylotrechus* Chevrolat, 1860  
 Subgenus *Xylotrechus* Chevrolat, 1860  
 \**arvicola* (Olivier, 1795)  
 \**stebbingi* Gahan, 1906

Tribe Deilini Fairmaire, 1864

Genus *Deilus* Audinet-Serville, 1834  
 [*fugax* (Olivier, 1790)]  
 \**kadleci rugosicollis* Rapuzzi et Sama, 2012

Tribe Graciliini Mulsant, 1839

Genus *Axinopalpis* Dejean, 1835  
 \**gracilis gracilis* (Krynicky, 1832)

Genus *Penichroa* Stephens, 1839  
 \**fasciata* (Stephens, 1831)

Tribe Hesperophanini Mulsant, 1839  
 Subtribe Hesperophanina Mulsant, 1839

Genus *Hesperophanes* Dejean, 1835  
 \**sericeus* Fabricius, 1787

Genus *Stromatium* Audinet-Serville, 1834  
\**unicolor* (Olivier, 1795)

Genus *Trichoferus* Wollaston, 1854  
\**fasciculatus fasciculatus* (Faldermann, 1837)  
\**griseus* (Fabricius, 1792)  
\**kotschy* (Ganglbauer, 1883)

Tribe Hylotruperini Zagajkevitch, 1991

Genus *Hylotrupes* Audinet-Serville, 1834  
\**bajulus* (Linnaeus, 1758)

Tribe Molorchini Gistel, 1848

Genus *Glaphyra* Newman, 1840  
*kiesenwetteri hircus* (Abeille de Perrin, 1881)

Genus *Molorchus* Fabricius, 1792  
\**juglandis* Sama, 1982

Tribe Nathriini Arnett, 1962

Genus *Nathrius* Brèthes, 1916  
\**brevipennis* (Mulsant, 1839)

Tribe Phoracanthini Newman, 1840

Genus *Phoracantha* Newman, 1840  
\**recurva* Newman, 1840  
\**semipunctata* (Fabricius, 1775)

Tribe Purpuricenini J. Thomson, 1861

Genus *Purpuricenus* Dejean, 1821  
Subgenus *Purpuricenus* Dejean, 1821  
\**budensis* (Götz, 1783)  
*dalmatinus* Sturm, 1843  
\**desfontainii inhumeralis* Pic, 1891  
\**interscapillatus interscapillatus* Plavilstshikov, 1937  
*interscapillatus hermonensis* Rapuyzzi et Sama, 2013

Tribe Stenhomalini Miroshnikov, 1989

Genus *Stenhomalus* A. White, 1855  
Subgenus *Obriopsis* G. Müller, 1948  
\**bicolor* (Kraatz, 1862)

Tribe Stenopterini Gistel, 1848

Genus *Callimus* Mulsant, 1846  
\**angulatus angulatus* (Schrank, 1789)

Genus *Lampropterus* Mulsant, 1862  
Subgenus *Lampropterus* Mulsant, 1862  
\**femoratus* (Germar, 1824)

Genus *Procallimus* Pic, 1907  
\**egregius* (Mulsant et Rey, 1863)

Genus *Stenopterus* Illiger, 1804  
\**atricornis* Pic, 1891  
\**flavicornis* Küster, 1846  
\**rufus syriacus* Pic, 1892

Subfamily LAMIINAE Latreille, 1825  
Tribe Acanthocinini Blanchard, 1845

Genus *Acanthocinus* Dejean, 1821  
\**griseus* Fabricius, 1792

Genus *Leiopus* Audinet-Serville, 1835  
\**syriacus* Ganglbauer, 1884  
\**wrzecionkoi* Sama et Rapuzzi, 2011

Tribe Acanthoderini J. Thomson, 1860

Genus *Aegomorphus* Haldeman, 1847  
\**grisescens* (Pic, 1898)

Tribe Agapanthiini Mulsant, 1839

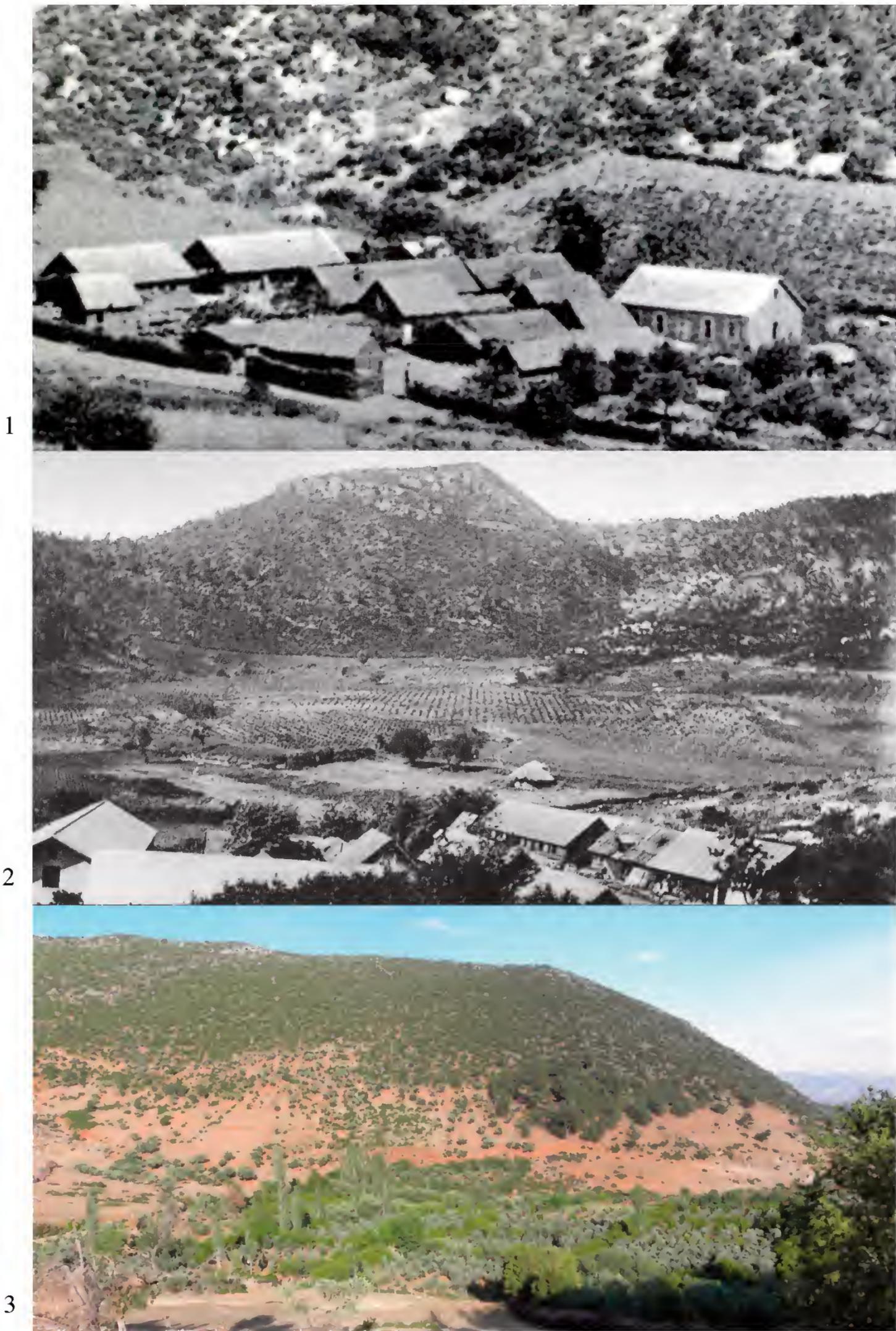
Genus *Agapanthia* Audinet-Serville, 1835  
Subgenus *Agapanthia* Audinet-Serville, 1835  
\**frivaldszkyi* Ganglbauer, 1884  
\**lais* Reiche et Saulcy, 1858  
\**suturalis* (Fabricius, 1787)

Subgenus *Epoptes* Gistel, 1857  
\**coeruleipennis* Frivaldszky, 1878  
\**kirbyi* Gyllenhal, 1817  
\**pustulifera* Pic, 1905

Genus *Calamobius* Guérin-Méneville, 1847  
\**filum* (Rossi, 1790)

Tribe Apodasyini Lacordaire, 1872

- Genus *Anaesthetis* Dejean, 1835  
*anatolica* Holzschuh, 1969
- Tribe Batocerini J. Thomson, 1864
- Genus *Batocera* Dejean, 1835  
*\*rufomaculata rufomaculata* (De Geer, 1775)
- Tribe Dorcadionini Swainson et Shuckard, 1840
- Genus *Dorcadion* Dalman, 1817  
Subgenus *Cribridorcadion* Pic, 1901  
*boucardi* Pic, 1942  
*\*drusoides* Breuning, 1962  
*\*halepense* Kraatz, 1873  
*impressicolle* Kraatz, 1873  
[*koechlini* Pic, 1898]  
*libanoticum* Kraatz, 1873  
*\*sauleyi javeti* Kraatz, 1873  
*\* sauleyi sauleyi* J. Thomson, 1865  
[*syriense* Breuning, 1943]
- Tribe Monochamini Gistel, 1848
- Genus *Monochamus* Dejean, 1821  
Subgenus *Monochamus* Dejean, 1821  
*\*galloprovincialis* Olivier, 1795
- Tribe Phytoeciini Mulsant, 1839
- Genus *Coptosia* Fairmaire, 1864  
Subgenus *Barbarina* Sama, 2010  
*\*nepheloides* (Sama, 1997)
- Subgenus *Coptosia* Fairmaire, 1864  
*brunnerae* Sama, 2000  
*\*compacta sancta* Reiche, 1877  
*\*ganglbaueri* Pic, 1936
- Genus *Mallosia* Mulsant, 1862  
Subgenus *Eumallosia* Danilevsky, 1990  
*imperatrix* Abeille de Perrin, 1885
- Subgenus *Semnosia* K. Daniel, 1904  
*baiocchii* Sama, 2001
- Genus *Oberea* Dejean, 1835  
Subgenus *Amaurostoma* J. Müller, 1906  
*\*erythrocephala erythrocephala* (Schrank, 1776)
- Subgenus *Oberea* Dejean, 1835  
*\*oculata* (Linnaeus, 1758)
- Genus *Opsilia* Mulsant, 1862  
*\*coerulescens* (Scopoli, 1763)
- Genus *Oxyilia* Mulsant, 1862  
*\*argentata languida* (Ménétriés, 1839)
- Genus *Phytoecia* Dejean, 1835  
Subgenus *Blepisanis* Pascoe, 1866  
*\*vittipennis leuthneri* (Ganglbauer, 1886)
- Subgenus *Helladia* Fairmaire, 1864  
*\*alziari* Sama, 1992  
*armeniaca armeniaca* Frivaldszky, 1878  
*ferrugata* Ganglbauer, 1884  
*\*humeralis* (Waltl, 1838)  
*insignata* Chevrolat, 1854  
*orbicollis adelpha* Ganglbauer, 1886  
*paulusi bludanica* Sama, 2000  
*pontica* Ganglbauer, 1884  
*\*praetextata nigricollis* Pic, 1891  
*\*pretiosa* Faldermann, 1837
- Subgenus *Musaria* J. Thomson, 1864  
*\*astarte astarte* Ganglbauer, 1886  
*\*wachanrui* Mulsant, 1851
- Subgenus *Neomusaria* Plavilstshikov, 1928  
*\*inapicalis* Pic, 1905  
*\*alepensis* Pic, 1931  
*\*merkli* Ganglbauer, 1884  
*mesopotamica* Breuning, 1948  
*\*waltli* Sama, 1991
- Subgenus *Phytoecia* Dejean, 1835  
*\*asiatica asiatica* Pic, 1891  
*\*caerulea bethseba* Reiche et Saulcy, 1858  
*\*caerulea caerulea* (Scopoli, 1772)  
*kabateki* Sama, 1997  
*\*manicata* Reiche et Saulcy, 1858  
*\*pubescens* Pic, 1895  
*\*rufipes latior* Pic, 1895  
*\*virgula* (Charpentier, 1825)
- Genus *Pilemia* Fairmaire, 1864  
*\*griseomaculata* Pic, 1891  
*\*hirsutula hirsutula* (Frölich, 1793)  
*\*vagecarinata* Pic, 1952



Figs. 1–3. Akbes (now Akbez), Hatay province (SE Turkey).

Genus *Pygoptosia* Reitter, 1895  
 \**speciosa* (Frivaldszky, 1884)

Tribe Pogonocherini Mulsant, 1839

Genus *Exocentrus* Dejean, 1835  
 \**adpersus* Mulsant, 1846  
 \**ritae* Sama, 1985

Genus *Pogonocherus* Dejean, 1821  
 \**anatolicus* K. Daniel et L. Daniel, 1898  
 \**barbarae* Rapuzzi et Sama, 2012

Tribe Pteropliini J. Thomson, 1860

Genus *Niphona* Mulsant, 1839  
 Subgenus *Niphona* Mulsant, 1839  
 \**picticornis* Mulsant, 1839

Tribe Saperdini Mulsant, 1839

Genus *Saperda* Fabricius, 1775  
 \**quercus ocellata* Abeille de Perrin, 1895

Tribe Tetrocini Portevin, 1927

Genus *Tetrops* Stephens, 1829  
 \**praeustus praeustus* (Linnaeus, 1758)

### Notes on the checklist

The records of *Prionus coriarius* (Linnaeus, 1758) (Löbl & Smetana, 2010) need to be confirmed. It is more likely that all the records of *Deilus fugax* (Oliver, 1790) must be referred to the recently described species *D. kadleci rugosicollis* Rapuzzi et Sama, 2012. *Dorcadion boucardi* and *Do. syriense* Breuning, 1943 are described from Amanos Mountains (Turkey) and never reported from Syria, so they are extraneous to the Syrian fauna. The real status of *Do. koechlini* Pic, 1898 needs to be checked. It was described from "Syria" by Pic (1898) and compared with *Do. triste* Frivaldsky, 1845. Later Breuning (1962) transferred it as a "morpha" of *Do. divisum* Germar, 1839.

*Stenopterus atricornis* Pic, 1891 is recorded for the first time from Syria on the basis of specimens preserved in Kadlec collection (National Museum Praha, Czech Republic) with the following data:

"W Syria: 28 Km S Jisr ash Sughur, Qal at Burzay, 4.VI.1999, Kadlec lgt."

Some species were erroneously recorded from Syria, e.g. *Rosalia alpina syriaca* Pic 1895, 1892; *Stictoleptura scutellata inscutellata* (Pic, 1892); *Isotomus syriacus* (Pic, 1902) and so on, because the type locality "Syria, Akbes". It is due to a mistake in the correct identification of this locality. For long time it was regarded as village somewhere in Syria but only recently right situated in Turkey.

Akbes (now Akbez) is a small village in Hatay province (SE Turkey) not far from the Syrian border and here, in the 1881, was build an abbey (Notre-dame-des-Neiges) by several french trap-pist monks. One of them was father Delagrange, entomologist, that for long time collected insects in the area around the abbey and sent them to European specialists (Pic and Reitter for example) who described many new taxa from his stuff. This abbey was abandoned during the First World War and the monks went back to France. In that time this territory was under the Ottoman administration inside the Alep province. After the war the abbey started again its activity but, during the kurdisch revolt in 1926, was definitively destroyed and closed.

One of the authors (P. Rapuzzi) had the opportunity to travel several times in that area and found the correct place of this abbey, now presidium of the red crescent. Of the old abbey remains only the stone walls and the orchards (Figs. 1–3). The place now is called Salman Uşağı and is located close to the village of Akbez (Hatay province).

### ACKNOWLEDGEMENTS

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## Seasonal biodiversity of cyanobacteria in besmirched habitats

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### ABSTRACT

Cyanobacteria inhabit a diverse range of ecosystems, a number of features often contribute to their success. Growth of these organisms in many ecosystems is limited by the availability of nutrients. High load of solids, carbon and nutrients indicate proliferation of cyanobacteria, while low nutrient condition diminishes cyanobacterial growth. This study examines cyanobacterial diversity in domestic and hospital sewage of Sagar, Madhya Pradesh (M.P), India, from January 2013 to December 2013. Cyanobacterial biodiversity was higher during study period and dominated by *Aphanocapsa*, *Chroococcus*, *Phormidium* and *Nostoc* species. The present investigation exhibits a baseline of information on cyanobacterial diversity associated with wastewater under the influence of urbanization. Massive urbanizations in developing countries have polluted fresh water bodies and terrestrial areas nearby. This information can be utilized to identify cyanobacterial species for bioremediation of sewage. There are a number of Cyanophyceae members which are tolerant to organic pollution and resist environmental stress by pollutants. These species may be further used as pollution indicators for such habitats. Cyanobacterial species can constrain future pollution and can play a key role to accomplish the dream of pollution-free environment.

### KEY WORDS

Biodiversity; bioremediation; cyanobacteria; urbanization.

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### INTRODUCTION

Nowadays, water pollution is a serious concern; due to unplanned urbanization and industrialization most of the resources have reached to a point of crisis. Dumping of different waste materials in different drainage systems pollutes aquatic bodies and surrounding terrestrial environment, thus affecting the growth of vegetation and aquatic life.

Cyanobacteria are common components of phytoplanktonic community in most aquatic ecosystems. The ecophysiology of cyanobacteria can provide them with a substantial advantage over other phytoplanktons. The recent studies on cy-

anobacteria have emphasized their important role in ecosystems. The abundance and composition of cyanobacterial population in surface waters of ponds and lakes have been discussed by many studies. Cyanobacteria flourish well either in nutrients-rich warm water or, at times, in water with apparently low temperature and bright light conditions (Philipose, 1960; Seenayya, 1972; Fogg, 1975). The number of water bodies suffering from eutrophication is increasing around the world. Such an eutrophication primarily comes from municipal wastewater, agricultural runoff, domestic sewage, stability of water column and increased light exposure.

Cyanobacteria are pioneer oxygenic, gram negative, photosynthetic prokaryotes and are widely distributed. The cyanobacterial diversity of sewage can be used as biomonitor of organic pollution load in other water habitats and surroundings. Cyanobacterial community structure was found to be influenced by anthropogenic activities. The use of cyanobacteria as an indicator of water quality and pollution has been emphasized by Venkateswarlu (1981). Only a few researchers (Manoharan & Subramanian, 1992a, b; Boominathan, 2005; Vijayakumar, 2005) have investigated the effect of effluents on the physiology and biochemistry of the cyanobacterial systems.

To develop suitable and an efficient wastewater treatment system, it is obligatory to understand the mutual influence and interactions between the effluents and the organisms, so that manipulations to improve the treatment system may become feasible and hence the future scenario must select suitable species of cyanobacteria which would be minimally influenced by the adverse conditions in the effluent, but would help removing pollutants maximally (Singh & Saxena, 1969; Rai & Kumar, 1979; Sahai et al., 1985; De la Noue & Proulx, 1988; Wilkinson et al., 1989).

Sagar, located in Bundelkhand region of Madhya Pradesh, has exhibited urbanization rapidly in last few years. It has a lake, Lakha Banjara, lying in the middle of the city, which has become a besmirched aquatic habitat. During the past few decades, partially treated and untreated wastewaters were discharged into the lake and surrounding crop-lands and used for agriculture, pisciculture and other domestic purposes. Keeping the above facts in view, the present study was aimed at the analysis of physico-chemical properties of wastewater in relation to cyanobacterial diversity.

## MATERIAL AND METHODS

### *Sampling sites*

District Sagar is situated in the north central region of Madhya Pradesh, India, and lies between the north latitude 23°10' to 24°27' and east longitude 78°4' to 79°21' at an altitude of 1758 feet above the sea level. A number of temporary and residential water bodies are present in this region.

The city harbours a shallow rained fresh water lake, Lakha Banjara (23°49'N and 78°44'E) with small catchment. A hot summer and general dryness characterize the climate of the area. The climate of Sagar can be categorized as "monsoon type" and commences from mid June and continues till September. This period is distinguished by heavy rains, high temperatures and relatively high humidity. About 90% of the annual rainfall is received during this period. The monsoon is followed by a brief post-monsoon period October to November, when temperature remains high and the humidity decreases considerably; only a nominal precipitation occurs and wind velocity is also lower. Winter starts from late November and continues up to February. It is characterized by low temperature, low irradiant and moderate relative humidity. The average annual rainfall varies from 565 mm to 1680 mm. The maximum temperature recorded was 44.8 °C in the month of May and the minimum temperature was 5 °C in January (IMD, 2013). Keeping in mind inflow sources of wastewater, present study was carried out at the besmirched sites of Lakha Banjara Lake viz. Site 1, Site 2 and Site 3.

Sites are subjected to human interferences and receive discharges from the surrounding localities which make the water highly polluted and pollutants like domestic sewage, straw, hospital discharge and industrial effluent etc. get accumulated in large quantities.

### *Collection of sample*

The wastewater samples were collected in triplicates (2 liters each) from each of the three sites in sterilized colored plastic bottles (Tarsons Products Pvt. Ltd., New Delhi, India) from January 2013 to December 2013 in every month of all seasons Winter (W), Summer (S) and Rainy season (R). Samples were taken in the mid of the each month in bottles thoroughly cleaned with diluted HCl (AR grade, 99.9% Merck Pvt. Ltd., Mumbai, India) and rinsed with distilled water twice, dried in an oven (Yarco) and then analyzed for various physico-chemical parameters.

### *Physico-chemical study*

Physico-chemical analysis of waste water was

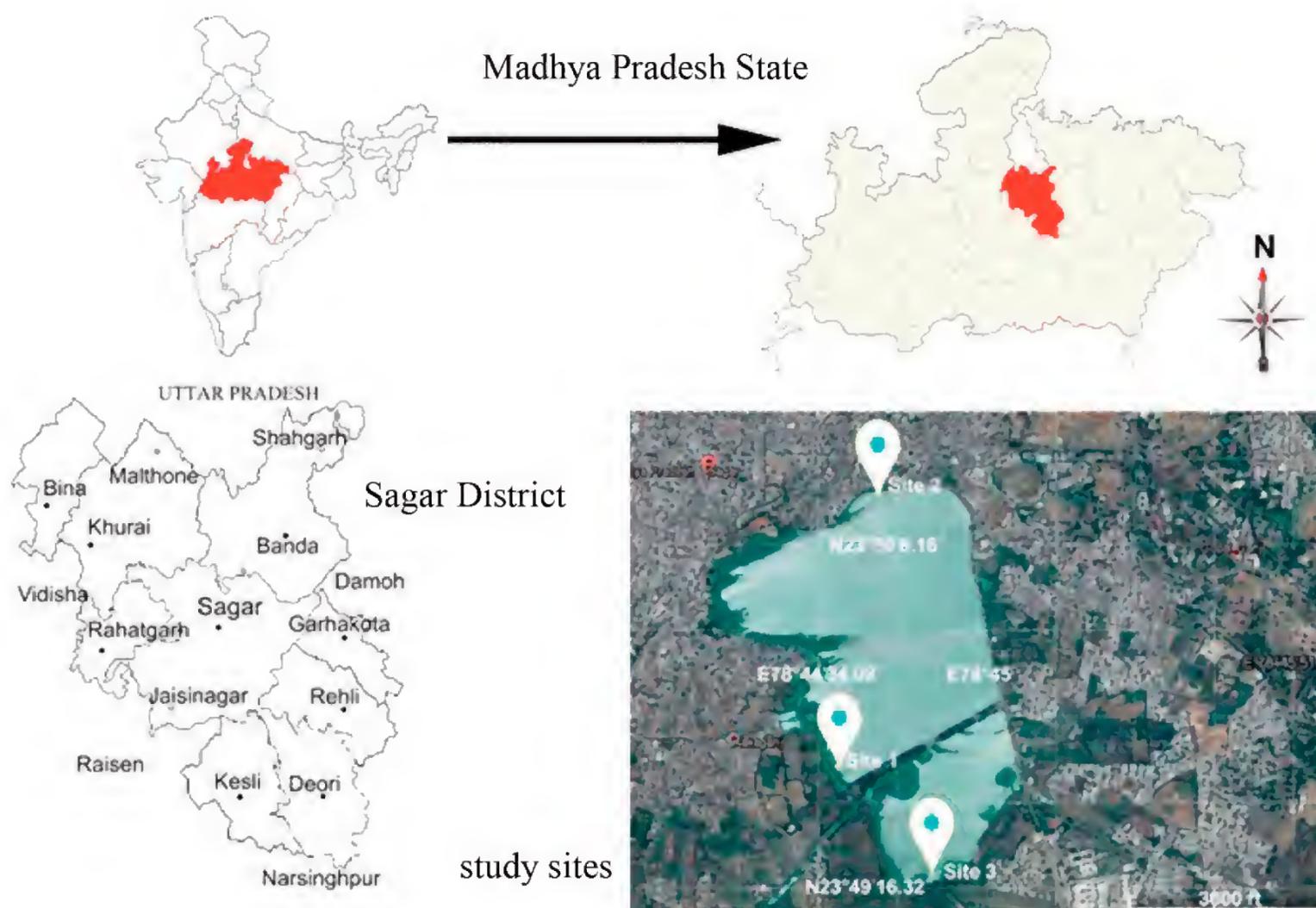


Figure 1. Map showing the locations of three different sampling sites of Sagar District, Madhya Pradesh State in India.

performed as per the standard methods of Adoni (1985) and APHA (2005). Turbidity (Turb), Dissolved Oxygen (DO), pH and temperature (Temp) were recorded onsite during collection of samples. pH, Temp and Total Dissolved Solids (TDS) were recorded with the help of digital meters. Turbidity was measured by Secchi disk method (Cialdi & Secchi, 1865). Water samples were taken directly from the sites into Biological Oxygen Demand (BOD) bottles for BOD and DO, and fixed instantly with manganese sulphate and alkaline iodide azide. They were analyzed immediately for DO and after five days for BOD as per Winkler's Modified method (APHA, 2005). Chemical Oxygen Demand (COD) was estimated by Close reflux method. Alkalinity (Alk) and Hardness (HN) were determined by Titrimetric method as per APHA (2005). Phosphate (Ph) and nitrate (N) were carried out by the Molybdophosphoric acid method and Brucine method respectively (APHA, 2005).

### ***Cyanobacterial quantification***

Samples were collected from each of three experimental sites and fixed with 1% Lugol's iodine solution (AR grade, 99.9% Merck) for cyanobacterial quantification. Serial dilutions were prepared for enumeration of Most Probable Number (MPN) of cyanobacteria (Buchanan & Fulmer, 1928) and tabulated.

### ***Isolation of cyanobacteria***

One ml of sample was added to agar plates made with 25 ml of sterilized BG-11 media (Rippka et al., 1979) and Chu No.-10 (Chu, 1942) in petri dishes and simultaneously one ml of sample was inoculated in 50 ml of sterilized BG-11 and Chu No.-10 broth media in flask. After inoculation samples were incubated for 45 days at 2500 lux light intensity for 16 hours and 8 hours of dark

interval at temperature  $25 \pm 2$  °C. After 12 days of incubation, cyanobacterial colonies appeared on the agar plates and on broth media in flasks. Isolated species further spread on to fresh agar plates. After the development, colonies appearing in agar plates were examined microscopically and transferred to agar slants. This process was repeated until axenic cultures were obtained.

### Microscopic analysis

Cyanobacterial species were observed under microscope for morphometric analyses. Camera lucida drawings were prepared and taxonomically important data such as trichome shape, filament color, akinetes and heterocyst shape, size, position and number were recorded. Identification of cyanobacteria was done using the keys given by Desikachary (1959) and Komarek & Anagnostidis. (1986; 1989).

### Data analysis

Following formulae were applied for data analysis

Frequency of occurrence (FO)

$$FO = \frac{\text{Number of samples containing the species}}{\text{Total number of samples examined}} \times 100$$

Relative Frequency (RF)

$$RF = \frac{\text{Number of samples containing a species}}{\text{Total number of occurrence of all the species}} \times 100$$

Relative Density (RD)

$$RD = \frac{\text{Number of CFU of a species in all samples}}{\text{Total number of CFU all the species in all the samples}} \times 100$$

Relative Abundance (RA)

$$RA = \frac{\text{Number of samples containing the species}}{\text{Total number of occurrence of all the species}} \times 100$$

Diversity index- Shannon-Wiener diversity index (Shannon, 1948)

$$H = - \sum_{i=1}^S (P_i)(\ln P_i)$$

Where,

H - Shannon-Wiener diversity index

S - The number of species in the sample

P<sub>i</sub> - The relative abundance of each group of organisms

N - Total number of individuals of all kinds

n<sub>i</sub> - Number of individuals of i<sup>th</sup> species

### Statistical analysis

The samples were analyzed in triplicates and a computer statistical software was used to calculate minimum and maximum mean with standard error. To understand the influence of seasonal physico-chemical properties of sampling sites on cyanobacterial diversity, correlation analyses and comparisons among them were performed using IBM SPSS-16.0 with level of significance maintained at 95% for each operation.

## RESULTS

During the present investigation water samples were collected in three seasons i.e. Winter, Summer and Rainy season from three sewage sites associated with lentic water body. Cyanobacterial species were observed microscopically and further illustrated with the help of camera lucida. Taxonomical characteristics such as presence of heterocysts, akinetes, hormogonia and size of vegetative cells etc. were studied. During the study period, a total of 45 species from 24 different cyanobacterial genera were isolated (Table 1). Of these 45 species, 9 were unicellular, 4 non-heterocytous filamentous and 32 heterocytous filamentous forms.

Genera belonging to orders Chroococcales and Nostocales showed the highest relative abundance in all three sites. Relative abundance of *Hydrococcus rivularis* Kützing, 1833 was exceptionally high at Site 3. Relative abundances of the two species of *Haplosiphon* were high at Site 1 and Site 2. The presence of *Chroococcus indicus* Zeller, 1873 was observed in all seasons at all three sites. *Aphanocapsa* spp., *Gleocapsa* spp. and *Phormidium* spp. were recorded at all sites in all seasons.

The pH is one of major characteristics which determine the growth of cyanobacteria (see Verma & Mohanty, 1995; Prasanna & Nayak, 2007). In all the study, pH of water was in the alkaline mean range of 7.50 to 8.50 in all seasons at all the sites shown in figure 1.

Generally speaking, water temperature plays an important role either in controlling the occurrence and abundance of phytoplankton (Nazneen, 1980) or in regulating the periodicity of cyanobacteria (Mahar et al., 2009). In this study, temperature values were minimum in rainy season at Site 1 with an

average of 19.7°C and maximum with an average of 29.7°C in summer season (Fig 2).

Maximum Turbidity of 39.8 NTU was recorded in rainy season at site 1 and minimum, 16.9 NTU, in summer at site 2. Turbidity is also a limiting factor of productivity because it affects light penetration (Semila Pushpam et al., 2014). Maximum TDS was recorded in pre-monsoon season with an average of 414 mg L<sup>-1</sup> at site 2 and minimum of 289 mg L<sup>-1</sup> at Site 1 (Fig 2). According to Goher (2002) TDS is a chemical constituent of water and contributes to productivity within water body. Due to high load of nutrients, an enhanced growth of cyanobacterial flora was noticed during pre and post-monsoon period. The high amount of TDS during pre-monsoon season might be due to the increase in the rate of evaporation. High concentration of TDS is an indication of nutrients enrichment leading to eutrophication (Gonzalves et al., 1946). Besides it, high level of alkalinity indicates the pollution level of surrounding of lentic water body. Among all sites, maximum alkalinity (461 mg L<sup>-1</sup>) was recorded at Site 1 in winter season and minimum values (289 mg L<sup>-1</sup>) at Site 2 in rainy season (Fig. 2). According to Solanki et al. (2010), decomposition of sewage materials coupled with mixing of garbage and industrial effluent increase the level of alkalinity in waste water bodies.

DO was lowest (3.30 mg L<sup>-1</sup>) at Site 1 in winter season and highest (4.70 mg L<sup>-1</sup>) in rainy season at Site 3 (Fig. 3). With an increase in water temperature, the DO was reduced in summer, whereas the DO was maximum during monsoon due to low temperature and increased mixing of waters. As per Central Pollution Control Board (CPCB), India (CPCB, 2010) threshold level of DO is 4.0 mg L<sup>-1</sup> for supporting aquatic lifes. Very low DO indicates limited growth of aquatic flora, irrespectively of heavy load of nutrients.

The maximum value of BOD (22.28 mg L<sup>-1</sup>) was recorded during summer at Site 3 and the minimum one (12.75 mg L<sup>-1</sup>) at Site 2 in rainy season (Fig. 3). High BOD in summer could be due to high evaporation and elevated temperature coupled with effluent of organic pollution load and reduced water inflow.

Discharge of treated and untreated sewage and other waste into the water body led maximum COD value up to 49.22 mg L<sup>-1</sup> at Site 3 in winter and min-

imum, 28.35 mg L<sup>-1</sup>, at Site 2 in summer (Fig. 3). According to Tiwari (2001) hardness of water, mainly due to presence of calcium and magnesium content, indicates water quality. Maximum hardness (178.44 mg L<sup>-1</sup>) was recorded at Site 1 in summer season and minimum (64.9 mg L<sup>-1</sup>) at Site 2 in rainy season.

According to Gupta & Dubey (2014) phosphate gets accumulated in sewage due to excessive use of detergent. Maximum of phosphate (0.40 mg L<sup>-1</sup>) was estimated at Site 1 in rainy season and minimum (0.15 mg L<sup>-1</sup>) at Site 3 in winter. The maximum nitrate value, 20.8 mg L<sup>-1</sup> at Site 3 in summer, can be attributed to effluent; whereas the minimum value (7.9 mg L<sup>-1</sup> at Site 1 in rainy season) might be due either to mixing of waters or biological nitrogen fixation by cyanobacteria. At site 1 a maximum mean value of cyanobacterial count (6650.3) in summer, and a minimum (1826.8) at site 2 in rainy season, were recorded. The minimum TN/TP ratio (8.1) was recorded in winter at site 2 and the maximum (20) at site 3 in summer. TN/TP ratio plays an important role in cyanobacterial diversity.

The correlation between the different physico-chemical parameters of Site 1, Site 2 and Site 3 is given in Tables 2–4. pH is positively correlated with TCC at all three sites. pH is statistically ( $p < 0.01$ ) higher during summer season and no significant difference was noted among the sites. Temperature is the main factor influencing the species richness and diversity of phytoplankton. Temperature values showed variation among sampling sites. Statistically ( $p < 0.01$ ), Site 1 temperature was higher than Site 2 and Site 3. Tables 2 to 4 show an inverse relationship between DO and temperature. Alkalinity showed significantly difference ( $p < 0.01$ ) in pH within Site 1 and slightly differences were noted among the sites. BOD and nitrate show significant differences (Annova test,  $p < 0.05$ ) with respect to the TCC during the seasons within sites. There was no significant difference ( $p < 0.05$ ) in hardness considering the seasons and sampling sites. Annova at  $p < 0.05$  shows significant differences in BOD and COD values during the seasons within the sites. COD shows significantly differences in the COD during the seasons within the sites. TCC shows significant differences at  $p < 0.05$  within the sites during the seasons and shows significant differences with DO and COD during seasons within sites.

Agarkar (1998) and Nair (1999) reported variation in correlation of the physico-chemical parameters and phytoplankton. In our present study both heterocystous and nonheterocystous forms are found in wastewater, while Rai & Kumar (1976) did not find heterocystous cyanobacteria in polluted water. Our observations of presence of nonheterocystous genera such as *Oscillatoria*, *Phormidium*, *Gleocapsa* and *Chroococcus* are in line with previous results (Palmer, 1969; Ghadai

et al., 2010).

Diversity indices of different genera of cyanobacterial populations were calculated with the aid of Shannon Wiener index (see Table 4). Genus *Chroococcus* had the highest diversity index (8.30) at Site 3, while *Aphanothece* and *Anabaenopsis* had the same lowest diversity index (0.03) at Site 3. *Aphanocapsa*, *Anabaena*, *Anabaenopsis*, *Aulosira*, *Haplosiphon* and *Phormidium* showed diversity indices between 2 to 3.

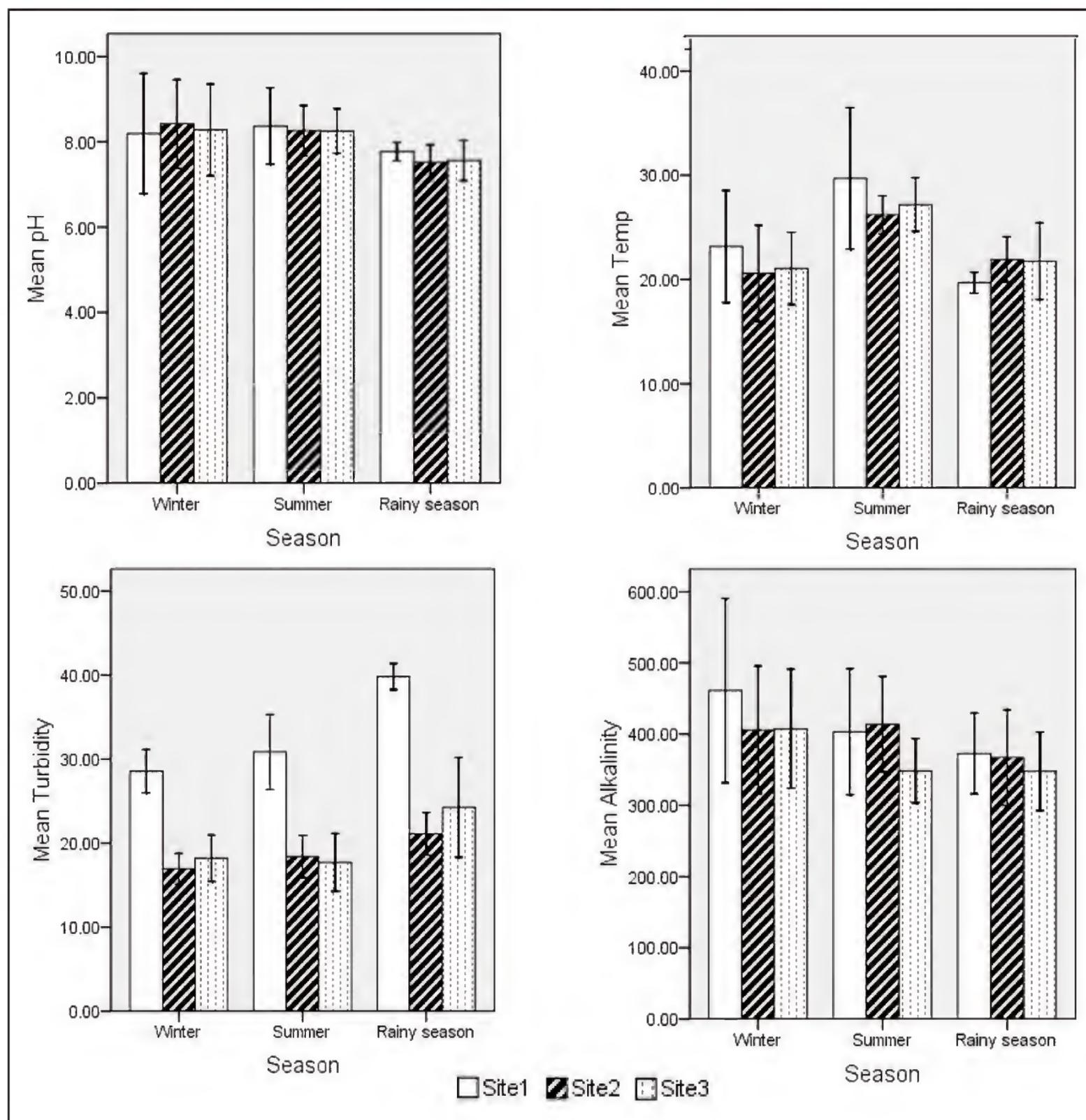


Figure 2. Seasonal variation of mean pH, Temperature, Turbidity and Alkalinity of three waste watersites.

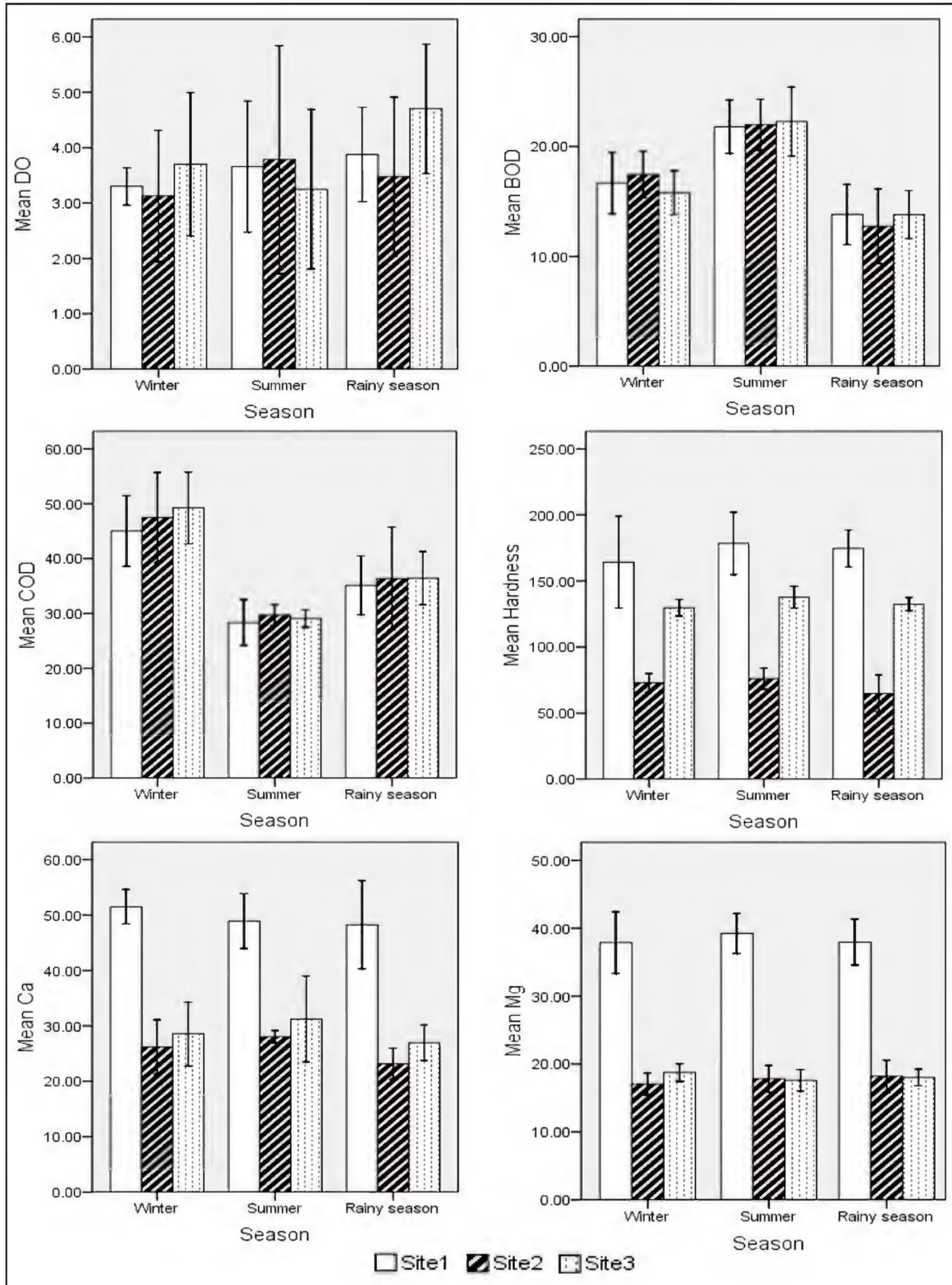


Figure 3. Seasonal variation of mean DO, BOD, COD, Total Hardness with Ca and Mg of three wastewater sites.

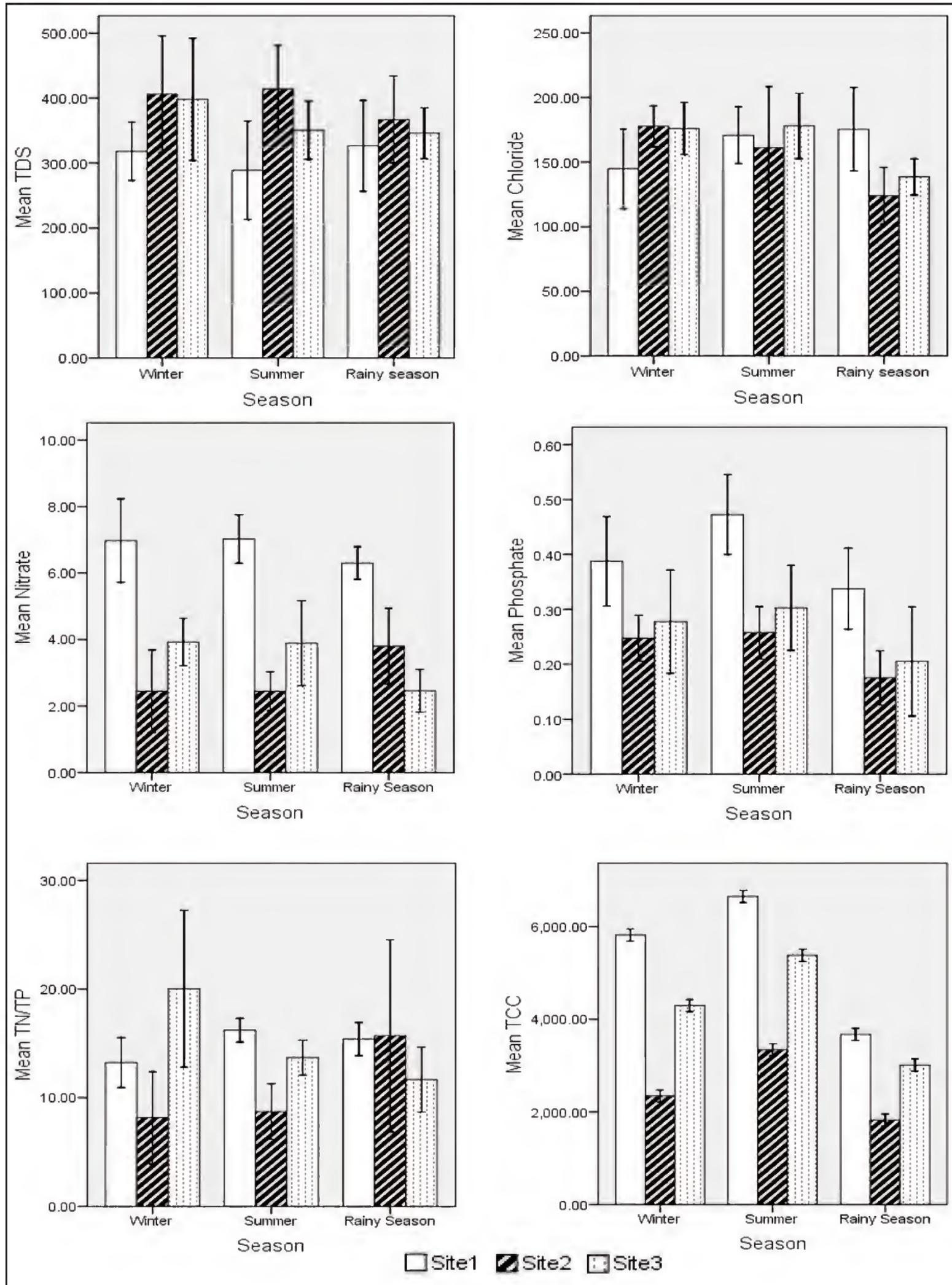


Figure 4. Seasonal variation of mean TDS, Chloride, Phosphate, Nitrate, TN/TP and Total cyanobacterial count (TCC) of three wastewater sites.

	Species	SITE 1			SITE 2			SITE 3			SITE 1				SITE 2				SITE 3			
		W	S	R	W	S	R	W	S	R	F	RF	RD	RA	F	RF	RD	RA	F	RF	RD	RA
1	<i>Anabaena azollae</i>	+	+	+	+	+	+	-	+	+	96.30	3.99	1.74	1.05	55.56	1.20	0.31	0.54	0	0.00	0.00	0.00
2	<i>Anabaenopsis arnoldii</i>	-	+	+	-	-	+	-	-	+	88.89	3.69	2.45	1.61	51.85	1.45	0.39	0.55	7	0.56	1.02	3.09
3	<i>Aphanocapsa biformis</i>	+	+	+	+	+	-	+	-	-	92.59	3.84	0.63	0.40	85.19	6.02	1.16	0.43	81	6.16	1.06	0.29
4	<i>Aphanocapsa koordersi</i>	+	+	+	+	+	-	+	-	-	25.93	1.08	0.32	0.72	18.52	1.69	0.85	1.04	30	2.24	0.42	0.32
5	<i>Aphanocapsa littoralis</i>	-	+	+	-	+	-	-	-	-	18.52	0.77	0.43	1.34	22.22	3.61	1.37	0.78	33	2.52	2.04	1.37
6	<i>Aphanothece microscopic</i>	+	+	-	+	+	-	+	-	-	29.63	1.23	0.47	0.93	25.93	3.37	2.59	1.59	26	1.96	3.69	3.18
7	<i>Aulosira fertilissima</i>	+	+	-	-	+	-	+	-	-	62.96	2.61	0.39	0.36	29.63	1.93	1.24	1.33	7	0.56	0.10	0.31
8	<i>Calothrix castellii</i>	+	+	+	-	+	-	-	+	-	66.67	2.76	0.80	0.70	7.41	0.48	0.38	1.64	4	0.28	0.48	2.88
9	<i>Calothrix marchica</i>	+	+	+	-	-	-	-	+	-	55.56	2.30	1.33	1.39	0.00	0.00	0.00	0.00	11	0.84	0.16	0.32
10	<i>Calothrix parietina</i>	+	+	-	-	-	+	-	+	-	62.96	2.61	0.41	0.38	3.70	0.24	0.35	3.03	11	0.84	0.44	0.88
11	<i>Chloroglea fritschii</i>	-	+	-	-	+	-	-	+	-	22.22	0.92	0.44	1.15	3.70	0.24	0.26	2.20	4	0.28	0.06	0.37
12	<i>Chroococcus disperses</i>	+	+	+	+	+	+	+	+	+	51.85	2.15	0.35	0.39	55.56	6.27	5.45	1.80	89	6.72	4.40	1.11
13	<i>Chroococcus indicus</i>	+	+	+	+	+	+	-	-	+	77.78	3.23	6.27	4.68	96.30	5.30	6.99	2.72	30	2.24	4.17	3.15
14	<i>Chroococcus micrococcus</i>	+	+	+	+	+	+	+	+	-	70.37	2.92	4.70	3.89	51.85	4.82	5.85	2.51	33	2.52	4.71	3.16
15	<i>Chroococcus minor</i>	+	+	+	-	+	+	+	-	-	70.37	2.92	5.50	4.54	59.26	3.37	5.81	3.56	26	1.96	5.96	5.15
16	<i>Chroococcus tenax</i>	+	+	+	-	+	+	-	+	+	96.30	3.99	5.14	3.10	59.26	3.86	2.48	1.33	30	2.24	6.97	5.26
17	<i>Chroococcus turgidus</i>	+	+	+	-	+	+	-	-	+	88.89	3.69	4.70	3.36	81.48	3.86	3.95	2.11	22	1.68	3.14	3.16
18	<i>Chroococcus varius</i>	+	+	+	-	+	+	+	+	+	92.59	3.84	12.53	7.87	74.07	2.89	7.44	5.32	63	4.76	1.88	0.67
19	<i>Gleocapsa atrata</i>	+	+	-	-	+	+	-	+	-	77.78	3.23	5.00	3.74	44.44	3.61	4.25	2.43	11	0.84	0.44	0.89
20	<i>Gleocapsa calcarea</i>	+	+	+	+	-	-	+	+	-	55.56	2.30	4.67	4.88	3.70	0.24	0.29	2.48	15	1.12	5.92	8.94
21	<i>Haplosiphon flagelliformis</i>	+	+	-	+	-	+	+	+	-	66.67	2.76	2.82	2.46	44.44	2.89	4.66	3.33	30	2.24	3.57	2.70
22	<i>Haplosiphon luteolus</i>	+	+	+	-	+	-	+	+	-	48.15	2.00	4.86	5.86	25.93	1.69	3.83	4.69	33	2.52	6.16	4.13
23	<i>Homoeothrix juliana</i>	+	+	+	-	+	-	+	+	-	59.26	2.46	2.51	2.46	33.33	0.24	0.39	3.31	15	1.12	2.38	3.60

Table 1. Diversity of cyanobacteria in three different wastewater sites.  
For the explanation of the abbreviations see in the text.

	Species	SITE 1			SITE 2			SITE 3			SITE 1				SITE 2				SITE 3			
		W	S	R	W	S	R	W	S	R	F	RF	RD	RA	F	RF	RD	RA	F	RF	RD	RA
24	<i>Hydrococcus rivularis</i>	+	+	+	-	+	-	+	+	-	44.44	1.84	1.88	2.46	3.70	2.17	4.09	3.90	4	0.28	3.18	19.20
25	<i>Johannesbaptisia pellucida</i>	+	+	+	-	+	-	+	+	-	25.93	1.54	1.10	2.46	3.70	0.24	0.15	1.27	7	0.56	1.39	4.20
26	<i>Lyngbya aerugineo-coerulea</i>	+	+	+	+	-	+	+	+	-	33.33	1.38	1.41	2.46	66.67	4.34	0.72	0.34	33	2.52	1.79	1.20
27	<i>Lyngbya palmarum</i>	+	-	+	+	-	+	+	-	-	7.41	0.31	0.17	1.35	3.70	4.34	1.63	0.78	26	1.96	0.41	0.35
28	<i>Mastigocladus laminosus</i>	+	-	+	+	-	-	+	-	-	7.41	0.31	0.19	1.48	22.22	0.24	0.18	1.55	15	1.12	0.22	0.33
29	<i>Merismopedia glauca</i>	+	+	-	+	-	+	-	-	+	18.52	0.77	0.32	1.01	66.67	1.20	0.53	0.90	7	0.56	0.21	0.64
30	<i>Microcoleus chthonoplastes</i>	+	-	+	+	-	+	-	-	+	11.11	0.46	0.17	0.87	18.52	0.96	0.90	1.92	7	0.56	0.26	0.78
31	<i>Microspora tumidula</i>	+	+	-	-	-	+	-	-	+	7.41	0.31	0.20	1.59	14.81	1.45	0.30	0.43	7	0.56	0.24	0.72
32	<i>Myxosarcina burmensis</i>	+	-	-	-	-	+	-	-	-	3.70	0.15	0.15	2.35	3.70	0.24	0.37	3.15	0	0.00	0.00	0.00
33	<i>Nodularia spumigena</i>	+	+	+	+	-	-	-	-	+	40.74	1.69	1.57	2.24	14.81	0.96	0.78	1.67	30	2.24	1.99	1.50
34	<i>Nostoc calcicola</i>	+	+	+	+	-	-	-	+	+	62.96	2.61	2.66	2.46	25.93	1.69	2.84	3.47	63	4.76	3.37	1.20
35	<i>Nostoc carneum</i>	+	+	+	+	-	+	-	+	+	59.26	2.46	2.51	2.46	48.15	3.13	4.29	2.83	67	5.04	3.18	1.07
36	<i>Nostoc linckia</i>	+	+	+	+	-	+	-	+	+	51.85	2.15	2.19	2.46	55.56	3.61	4.54	2.60	52	3.92	2.78	1.20
37	<i>Nostoc paludosum</i>	+	+	+	-	-	+	-	+	-	40.74	1.69	1.72	2.46	44.44	2.89	1.03	0.74	33	2.52	2.18	1.47
38	<i>Nostoc spongiaeformae</i>	+	+	+	-	+	-	+	+	-	66.67	2.76	3.29	2.87	18.52	1.20	0.81	1.39	59	4.48	4.17	1.57
39	<i>Oscillatoria angusta</i>	+	+	+	+	-	-	+	+	-	62.96	2.61	2.04	0.19	3.70	0.24	0.18	1.52	30	2.24	2.58	1.95
40	<i>Oscillatoria tenuis</i>	+	+	-	-	-	+	+	+	-	48.15	2.00	1.88	2.27	11.11	1.45	2.62	3.75	30	2.24	1.59	1.20
41	<i>Oscillatoria willei</i>	+	+	-	-	+	-	-	+	-	55.56	2.30	1.25	1.31	22.22	0.72	1.69	4.84	26	1.96	2.38	2.06
42	<i>Phormidium dimorphum</i>	+	+	-	+	+	-	-	+	-	66.67	2.76	1.74	1.52	40.74	2.65	2.69	2.10	33	2.52	2.20	1.48
43	<i>Phormidium jenkelianum</i>	+	+	+	-	+	-	+	+	+	96.30	3.99	2.33	1.41	33.33	2.17	1.44	1.38	96	7.28	2.96	0.69
44	<i>Phormidium molle</i>	+	+	+	+	+	+	-	+	-	66.67	2.76	2.02	1.76	40.74	0.72	1.82	5.19	56	4.20	0.79	0.32
45	<i>Phormidium purpurascens</i>	+	+	+	-	+	-	+	+	+	40.74	1.69	0.63	0.89	11.11	2.65	4.86	3.79	30	2.24	2.56	1.93

Table 1. Diversity of cyanobacteria in three different waste watersites.  
For the explanation of the abbreviations see in the text.

	pH	Temp	Turb	Alk	TDS	DO	BOD	COD	HN	Ca	Mg	N	Chl	Ph	TCC	TNIP
pH	1															
Temp	0.783**	1														
Turb	-0.129	-0.279	1													
Alk	0.749**	0.453	-0.369	1												
TDS	-0.226	-0.413	0.070	-0.034	1											
DO	-0.346	-0.416	0.155	-0.115	0.333	1										
BOD	0.250	0.669*	-0.550	0.165	-0.306	-0.429	1									
COD	-0.236	-0.358	-0.139	-0.069	0.238	0.073	-0.519**	1								
HN	0.192	0.077	0.146	-0.193	0.194	-0.285	0.169	-0.399**	1							
Ca	-0.293	-0.188	-0.173	-0.099	0.503	0.331	-0.207	0.564	-0.494	1						
Mg	0.171	0.259	-0.111	0.206	-0.238	-0.171	0.314	-0.111	-0.395	0.306	1					
N	0.533	0.724**	-0.710**	0.450	-0.215	-0.492	0.791**	-0.176	0.076	0.083	0.480	1				
Chl	-0.134	0.081	0.181	-0.431	0.185	0.257	0.230	-0.444	0.341	-0.159	-0.094	-0.108	1			
Ph	-0.580*	-0.574	0.217	-0.502	0.194	0.193	-0.426	0.442	-0.057	0.074	-0.443	-0.508	0.177	1		
TCC	0.296	0.644*	-0.839**	0.231	-0.242	-0.233	0.749**	-0.130	-0.018	0.121	0.134	0.826**	0.038	-0.365	1	
TNIP	-0.018	-0.476	0.260	0.284	0.380	0.253	-0.582*	0.494	-0.110	0.071	-0.069	-0.391	-0.300	0.333	-0.647*	1

Table 2. Correlation between the physico-chemical parameters of Site 1. For abbreviations see in the text.

	pH	Temp	Turb	Alk	TDS	DO	BOD	COD	HN	Ca	Mg	N	Chl	Ph	TCC	TNIP
pH	1															
Temp	0.434	1														
Turb	-0.428	0.125	1													
Alk	0.696*	0.262	-0.399	1												
TDS	0.129	-0.394	0.047	-0.047	1											
DO	0.099	0.206	-0.465	0.457	-0.258	1										
BOD	0.657*	0.551	-0.437	0.489	-0.239	0.037	1									
COD	-0.177	-0.785**	-0.356	-0.194	0.160	-0.138	-0.342	1								
HN	0.156	0.189	-0.294	0.341	-0.158	-0.030	0.434	-0.051	1							
Ca	0.381	-0.058	-0.592*	0.386	0.021	0.171	0.500	0.167	0.069	1						
Mg	-0.358	-0.251	0.110	0.079	-0.464	-0.180	0.009	0.226	0.180	0.046	1					
N	0.773**	0.453	0.535	0.267	0.002	0.009	0.779**	-0.128	0.204	0.409	-0.483	1				
Chl	0.644*	0.088	0.458	0.394	0.024	-0.015	0.337	0.247	0.145	0.397	-0.207	0.635*	1			
Ph	-0.194	-0.159	0.578*	-0.223	0.408	-0.633*	-0.393	-0.132	0.062	-0.313	0.091	-0.458	-0.331	1		
TCC	0.326	0.526	-0.412	0.241	-0.426	0.138	0.801**	-0.391	0.409	0.547	-0.032	0.650*	0.359	-0.455	1	
TNIP	-0.033	-0.344	0.122	0.270	-0.152	0.105	-0.322	0.276	-0.368	-0.276	0.474	-0.402	0.070	-0.083	-0.499	1

Table 2. Correlation between the physico-chemical parameters of Site 2. For abbreviations see in the text.

	pH	Temp	Turb	Alk	TDS	DO	BOD	COD	HN	Ca	Mg	N	Chl	Ph	TCC	TNIP
pH	1															
Temp	0.503	1														
Turb	-0.339	-0.145	1													
Alk	0.556	-0.110	-0.292	1												
TDS	0.077	-0.027	0.161	-0.213	1											
DO	-0.376	-0.429	0.459	-0.377	0.026	1										
BOD	0.489	0.572	-0.567	0.090	0.032	-0.294	1									
COD	-0.089	-0.652*	-0.090	0.322	-0.403	0.076	-0.578*	1								
HN	0.109	0.737**	-0.080	-0.251	-0.087	-0.377	0.256	-0.581*	1							
Ca	0.635*	0.684*	-0.258	0.316	0.077	-0.790**	0.321	-0.283	0.625*	1						
Mg	-0.432	-0.468	-0.048	0.065	-0.618*	0.420	-0.294	0.546	-0.331	-0.643*	1					
N	0.675*	0.499	-0.691*	0.314	-0.148	-0.534	0.838**	-0.172	0.177	0.453	-0.235	1				
Chl	0.698*	0.258	-0.590*	0.503	0.110	-0.609*	0.648*	-0.046	-0.070	0.462	-0.424	0.879**	1			
Ph	0.332	0.576*	0.252	0.082	0.344	-0.182	0.176	-0.553	0.464	0.592*	-0.502	-0.077	-0.075	1		
TCC	0.405	0.533	-0.710**	0.015	-0.309	-0.401	0.814**	-0.280	0.298	-0.111	0.884**	0.624	-0.235	-0.132*	1	
TNIP	0.085	-0.309	0.144	0.057	0.486	0.194	0.019	-0.199	-0.201	-0.113	-0.276	-0.164	-0.007	-0.180	0.402	1

Table 2. Correlation between the physico-chemical parameters of Site 2. For abbreviations see in the text.

## DISCUSSION AND CONCLUSIONS

Sagar lake had become hypertrophic due to unbalanced physical and chemical factors (Vaishya & Adoni, 1993) which raised the trophic level of water body. Cyanobacteria are important primary producers in food web in many aquatic environments. The present study reveals that the physico-chemical characteristics of wastewater determine the growth and diversity of cyanobacteria. Species belonging to the genera *Chroococcus*, *Gleocapsa*, *Haploisiphon* and *Phormidium* were dominant at all sites. These taxa are adapted to flourish under stress environment and are able to utilize high load of nutrients and immobilize pollutants. Our observation on presence of *Anabaena* spp., *Oscillatoria* spp. and *Nostoc* spp. in wastewater is in line with the findings of Deep et al. (2013). *Aphanocapsa* and *Anabaena* were found to be very frequent, which suggests their potential to exploit sewage waste. Availability of nitrate and phosphorus nutrients at Site 3 can justify the highest diversity of species. Increased nutrients such as nitrate, phosphate, chloride and temperature accelerated the growth of cy-

anobacteria. In fact, different physico-chemical properties effect relative frequency, relative density, relative abundance and occurrence of cyanobacteria. Species can tolerate fluctuation of available resources, predation and high load of chemical contaminants. Cyanobacterial flora of wastewaters should be defined genotypically and metabolically in their natural microbial community and anthropogenic stressed environment. High pH values accelerate the pollution rate in lake. pH 6-8.5 is ideal for planktonic growth (Veerendra et al., 2008). In present study pH 7-8 increased the growth of cyanobacteria in all 3 sites. Trophic level of water rises due to high alkalinity (Kumar & Sharma, 1991) and it favours abundance of cyanobacteria (Nandan et al., 2002). Alkalinity was high in summer at site 3 which induced the growth of cyanobacteria (Tiwari & Shukla, 2007); but other nutrients limited the growth as compared to the other two sites. High turbidity influences primary productivity because it affects the penetration of light in water body, moreover, causing particles to absorb phosphate, nitrogen and potassium in ionic form, turbidity limit the growth of phytoplankton

(Pandey et al., 1999). Phosphorus and nitrogen are limiting factors for the growth of cyanobacteria (Lapointe, 1989; Larned, 1998; Russ & McCook, 1999). Increasing nutrients availability at Site 1 in summer season resulted in a better growth of cyanobacteria (Miller et al., 1999). Agricultural runoff and domestic sewage from catchment area increase the phosphate level in Site 1, 2 and 3 during summer. These results imply that biodiversity of cyanobacteria was driven by local environmental factors such as temperature, pH, DO, nitrate and phosphorus contents.

Physico-chemical parameters and biological monitoring together provided evidence of evolution of microbes of polluted habitats. These species are stress tolerant, so they easily grow on these environments and can be further deployed for bioremediation and carbon sequestration purposes. Bloom forming species were also encountered near cultivated land and freshwater lake, thereby it is to be considered a threat for aquatic flora and fauna. The discharge of untreated wastewater nearby the lake area and agricultural land should be immediately stopped.

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## A new alien limpet for the Mediterranean: *Lottia* sp. (Patellogastropoda Lottiidae)

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### ABSTRACT

Some living specimens of a new limpet were found between January and August 2015 in the intertidal of the eastern coast of Sicily (Jonian Sea, Mediterranean). The study of the shell morphology and anatomical soft parts of these specimens has revealed fundamental differences compared with the native, mostly Patellidae, species. Further observations of the morphology of the radula led to the provisional identification of the newly introduced limpet as a Lottiidae, tentatively a *Lottia* sp. A more precise species identification was not achieved, and will need to await ongoing DNA sequencing and further comparative studies. The new record of an introduced species for the Mediterranean is the first limpet so recognized, and the species appears to be represented by a range of sizes, implying that it is well established along the intertidal Sicilian rocky-shores and is successfully recruiting in this region.

### KEY WORDS

Species introduction; new record; invasive species; biogeography; Gastropoda; Mollusca.

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### INTRODUCTION

The discovery from Italian shores of a limpet whose shell features clearly differed from the about 10 known Mediterranean limpet species, all of which belong to Patellidae Rafinesque, 1815 and one to Lottiidae Gray, 1840 (CLEMAM, 2016), led us to conclude that this was an introduced exotic species of Lottiidae not yet recorded from the Mediterranean. Our molecular investigations are still ongoing, but here we report the occurrence of this newly introduced species and present shell, radula, and morphological evidence for our assignment to Lottiidae, and tentatively to the genus *Lottia* Gray, 1833.

True limpets are assigned to Patellogastropoda Lindberg, 1986, whose members have a different shell geometry and microstructure and morpholo-

gical distinctions in gills, pericardial structure, and alimentary system (reviewed by Lindberg, 1988). Most authorities now follow Ponder & Lindberg (1996; 1997) in considering patellogastropods a monophyletic taxon that is either sister taxon to all other extant gastropods (e.g., Lindberg, 1998) or is at least a distinctive clade of gastropods whose higher phylogenetic position has been somewhat unstable in molecular analyses (Nakano & Sasaki, 2011; Zapata et al., 2014). Within patellogastropods, Patellidae is characterized by an anti-tropical distribution (Koufopanou et al., 1999) and this family has been considered the monophyletic sister taxon of all other extant patellogastropods (Lindberg, 1988; Lindberg & Hedegaard, 1996) or as sister taxon to all other patellogastropods except for Eoacmaeidae Nakano & Ozawa, 2007 (ibid.). Although patellogastropods exhibit more variation

in shell microstructure than all other gastropods combined (MacClintock, 1967; Lindberg, 1988), shell microstructure itself is known to be subject to phenotypic plasticity (Lindberg, 1998; Gilman, 2007) so is not an infallible indicator of phylogenetic affinity and this complicates the assignment of limpet fossil shells to extant families.

One of the most interesting aspects of the evolutionary history of patellogastropods is the striking restriction of different families to specific geographic regions (Powell, 1973; Lindberg, 1986; Lindberg, 1988; Koufopanou et al., 1999; Nakano & Ozawa, 2007; Reisser et al., 2012). Radiations of particular genera of limpets have been surprisingly restricted to particular ocean basins, probably reflecting the relatively short planktonic duration of the typically lecithotrophic larval stage of limpet genera that have been studied (Amio, 1963; Rao, 1975; Wanninger et al., 1999; Wanninger, Ruthensteiner & Haszprunar, 2000; Kay & Emlet, 2002; earlier references therein). The first known long-distance introduction of a patellogastropod is documented by Nakano & Espinoza (2010), who reported for the W-Africa a new alien *Cellana* from the Indian Ocean.

The northeastern Atlantic and Mediterranean is dominated by Patellidae, with Lottiidae represented by only two species, of which only *Tectura virginea* (Müller O.F., 1776) is inside the Mediterranean (Koufopanou et al., 1999). Conversely, the North Pacific is dominated by numerous species of Lottiidae, with only a single Patellidae species, the nearly extinct giant, *Scutellastra mexicana* (Broderip et G.B. Sowerby I, 1829), restricted to the vicinity of the Gulf of California, Mexico.

Patellogastropod taxonomy is confounded by the relatively simple shell geometry, convergent shell shape and sculpturing and impressive phenotypic plasticity. This has produced a confusing history of generic names first proposed to be geographical widespread, and later re-evaluated as groupings based on only superficial similarity. Even within species there can be striking variation. For example, there are many known cases of phenotypic plasticity that correspond to ecotypes characteristic of particular microhabitats or host associations. These can further confound identifications that are based only on shell morphology.

Seven families currently compose Patellogastropoda: Acmaeidae, Eoacmaeidae, Lepetidae, Lot-

tiidae, Nacellidae, Patellidae and Pectinodontidae (Nakano & Sasaki, 2011).

In European waters two species of Lottiidae are reported (CLEMAM, 2016): *Tectura virginea* and *Lottia testudinalis* (Müller O.F., 1776). Both were previously assigned to *Acmaea* Eschscholtz, 1833 but this genus and the family, Acmaeidae, is now restricted to relatively few North Pacific species. Instead, these two species are currently assigned to Lottiidae. *Tectura virginea*, the type species of *Tectura* Gray, 1847, appears to be a highly divergent monotypic lineage that has little to do with other Lottiidae species (Eernisse, unpublished). *Lottia testudinalis* has often been incorrectly referred to the genus *Tectura* but this species also occurs in the North Pacific (Lindberg, 1979) and is closely related to multiple other *Lottia* species there, based on mitochondrial DNA evidence (D.J. Eernisse, unpublished). Because all of its close relatives are also found in the North Pacific, this implies a geologically recent invasion of this species to the North Atlantic through the Arctic Ocean.

In the Mediterranean, there is also one alien species of Cellanidae, *Cellana rota* (Gmelin, 1791), which is somewhat similar to Lottiidae in general shell characters. However, besides the shell and anatomical differences associated with limpets in this family when compared with Lottiidae, *C. rota* is common only along the extreme eastern coasts of the Mediterranean.

Here we report for the first time the discovery of a species of *Lottia* in the Mediterranean. The new alien species was assigned to Lottiidae on account of the presence of a single ctenidium (compared with none in Patellidae), the absence of the rachidian tooth in the radula and reduction of the marginal. The population of this new alien species seems well established along the eastern rocky-shore of Sicily in the vicinity of Catania. We suspect that the present finding is due to a human-mediated introduction because this relatively striking species was never reported previously anywhere in the Mediterranean. Whether this species has entered through one of the two most important allochthonous species entrances, the Strait of Gibraltar or the Suez Canal, is unknown.

Because of the difficulties inherent in the identification of lottiid species and because the family is still poorly known in many parts of the world, the geographical origin of the Mediterranean invader is

unfortunately still unknown. Our attempts to use existing literature on Lottiidae to identify this species confidently has been problematic. There are some other morphologically similar species found in the Caribbean, Eastern Pacific, Japan, and Oceania, but we have so far found contrary evidence discounting each of the species known to us from these regions as a satisfactory match. Although our identification to species is still in doubt, we suspect that our ongoing activities to undertake DNA sequencing could at least help narrow our identification to a specific species group and geographic region. One of us (DJE) has observed that Lottiidae species tend to cluster together in regional monophyletic groupings (D.J. Eernisse, unpublished observation), so sequences could help reveal where to look. For all these reasons and because the radula features have allowed us to make a tentative generic assignment, we refer to the new alien Lottiidae for now simply as *Lottia* sp., awaiting sequencing of other studies for a more precise identification.

ABBREVIATIONS. DEC: Douglas Eernisse collection (California, USA); DSC: Danilo Scuderi collection (Catania, Italy); HMC: Henk Mienis Collection (Tel Aviv, Israel).

## MATERIAL AND METHODS

After the finding of a single unrecognized limpet shell near the southern branch of the harbour of Catania, Sicily, a more thorough sampling was undertaken between the harbour of Catania to the rocky artificial substrates of Messina, almost 150 km away from Catania. We only found this species of *Lottia* in localities close to Catania, within about 5 km from the harbour. Two collecting methods were followed: collection of specimens by hand from the rocky substrates in the intertidal environment and a visual census method without removing specimens from the substrate. The hand-collected material yielded 55 living specimens between January and August 2015 (DSC and DEC), while almost 150 specimens were observed with the visual census sampling during the same period. Representative specimen vouchers will be deposited in appropriate museums following our ongoing molecular studies.

For morphological analysis, shells were measured and shell shape was studied after removing the soft body from each specimen's shell. Radular composition as well as the external soft body parts were observed with a stereoscope and documented by photographs and drawings. Some individuals were preserved in ethanol and the related shells were numbered, photographed, and separately processed or stored for ongoing DNA studies. Some shells of *C. rota* from Israel (HMC) were studied for comparisons.

## RESULTS

*Lottia* Gray, 1833

Type species: *Lottia gigantea* Sowerby, 1834

*Lottia* sp.

EXAMINED MATERIAL. Catania, eastern coast of Sicily, 30 living specimens, intertidal breakwater of the harbour and 15 living specimens along the northern rocky shore of the city (DSC).

DESCRIPTION. Medium size: typical length 16 mm, height 5 mm (maximum 18.2 mm length and 7.0 mm height). Shell patelliform, relatively flat but somewhat conical, moderately solid (Figs. 1–8). Profile medium-high, aperture oval. Anterior slope slightly concave, not very steep; apex in the anterior third (Fig. 8). Dorsal sculpture has about 35–45 major ribs, almost flat, each alternated by 2–4 narrower and not very marked ribs (Fig. 9). Numerous concentric growth lines can be detected between ribs, more marked on young shells. A few nodules are sometimes present on uneroded shells at the intersections of ribs. External colour cream with dark radial lines (Figs. 1–3). Internal side shiny, opalescent, not metallic as in Patellidae, with intermediate area pale cream to azure, almost ochre to dark brown on the central area (Fig. 4). The external dark lines become visible through the otherwise translucent shell toward the margin, where a dark marginal band, alternated with whitish stains, encircles the aperture (Fig. 4).

Foot round and whitish (Fig. 10); attachment muscles whitish with few dark stains. A single ctenidium is found in the nuchal portion of the mantle cavity (Fig. 12), and there is no branchial cord (secondary gill) as found in some other patellogastropods. Mouth and lateral side of cephalopod.

alic tentacles orange but otherwise white (Fig. 11). Snout and head pale purplish (Fig. 11). External side of the edge of mantle yellowish, internal side pale but bright green (Fig. 13). Marginal mantle tentacles short and fine, about 0.2 mm in length, numerous (Fig. 13). Radula with one pair of uncini per row (Fig. 14); first lateral teeth pointed, second lateral teeth broad and rounded, third lateral teeth slightly reduced and rounded; ribbon segment almost elongated (Figs. 14–15).

**VARIABILITY.** Size of shell ranges from 15 to 18 mm in length, 12–16 mm wide and 4 to 7 mm high. Colour variations of dorsal shell surface usually with whitish striped by dark radial lines, sometimes coalescing to form mottled markings (Figs. 3, 6), to almost uniformly dark (Fig. 5). Internal central area can be uniformly whitish (Fig. 7) or completely brown-black (Fig. 5, left). The continuous band along the internal margin of the shell can be uniformly dark (Fig. 5, right), or rarely the entire specimen is whitish with a few brown strips (Fig. 6). Sculpture can be faint or eroded in some specimens.

**DISTRIBUTION.** In the Mediterranean the species is known only from the above-mentioned material, representing the first record for this basin. The original geographical distribution remains unknown pending successful identification.

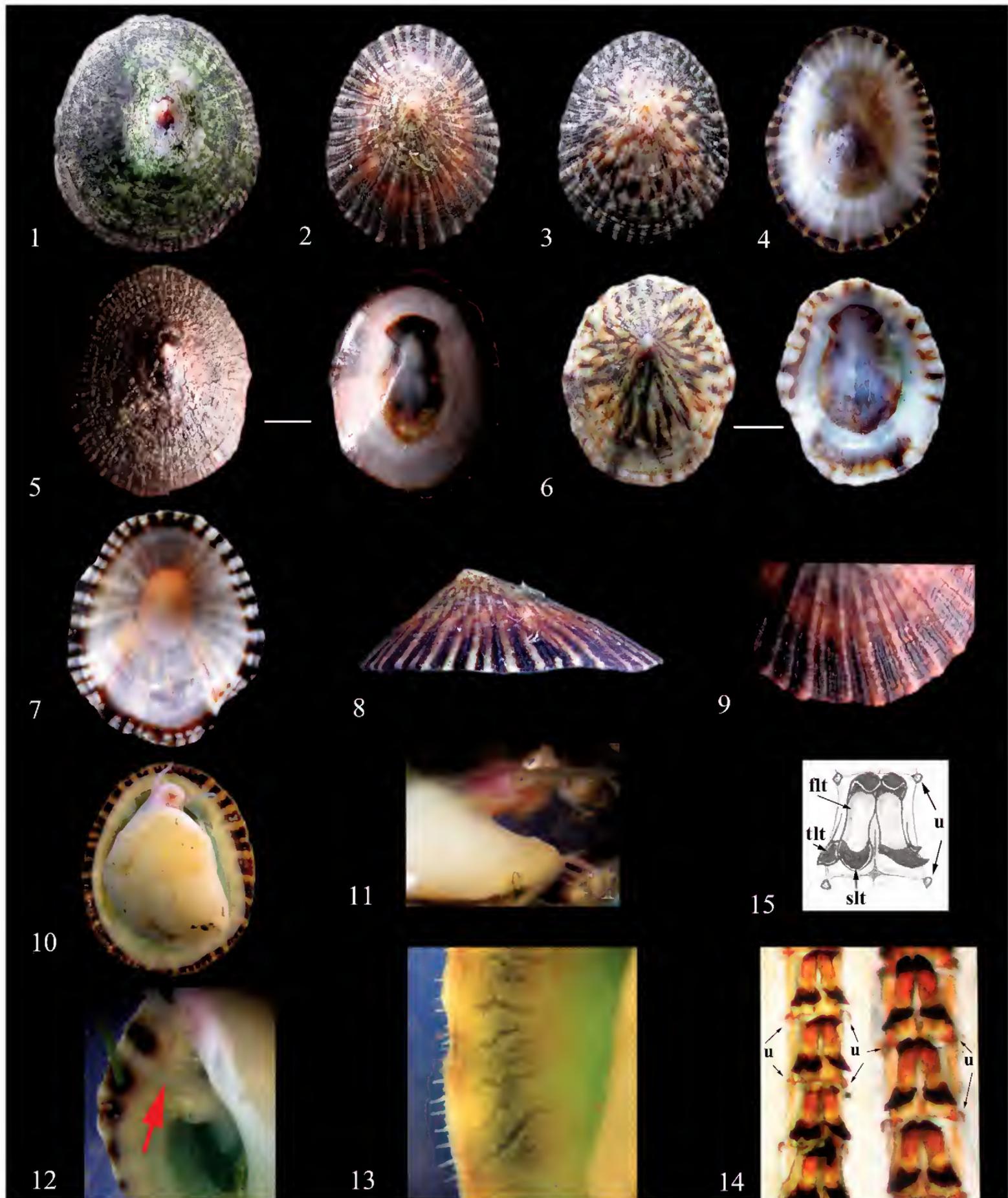
## DISCUSSION

Based on the reported variation from the literature of morphological characters of the shell, external soft parts, and radula of Mediterranean patellogastropod species, we identified this newly discovered species as not only distinct from any of the known limpet species, but also as a member of a family, Lottiidae, which is nearly absent from the region. However, this left the challenge of a specific identification of this species, and members of Lottiidae worldwide are still poorly known and their taxonomy is notorious for its difficulty. At a higher level, they are especially distinguished by the presence or absence of a primary ctenidium or accessory (secondary) gill-like structures between the mantle edge and the foot known as a branchial cordon, characteristic layers of their shell, and radular tooth arrangement. Lottiidae have a ctenidium and generally lack secondary gills, among other fea-

tures. At a species level, members of Lottiidae are distinguished by their shape including position of the apex and lateral profile, fine details of their shell sculpture, their shell colour to some extent, their radular teeth arrangement, and characteristics (including colour) of external soft parts, although poorly documented for most species. Intraspecific variability for the characters mentioned is known. In order to identify this exotic species, we focused our studies on the group of Lottiidae characterized by a subcentral (only slightly anterior) apex, broadly oval profile, weak but definite rib sculpturing, shells drab with long dark stripes, whitish animals almost entirely lacking pigmentation except for parts of the head, and radula with almost elongated lateral teeth.

Following here are species to which the Mediterranean alien limpet, tentatively identified as a *Lottia*, has been compared. We have focused on *Lottia* species of medium size with sculpture, if not eroded, with major ribs that often are interspersed with up to two minor ribs, apex subcentral, with straight anterior slope, papillae extending distally from mantle attachment to shell small, fine, short, and well spaced compared to many other members of the genus; colouration of shell with alternating whitish and dark radial stripes. The only European species which shows only slight resemblance to the Mediterranean invader *Lottia* sp. is *L. testudinalis*, a cold-water circumboreal species, distributed between the northern part of the United Kingdom, the northwestern Atlantic as far south as about Cape Cod, and also known from subtidal depths off the Aleutian Islands, Alaska, in the northern Pacific Ocean (Lindberg, 1979). But the apex of *L. testudinalis* is more central, and the species found on Sicilian shores lacks its numerous finely beaded riblets. The living animal of *L. testudinalis*, which is known only from the cooler waters of higher latitudes, also seems more deep yellow in colour, and the radular teeth are differently arranged. Plus, its habitat is different; it does not occur in the subtidal and has not been observed on seaweeds, unlike *L. testudinalis*.

Among the many northeastern Pacific Lottiidae species, the only one with similar features including ribs is *L. pelta* (Rathke, 1833), and the “brown” and “coralline” forms are in particular somewhat similar (Lindberg, 1981). But compared to the Mediterranean invader, *L. pelta* has broader and knobbier



Figs. 1–15. *Lottia* sp., Catania, Sicily. Fig. 1: dorsal view of the shell (length 18.2 mm), harbour of Catania. Figs. 2–4: San Giovanni Li Cuti, Catania; dorsal view of the shell, length 15.1 and 13.2 mm (Figs. 2, 3); internal side of the shell (Fig. 4). Fig. 5: entirely blackish specimen (length 15.0 mm), San Giovanni Li Cuti, Catania. Fig. 6: paler specimen with mottled dark drawings (length 12.8 mm), harbour of Catania. Fig. 7: internal side of a specimen with whitish central area (length 16.8 mm), harbour of Catania. Figs. 8–14: San Giovanni Li Cuti, Catania; lateral view of the shell (Fig. 8); detail of the shell sculpture, length 16.8 mm (Fig. 9); ventral view of a living specimen, length 15.0 mm (Fig. 10); lateral view of a living specimen (Fig. 11); detail of the ctenidium (red arrow) (Fig. 12); detail of the edge of mantle, with mantle tentacles (Fig. 13); radular teeth in dorsal view (right) and in slightly tilted view (left) to show uncini (u) (Fig. 14); Fig. 15: drawing of radular teeth (flt: first lateral tooth; slt: second lateral tooth; tlt: third lateral tooth; u: uncini).

ribs, which deform the shell margin with weak scalloping. True ribs are also present in *Lottia gigantea* (Sowerby, 1834), but this species is completely different, for example with an anterior apex and completely different colouring of the living animal, with black head, tentacles and margin of foot. Many of the other members of *Lottia* differ in having fine riblets (not ribs) and different radula arrangement. One of us (DJE) is familiar with most of the East and North Pacific species and none of the species there seems to match it well.

Western Atlantic species share with the Mediterranean alien species more similar characters in dimensions, shell, external soft parts and radular morphology. Compared to the Mediterranean *Lottia* spp., *L. subrugosa* (d'Orbigny, 1846) is the most similar among Western Atlantic species, common along the Brazilian coasts, south to Uruguay. The size, colour and apex position of the shell seem to be similar to the Mediterranean alien species. But, judging from the original description of the species the shell sculpture seems somewhat different, characterized by large flattened axial ridges, which give the margin of the shell a winding outline. Compared to the description and pictures by Righi (1966), the radular teeth seem arranged in the same way. Two other species that are similar to *L. subrugosa*, *L. noronhensis* (E.A. Smith, 1890) and *L. marcusii* (Righi, 1966), also seem unlikely because of their extremely restricted geographical distribution, i.e. the Island of Fernando de Noronha Brasil, and that of Trinidad, respectively. Other similar Western Atlantic species are *L. jamaicensis* (Gmelin, 1791) and *L. leucopleura* (Gmelin, 1791), which however are characterized by more robust and prominent ribs. Another undetermined Atlantic species, called *Lottia* morph B, is reported from Nevis, Leeward Islands (Caribbean) (Hewitt, 2008), and resembles the Mediterranean invader in general shape, but is characterized by numerous and almost equally thin riblets on the shell.

Species of the western Pacific regions, including Australia, New Zealand, and southeastern Asia, were compared with available literature, but no close matches were found to the alien Mediterranean species. For example, *Notoacmea corrodenda* (May, 1920) is perhaps the most similar of these in shell morphology, but differs in its more flattened shell, smaller size, coarser sculpture, and different radular tooth arrangement.

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