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A new species of *Amphictene* (Annelida, Pectinariidae) from the Gulf of Mexico, with a redescription of *Amphictene guatemalensis* (Nilsson, 1928)

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Abstract

The genus *Amphictene* is reported for the first time from Mexico. Previous records for America are restricted to Brazil (*A. catharinensis*) (Grube, 1870), and Guatemala (*A. guatemalensis*) (Nilsson, 1928). In this paper we describe a new species, *Amphictene helenae* **sp. n.**, characterized by the presence of three pairs of tentacular cirri, while other species have only two pairs. The new species is closely similar to *Amphictene catharinensis*, and can be distinguished by the presence of a circular group of glandular papillae inserted between the lines of glandular cirri present from the second segment. *A. guatemalensis* is redescribed based on type material; it differs from the new species in the presence of two pairs of tentacular cirri on segments 1 and 2, six pairs of glandular cirri on the third segment, and four glandular lobes fused in pairs on the fourth segment.

Keywords

Taxonomy, polychaete, Pectinariidae, *Amphictene guatemalensis*, Gulf of Mexico

Introduction

Pectinariidae de Quatrefages, 1865, comprises a group of benthic polychaetes living in characteristically shaped tubes, made of different types of materials, such as sand grains, mollusk shell fragments, foraminifers or coral fragments; the tubes resemble an "ice cream cone". These worms live in soft bottom sediments with the cephalic region pointing downward, and posterior end upwards to the surface. This family currently contains five genera: *Amphictene* Savigny in Lamarck, 1818, *Cistenides* Malmgren, 1866, *Lagis* Malmgren, 1866, *Pectinaria*, Savigny in Lamarck, 1818 and *Petta* Malmgren, 1866. All these genera, except *Amphictene*, have been reported previously from Western Mexico. Nevertheless, Pectinariidae has not been previously reported from Eastern Mexico.

Amphictene is represented by 12 species, and one subspecies (Hutchings and Peart 2002): *A. auricoma* (Müller, 1776) from Denmark, *A. capensis* (Pallas, 1776) from Cape of Good Hope, *A. catharinensis* (Grube, 1870) from Santa Catarina Island, Brasil, *A. crassa* (Grube, 1870) from New Caledonia, *A. favona* Hutchings & Peart, 2002 from NSW, Australia, *A. guatemalensis* (Nilsson, 1928) from Guatemala, *A. japonica* (Nilsson, 1928) from Japan, *A. leioscapha* (Caullery, 1944) from Banda, Indonesia, *A. moorei (*Annenkova, 1929) from East coast of Siberia, *A. souriei* (Fauvel, 1949) from Dakar, West Africa, *A. uniloba* Hutchings & Peart, 2002 from NSW, Australia, and *A. auricoma mediterranea* (Nilsson, 1928) from Mediterranean Sea (Fig. 1). In this study, a new species from the southern Gulf of Mexico is described; furthermore, *A. guatemalensis* is redescribed based on type material.

Material and methods

Type and non-type material of *Amphictene helenae* sp. n., were collected in Bahamintas Beach, Ciudad del Carmen, Campeche (18°38'36"N, 91°49'51"W). The specimens were collected by hand from the intertidal zone, in mixed sediments of coarse sand and shells fragments, using two sieves of 0.5 and 1.0 mm, at depths of 0.50–1.0 m. Specimens were fixed with 10% formalin, and preserved in ethanol 80%. The terminology used follows Hutchings and Peart (2002). The holotype was deposited in the Polychaetological Collection of the Universidad Autónoma de Nuevo León (UANL), México, and paratype were deposited in Los Angeles County Museum of Natural History, Allan Hancock Foundation (LACM-AHF), Los Angeles, USA. Specimens of *Amphictene* sp. A, are deposited in the National Museum of Natural History, Smithsonian Institution (USMN), Washington, USA.

Type material of *Amphictene guatemalensis* was borrowed from the collection of the Zoologisches Institut und Zoologisches Museum der Universität Hamburg (HZM-P), Germany.

Figure 1. A world map showing the reported type locations of the species of *Amphictene*: **1** *A. auricoma* **2** *A. auricoma mediterranea* **3** *A. capensis* **4** *A. catharinensis* **5** *A. crassa* **6** *A. favona* **7** *A. guatemalensis* **8** *A. helenae* **9** *A. japonica* **10** *A. leioscapha* **11** *A. moorei* **12** *A. souriei* **13** *A. uniloba.*

Methyl green staining was used to determine specific patterns of glandular areas. Specimens were immersed for two minutes in a saturated solution of methyl green in 70% ethanol; later, specimens were washed with ethanol 70% to remove excess methyl green, according to Warren et al. (1994).

In this paper, we propose to use the term "bayonet shaped" to describe the notochaeta with a median broad tooth, these kind of chaetae can be observed on *Amphictene catharinensis*, *A. guatemalensis, A. capensis*, as well as on the new species here described, and on some species of *Pectinaria.* Nilsson (1928) describes these chetae as short capillary chaetae *"Kurze Kapillarborste";* Long (1973) as *"capilaris with boss separated from shaft by incision and with tapered, narrowly blade"*; Londoño Mesa (2009) as *"notochaeta with middle tooth".*

Systematics

Order TEREBELLIDA Levinsen, 1883
Family PECTINARIIDAE de Quatrefages, 1865

Genus *Amphictene* Savigny in Lamarck, 1818

Type species. *Amphitrite auricoma* Müller, 1776; subsequent designation by Hartman 1959.

Amphictene helenae sp. n.

http://zoobank.org/5752E5B9-4787-4D94-9BBC-F597566C5328
http://species-id.net/wiki/Amphictene_helenae
Figure 2

Amphictene sp. A. Wolf, 1984: 50-4-6 fig. 50-1, 2 a-j.

Type material. Holotype (UANL-7824); Paratype (LACM-AHF-Poly 5741) Bahamintas Beach, Ciudad del Carmen, Campeche, México, St. 2, [18°41'60"N, 91°41'00"W], 0.50 m deep, January 3, 2011, coll. ME García-Garza and JH Landín-Delgado.

Additional material. *Amphictene* sp. A (USMN 86826) St. I-4, off Port O'Connor Texas [28°22'60"N, 96°47'60"W], STOCS expedition, 10 m deep, May 1976; (USMN 86827) St. M-21, off Texas [27°53'60"N, 97°21'60"W], IXTOC expedition, 10 m deep, December 1980; (USMN 86828) St. IV 2419, off Apalachicola river, Texas [30°18'00"N, 84°08'00"W], MAFLA expedition, 10 m deep, November 1977.

Description. Holotype complete, 25.7 mm long, 5.3 mm wide, with 19 segments, body robust and soft, light brown in color. Cephalic veil formed by one semicircular lobe inserted at base of paleae, forming shelf on buccal tentacles. Rim of cephalic veil with 38 long, thin cirri; each cirrus with subtriangular base, tapering toward distal end; curved toward dorsum (Fig. 2A). Operculum covered by numerous papilliform structures randomly distributed; nine pairs of long and slightly curved paleae, sharply pointed. Opercular margin with 19 subtriangular cirri (Fig. 2B).

First segment with two pairs of tentacular cirri: first pair inserted on antero-posterior margin of segment; second pair arising from posterior middle part of segment, below first pair. Second segment with one pair of tentacular cirri inserted on lateral margin of segment, larger than cirri of first segment (Fig. 2C). Second segment dorsally indistinguishable, aerolated; with 8 pairs of thin and subtriangular ventral glandular cirri, attenuated distally; one plate with numerous small papillae in central part segment. Third segment with one middle ventral lobe and one pair of shorter lateral expansions. Fourth segment with six glandular lobes, robust and subtriangular, fused in pairs (Fig. 2A). Two pairs of latero-ventral branchiae inserted on segments 3 and 4, forming series of flat and free lamellae, fused only at base, anterior pair larger than posterior one (Fig. 2C).

Chaetigers 1–3 (segments 5–7) only with notopodia. Chaetigers 4-15 biramous with notopodia and neuropodia. Capillary notochaetae on chaetigers 1-15, some small, thinner, with external margin slightly denticulate, others bent with smooth margin, distally thin, slightly hirsute; bayonet-shaped notochaetae appear on chaetigers 4-15, with well-developed middle tooth, blade serrated throughout (Fig. 2D). Neuropodia wedge-shaped, slightly glandular, torus with numerous uncini arranged in single row. Neuropodial uncini with a group of 6-7 small apical teeth randomly placed, and two longitudinal rows, each one consisting of 5-6 larger teeth, and small group of basal teeth with undefined arrangement, decreasing in size towards base (Fig. 2E-F).

Last three posterior segments, without noto- or neurochaetae, followed by five fused segments forming scaphe, clearly separated from abdomen, wider than longer,

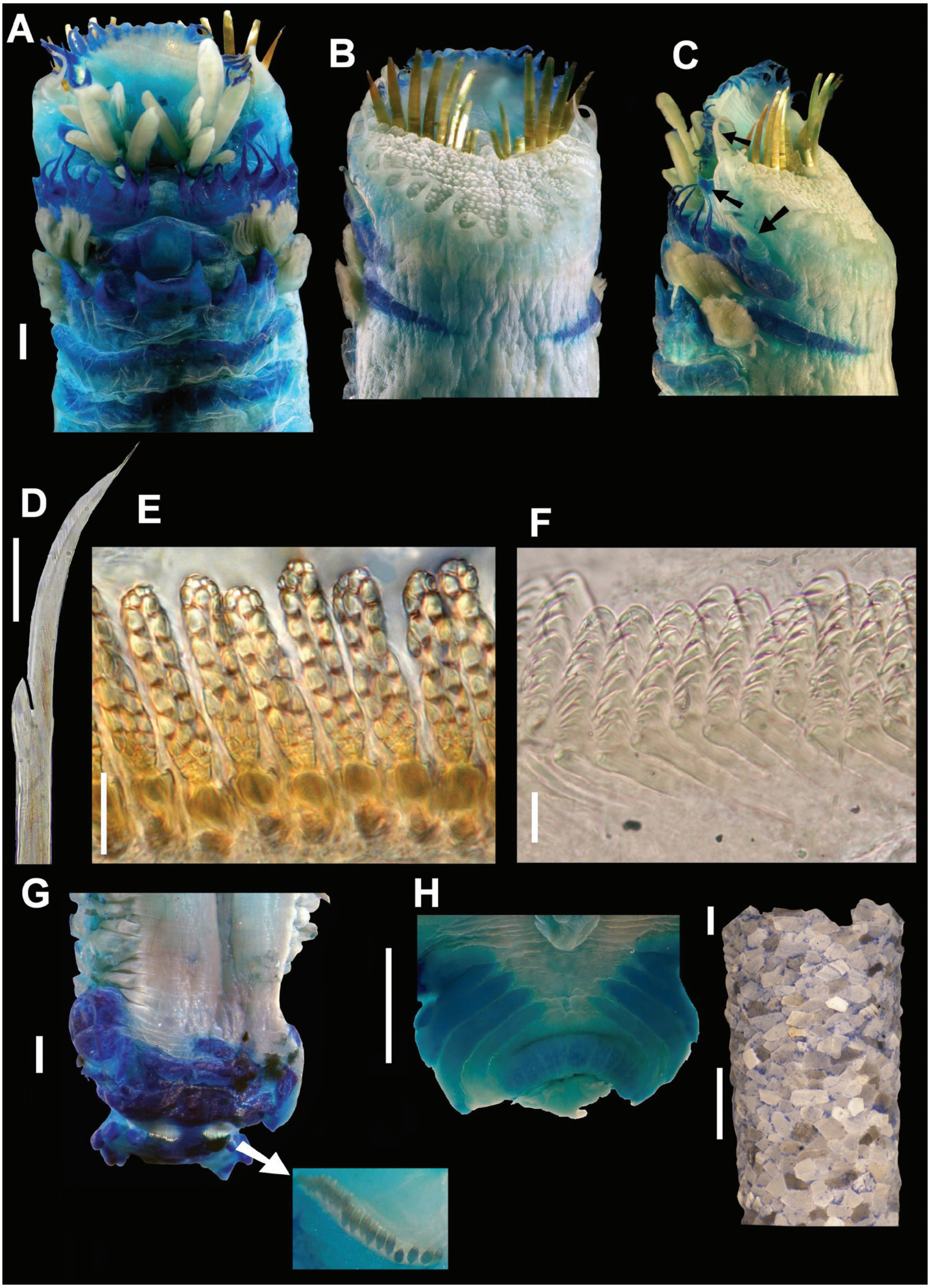

Figure 2. *Amphictene helenae*. Holotype. **A** ventral view of anterior end **B** dorsal view of anterior end **C** lateral view of anterior end, showing tentacular cirri **D** notochaetae from 7th chaetiger **E** front view of bayonet shaped neurochaetae from 7th chaetiger **F** lateral view of neurochaetae from 7th chaetiger **G** dorsal view of scaphe (**G'**) scaphal hooks detail **H** ventral view, anal papillae **I** tube of holotype. Bar scale= **A, B, C, G, H**= 1mm; **D**= 50mm **E, F**= 10mm; **I**= 3mm.

with 21 pairs of short and thick scaphodal hooks, golden in color, with brown margins (Fig. 2G). Five marginal lobes triangular-shaped, with one fold in antero-dorsal end, and margin somewhat crenulate; anal lobe with large anal papilla and three pairs of lateral papillae, in middle dorsal region (Fig 2H).

Tube cone-shaped, made of cemented shell fragments of similar sizes, most of them clear, with few dark fragments (Fig. 2I).

Remarks. *Amphictene helenae* sp. n., is similar to *A. guatemalensis* (Nilsson, 1928) and *A. catharinensis* (Grube, 1870) by having a glandular cirrus on the second segment and lobes on segment 4. Nevertheless, these species differ in some morphological characters: *A. helenae* sp. *n.,* has three pairs of tentacular cirri, two pairs on the first segment, and a pair in the second one, while *A. guatemalensis* and *A. catharinensis* have only one pair in the first segment and a pair in the second one; *A. helenae* sp. n., has eight pairs of glandular cirri on the second segment, and six robust glandular lobes on the fourth segment, subtriangular, fused in pairs. *Amphictene guatemalensis* has six pairs of glandular cirri in the second segment, two pairs of glandular subtriangular lobes in the fourth segment. *Amphictene catharinensis* has 17 or 18 glandular cirri on the second segment, in the fourth a central lobe with subtriangular lateral extensions and two pairs of free subtriangular broad lobes. Furthermore, *A. catharinensis* and *A. helenae* can be distinguished by the presence of a circular group of small glandular papillae between both lines of glandular cirri on the ventral side of the second segment, which is absent in *A. catharinensis*.

Examination of the material described by Wolf (1984) as *Amphictene* sp. A, from Florida and Texas, USA, and deposited at the USNM, indicated that it belongs to this new species, however, the specimens were found to be in poor condition.

Type locality. Bahamintas Beach, Ciudad del Carmen, Campeche, México.

Distribution. Gulf of Mexico.

Etymology. The species is named in honour of Helena Landín García, daughter of the first author.

Amphictene guatemalensis (Nilsson, 1928)

http://species-id.net/wiki/Amphictene_guatemalensis
Figure 3

Pectinaria (Amphictene) guatemalensis Nilsson, 1928: 46 fig.14 a–f.
Amphictene guatemalensis. Hartman 1959: 479; Hutchings and Peart 2002:102; Fauchald 1977:120.

Material examined. Holotype (HZM V-1755), west coast of Central America, San José de Guatemala, Guatemala. [13°55'28"N, 90°47'25"W] coll. Captain R. Paeslin.

Description. Holotype complete, divided in two fragments, 14 mm long (10 mm anterior fragment, and 4 mm posterior fragment), 4 mm wide, with 19 segments. Cephalic veil formed by semicircular lobe insert at base of paleae forming shelf on buccal

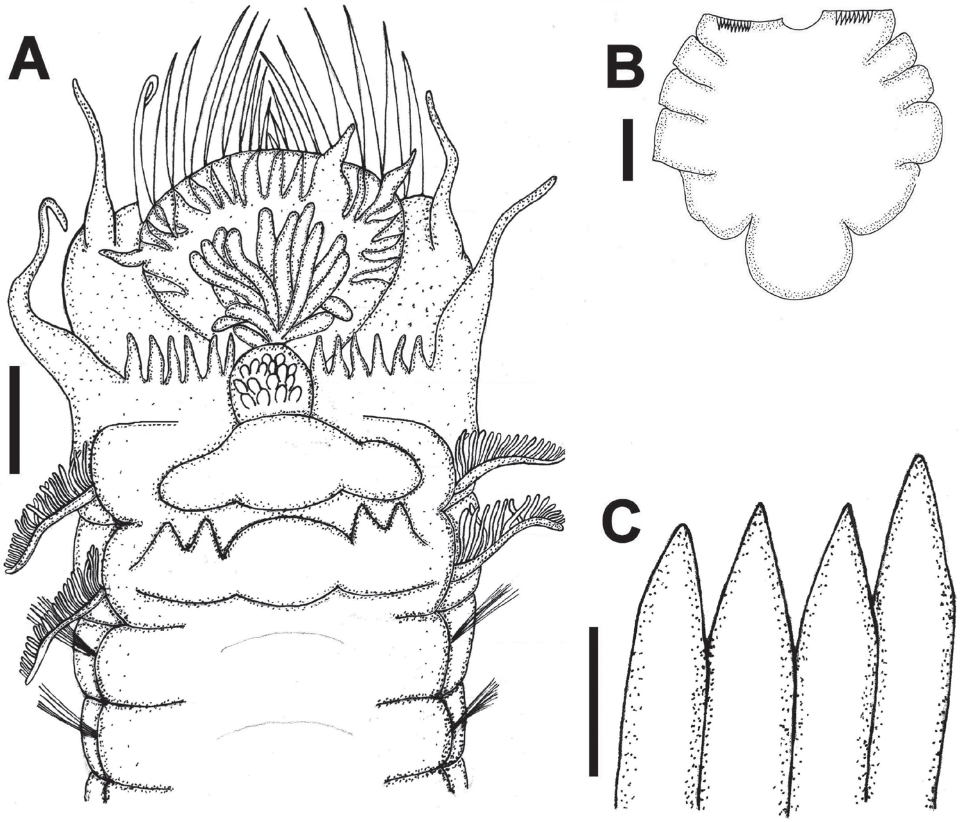

Figure 3. *Amphictene guatemalensis*. Holotype. **A** ventral view of anterior end **B** dorsal view of scaphe **D** scaphal hooks. Bar scale= **A, B**= 1 mm; **C**= 20mm.

tentacles. Cephalic veil margin with 20 long, thin cirrus, inserted anterior end each cirrus with slightly wider base, decreasing in width distally. Opercular plate covered by numerous papilliform structures without any apparent order, with 9 pairs of long and slightly curved paleae, ending in thin filament. Opercular margin with 13 subtriangular cirri (Fig. 3A).

First pair of tentacular cirri inserted on anterior-posterior margin of first segment; second pair of tentacular cirri inserted on lateral margin of second segment. Second segment dorsally indistinguishable, very soft epithelium, with six pairs of glandular cirri on ventral side, subtriangular, fading distally, in central part of segment with a quadrangular plate having numerous small papillae. Third segment with oval central lobe, and pair of lower lateral expansions. Fourth segment with four glandular lobes, robust, subtriangular, fused in pairs, and oval central lobe. Two pairs of lateral branchiae inserted in segments 3 and 4, forming series of flat and free lamellae. Chaetigers 1-3 (segments 5–7) only with notopodia. Chaetigers 4–15 biramous with noto- and neuropodia; two types of notochaetae, thin and long simple capillary on chaetigers 1–15, and bayonet shaped ones, shorter than first ones, present on chaetigers 4–15, with well-developed median tooth and inner edge of blade dentate. Neuropodia wedge shaped, slightly glandular, torus with numerous uncini, each one with 4–5 rows of small denticles.

Last three posterior segments without notochaetae or neurochaetae, followed by 5 fused segments forming scaphe; segments broad and lobed, with smooth margin, scaphe slightly longer than wide, clearly separated from abdomen; 9 pairs of short, thick scaphal hooks, golden (Fig. 3C). Anal lobe semicircular, with cleft, bearing marginal middle papilla (Fig. 3B).

Remarks

The holotype of *Amphictene guatemalensis* is in poor condition, broken into two parts; the epithelium is very fragile. Structures like the cirrus of cephalic veil and the glandular cirrus of second segment are bent and some others fragmented. Unlike that observed by Nilsson (1928) in the description of the species, we observed in the anal lobe only one cleft in which probably one marginal middle papilla was inserted; the remaining margin is smooth.

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A new species of *Phymatodes* Mulsant (Coleoptera, Cerambycidae) from China

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Abstract

A new species, *Phymatodes* (*Poecilium*) *latefasciatus*, **sp. n.** (Coleoptera, Cerambycidae, Cerambycinae, Callidiini) from China is described and illustrated. Features distinguishing the new species from its congeners are presented.

Keywords

Guizhou, longhorn beetles, taxonomy

Introduction

Phymatodes Mulsant, 1839 is a genus in the tribe Callidiini Mulsant, 1839. Nearly 70 species of *Phymatodes* have been recorded around the world. There are 32 species described from the Palearctic region (Rapuzzi and Sama 2009, Löbl and Smetana 2010, Danilevsky 2010b, Sama et al. 2011). Gressitt (1951) recorded 10 *Phymatodes* species (actually 9 species) from China in subgenera, *Phymatodellus*, *Paraphymatodes* and *Poecilium*. The 10 species were *Phymatodes* (*Phymatodellus*) *kozlovi* Semenov & Plavilstshikov, 1936, *P.* (*Phymatodellus*) *semenovi* Plavilstshikov, 1935, *P.* (*Phymatodellus*) *sinensis* (Pic, 1900), *P.* (*Phymatodellus*) *ussuricus* Plavilstshikov, 1940, *P.* (*Paraphymatodes*) *albicinctus* (Bates, 1873), *P.* (*Paraphymatodes*) *hauseri* (Pic, 1907), *P.* (*Paraphymatodes*) *mediofasciatum* (Pic, 1933), *P.* (*Poecilium*) *infasciatus* Pic, 1935, *P.* (*Poecilium*) *maaki* (Kraatz, 1879), *P.* (*Poecilium*) *savioi* Pic, 1935. Afterwards, *P.* (*Phymatodellus*) *ussuricus* Plavilstshikov, 1940 was treated as a synonym of *P.* (*Phymatodellus*) *infasciatus* Pic, 1935 (Hua 1982), and four new species were described in the genus: *P.* (*Poecilium*) *mizunumai* Hayashi, 1974, *P.* (*Poecilium*) *eximium* Holzschuh, 1995, *P.* (*Phymatodellus*) *jiangi* Wang & Zheng, 2003, *P.* (*Phymatodellus*) *ahenum* Holzschuh, 2007. Totally 13 *Phymatodes* species are distributed in China.

Gressitt (1951) placed Chinese *Phymatodes* species in subgenus *Poecilium* by characters: elytra with a cluster of long erect hairs behind scutellum, reddish at base and blackish posteriorly, generally with two subobliquely transverse pale bands; eyes nearly divided by emargination. Ohbayashi and Niisato (2007) divided Japanese *Phymatodes* species into subgenus *Poecilium* by fewer characters: roughly equal length of first hind tarsal segment to total length of second and third segments; and presence of two elytral bands. Löbl and Smetana (2010) elevated the subgenus *Poecilium* to genus with subgenera *Paraphymatodes* and *Phymatoderus* as its synonyms. Later, *Poecilium* was re-placed as subgenus (Danilevsky 2010a). In this study, *Poecilium* is considered as a subgenus of *Phymatodes* by a synthesis of characters of Gressitt (1951) and Ohbayashi and Niisato (2007).

According to the above characters, currently, there are totally nine species in the subgenus *Poecilium*. Among the 13 Chinese *Phymatodes* species, *P. maaki* (Kraatz, 1879), *P. savioi* Pic, 1935, *P. mizunumai* Hayashi, 1974, and *P. eximium* Holzschuh, 1995 are recognized in subgenus *Poecilium*. Besides the four Chinese species, five other species in subgenus *Poecilium* were recorded: *P. alni* (Linné, 1767) (distribution: Europe; Asia: Kazakhstan, Turkey), *P. antonini* Rapuzzi, Sama & Tichy, 2011 (distribution: Syria), *P. ermolenkoi* (Tsherepanov, 1980) (distribution: Russia: Primorskii Krai Province), *P. kasnaki* Sama, 2011 (distribution: Turkey), and *P. quadrimaculatum* Gressitt, 1935 (distribution: Japan).

Recently, specimens representing a new species of *Phymatodes* from Guizhou province of China were discovered and it fits into the subgenus *Poecilium* according to aforementioned characters. The new species is described herein.

The collection acronyms used in the text are as follows:

GZNULS	School of Life Sciences, Guizhou Normal University, Guiyang, Guizhou China.

Taxonomy

Phymatodes (*Poecilium*) *latefasciatus* sp. n.

http://zoobank.org/DB67D24A-8EAC-4613-861B-48E72B23D6A0
http://species-id.net/wiki/Phymatodes_latefasciatus
Figure 1

Etymology. The name refers to the second elytral band which is gradually widening toward suture after mid-point.

Diagnosis. Characters of the new species conform with all established characters of subgenus *Poecilium,* elytra with a cluster of long erect hairs behind scutellum, reddish at base and blackish posteriorly, with two pale bands; eyes nearly divided by emargination; ratio of first hind tarsal segment's length to total length of second and third segments nearly 1:1 (Gressitt 1951, Ohbayashi and Niisato 2007). Thus, it is placed in the subgenus *Poecilium*.

Phymatodes (*Poecilium*) *latefasciatus* sp. n. is distinguished from its congeners by the combination of the following characters: shape of the second elytral band; proportion of reddish brown area on basal elytron to the whole elytron; the color of antennae; and shapes of swelling part of femur. *P. latefasciatus* can be distinguished from all other congeners by the shape of its 2nd elytral band which is gradually widening towards suture after mid-point (Fig 1a). In addition to this most obvious one, other characters distinguish the new species from three other morphologically close Chinese species in the same subgenus: *P.* (*Poecilium*) *maaki* (Kraatz, 1879) (distribution: China: Heilongjiang, Jiangxi, Sichuan, Taiwan; Russia: Far East; Korea, Japan) (Kraatz 1879, Hua 2002, Löbl and Smetana 2010); *P.* (*Poecilium*) *savioi* Pic, 1935 (distribution: China: Jiangxi, Shanghai) (Pic 1935, Hua 2002, Löbl and Smetana 2010); and *P.* (*Poecilium*) *mizunumai* Hayashi, 1974 (distribution: Taiwan) (Hayashi 1974, Hua 2002, Chou 2008, Löbl and Smetana 2010). The new species is also different from *P. maaki* (Kraatz, 1879), a species most similar to the new species, by these characters: 1) proportion of the size of reddish brown area on elytral base to the whole elytron smaller, approximately 1/3; 2) antenna black; 3) clubbed part of meso-femora and hind femora shorter comparing to length of whole femur, suddenly swelling toward tibiae after middle. Beside shape of second elytral band, *P. latefasciatus* also differs from *P. savioi* Pic, 1935 by characters: 1) smaller proportion of reddish brown basal elytral area; 2) antenna black; 3) elytral bands ivory not yellowish, and first band not reaching suture. As the above two species, three other characters are also used to distinguish *P. latefasciatus* from *P. mizunumai* Hayashi, 1974, 1) antenna black; 2) first elytral band nearly transverse, not arcuate and shape as a caret symbol; 3) ratio of femoral clubbed part to femoral basal part larger.

Description. Female (male unknown). Moderate body size, length 8.4–8.5 mm (holotype 8.4mm), width 2.9 – 3.2 mm (measured across humeri, holotype 2.9 mm). Yellowish-brown, head, prothorax, swollen part of femurs black, antennae and tibiae lighter, basal part of elytra (ca 1/3 of total elytral length) reddish brown, the rest black, two subobliquely transverse ivory bands on each elytron.

Front nearly flat, transverse; head slightly concave between antennal tubercles which are slightly raised and separated by approximately the width of one antennal socket, front and vertex with sparse punctures and short yellow pubescences on some of these punctures; eyes coarsely-faceted; scape and antennomere 2 with semi-erect long yellow hairs, rest of the antennomeres covered with short dark brown hairs, antennomeres 2, 3 and 4 with sparse long yellow hairs especially at tips, relatively long yellow hairs also presenting at ends of antennomeres 5 to 10 but length gradually reduced by antenna segment; outer tips of antennomeres 6 to 10 slightly serrated.

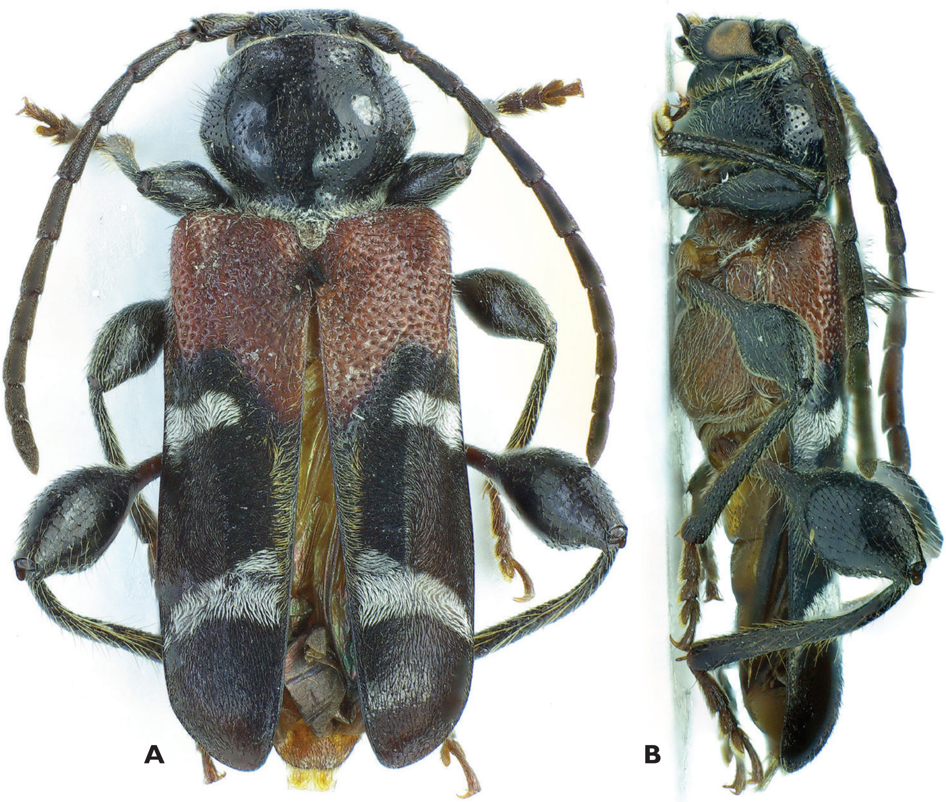

Figure 1. *Phymatodes (Poecilium) latefasciatus*, sp. n. **A** dorsal view **B** lateral view.

Prothorax transverse, approximately 1.2 times wide as long, widest and slightly angulated laterally near middle, contracting towards base and narrowest at base; pronotum slightly convex, shining, with irregular punctures and covered with moderately long erect black setae; short thick pale yellow hairs at collar edge and base of pronotum, forming a narrow transverse strip at the base; prosternal intercoxal process short, spine shaped, not reaching coxal middle; scutellum reddish yellow, length longer than width, nearly rectangle, semicircular at end.

Elytron long, approximately 4 times as basal width, parallel sided, with rounded apex; basal third red brown area irregularly dense punctured, with erect hairs, a cluster of long erect brown hairs after scutellum; rest of the elytron covered with dense black hairs except two nearly transverse ivory bands and a narrow golden strip lengthwisely along suture between the two bands; the first ivory band extending from elytral margin, approximately half of elytron width, not reaching suture; the second ivory band slightly curving towards base, gradually widening towards suture after mid-point of elytron, nearly reaching suture but interrupted by the lengthwisely golden strip.

Femora strongly swollen, fore-femur swollen gradually from near fore-coxa, mesofemur and hind femur swollen after approximately half of femoral length; legs cover with moderately long thick pale golden hairs, hair on tibiae longer and darker than that on femora; non-swollen part of femora reddish brown, swollen parts black; 1st segment of hind tarsi short, approximately 1.2 times as long as 2nd and 3rd together.

Abdomen slightly shining with small punctures, with relatively sparse moderately long semi-erect pale yellow hairs.

Type material. Holotype ♀ from Heichong, Shibing County, Guizhou Province, CHINA, 2013.IV.17, 27°09.068'N, 108°07.384'E, net sweeping on a *Viburnum* sp. plant, S. Yang col. (**GZNULS**). Paratype ♀ from Leigongshan, Leishan County, Guizhou Province, CHINA, 26°22.781'N, 108°11.534'E, 2012.V.23, Lindgren funnel trap, S. Yang col. (**GZNULS**).

Modified couplets to key to Chinese *Phymatodes* species of subgenus *Poecilium*

A modified key to *Phymatodes* species of subgenus *Poecilium* is presented based on Gressitt's (1951, page 228) key to Chinese *Phymatodes* species. In his key, *P. latefasciatus* will run to couplet 8. Couplets 8–9 can be modified, as presented blow, to accommodate the new species and other species described in the subgenus after his key published.

8 Dark portions of elytra with two silvery white bands; first band subtransverse, not reaching suture **9**
– Dark portions of elytra with two yellowish gray bands; first band arched; reaching suture; second band transverse; only hind femoral clubs pitchy .... ***P. savioi*** **Pic**
9 Second elytral band subtransverse, reaching or nearly reaching suture, not caret symbol shaped **10**
– Second elytral band oblique, not reaching suture, caret symbol shaped; front wrinkled with ridges .... ***P. eximium*** **Holzschuh**
10 Width of whole second elytral band roughly constant, not gradually widening towards suture **11**
– Width of whole second elytral band not constant, gradually widening towards suture after middle .... ***P. latefascitus*** **Yang**
11 First elytral band arcuate and acute angled as a caret symbol; ratio of femoral clubbed part to un-swelling femoral basal part smaller... ***P. mizunumai*** **Hayashi**
– First elytral band slightly bend smoothly, not acute angled as a caret symbol; ratio of femoral clubbed part to un-swelling femoral basal part larger .... ***P. maaki*** **Kraatz**

Acknowledgements

The study is supported by the Research Foundation of Guizhou Normal University (Grant No. 11904-05032110004) and the Joint Fund of Guizhou Science and Technology Department and Guizhou Normal University (Grant No. 11904-0502211Y0106, 黔科合J字LKS[2011]38号). I thank Xinming Zhu, Jijun Chen, Zhenguo Xie, Yongfu Yu and Shengguo Yang of the Leigongshan National Natural Reserve for their help in the field work, and Vitali Nagirnyi, Maxim Smirnov and Francesco Vitali for their help on specimen determination. I also thank Guiqiang Huang for his help on literature. I thank two reviewers, Steven Lingafelter and Olivier Gregory, for their help to improve the manuscript.

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Taxonomic note on the genus *Taiwanocantharis* Wittmer: synonym, new species and additional faunistic records from China (Coleoptera, Cantharidae)

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Abstract

Taiwanocantharis thibetanomima (Wittmer, 1997) is redefined and its type series is clarified. Three new species are described and illustrated, *T. wittmeri* **sp. n.** (CHINA: Yunnan), *T. adentata* **sp. n.** (CHINA: Gansu, Sichuan) and *T. parasatoi* **sp. n.** (CHINA: Guangxi). *T. gansosichuana* (Kazantsev, 2010) is synonymized with *T. drahuska* (Švihla, 2004). *T. dedicata* (Švihla, 2005) and *T. malaisei* (Wittmer, 1989) are recorded to China for the first time. A key to the species of the *Taiwanocantharis thibetana* species-group is provided.

Keywords

Cantharidae, *Taiwanocantharis*, synonym, new species, new record, China

Introduction

The genus *Taiwanocantharis* Wittmer, 1984 was upgraded from the subgenus of *Cantharis* L., 1758 by Švihla (2011). It was divided into 3 species groups, which included 16 species in total (Švihla 2011).

During our study, the type series of *T. thibetanomima* (Wittmer, 1997) was shown to be plural and consist of two species, except the true *T. thibetanomima* (China: Sichuan), a part of the paratypes belong to an unknown species, *T. wittmeri* sp. n. (China: Yunnan). Except this, another two new species are discovered and described under the names of *T. adentata* sp. n. (China: Gansu, Sichuan) and *T. parasatoi* sp. n. (China: Guangxi). Now the number of the species of the *T. thibetana* species-group is increased from 3 to 6, and a key is provided to distinguish them. Besides, *T. gansosichuana* (Kazantsev, 2010) is considered to be a junior synonym of *T. drahuska* (Švihla, 2004) based on the examination of the types of both nominal species. Additionally, *T. dedicata* (Švihla, 2005) and *T. malaisei* (Wittmer, 1989) are recorded to the Chinese fauna for the first time.

Material and method

The aedeagi and abdominal sternites VIII of females were dissected under a stereoscopic microscope, cleared in 10% KOH solution for several minutes, then placed in a droplet of glycerol and examined under a compound light microscope. Photographs of the type specimens were taken with a Leica DFC320 microscope, multiple layers were stacked using CombineZM software. Line drawings were made with the aid of camera lucida attached to a Leica MZ12.5 stereomicroscope. Body length is measured from the anterior margin of the clypeus to the elytral apex, body width is measured across the humeral part of elytra.

Complete label data are listed for type specimens, using square brackets "[ ]" for our remarks and comments, [p] indicating that the following data are printed and [h] that they are handwritten. Quotation marks are used to separate data from different labels and a backslash "\" to separate data from different lines of the same label.

The material is preserved in the following collections:

CAS	California Academy of Sciences, San Francisco, USA;
IZAS	Institute of Zoology, Chinese Academy of Sciences, Beijing, China;
MHBU	Museum of Hebei University, Baoding, China;
NHMB	Naturhistorisches Museum Basel, Switzerland;
NMPC	Národní muzeum, Praha, Czech Republic;
SKCR	Sergey V. Kazantsev private collection, Moscow, Russia.

Taxonomy

A key to the species of *Taiwanocantharis thibetana* species-group

1 Aedeagus: ventral process of each paramere distinctly widened, conjoint dorsal plate emarginated at lateroapical angles.... ***T. thibetana* (Gorham, 1889)**

– Aedeagus: ventral process of each paramere narrow or slightly widened, conjoint dorsal plate not emarginated at lateroapical angles **2**

2 Aedeagus: conjoint dorsal plate of parameres with the emargination of apical margin each side triangularly protuberant, the protuberance extending laterally into a short ridge on inner surface and bent ventrally **3**

– Aedeagus: conjoint dorsal plate of parameres unlike above......................... **4**

3 Pronotum with posterior angles slightly protruding, disc with a large black marking extending from anterior to posterior margin; legs uniformly black; abdominal sternite VIII of female largely emarginated in middle of posterior margin .... ***T. satoi* (Wittmer, 1997a)**

– Pronotum with posterior angles not protruding, disc with a large central and four small prebasal black markings; legs yellow at coxae, trochanters and femora, mostly black at tibiae and tarsi; abdominal sternite VIII of female moderately emarginated in middle and slightly emarginated on both sides of posterior margin .... ***T. parasatoi* sp. n.**

4 Aedeagus: conjoint dorsal plate of parameres without any tooth on inner surface .... ***T. adentata* sp. n.**

– Aedeagus: conjoint dorsal plate of parameres each side with a tooth near apical margin on inner surface.. **5**

5 Each outer tarsal claw with a lobe at base in female; aedeagus: conjoint dorsal plate of parameres each side with a large tooth near apical margin on inner surface, lateroapical angles obtusely dentated .... ***T. thibetanomima* (Wittmer, 1997b)**

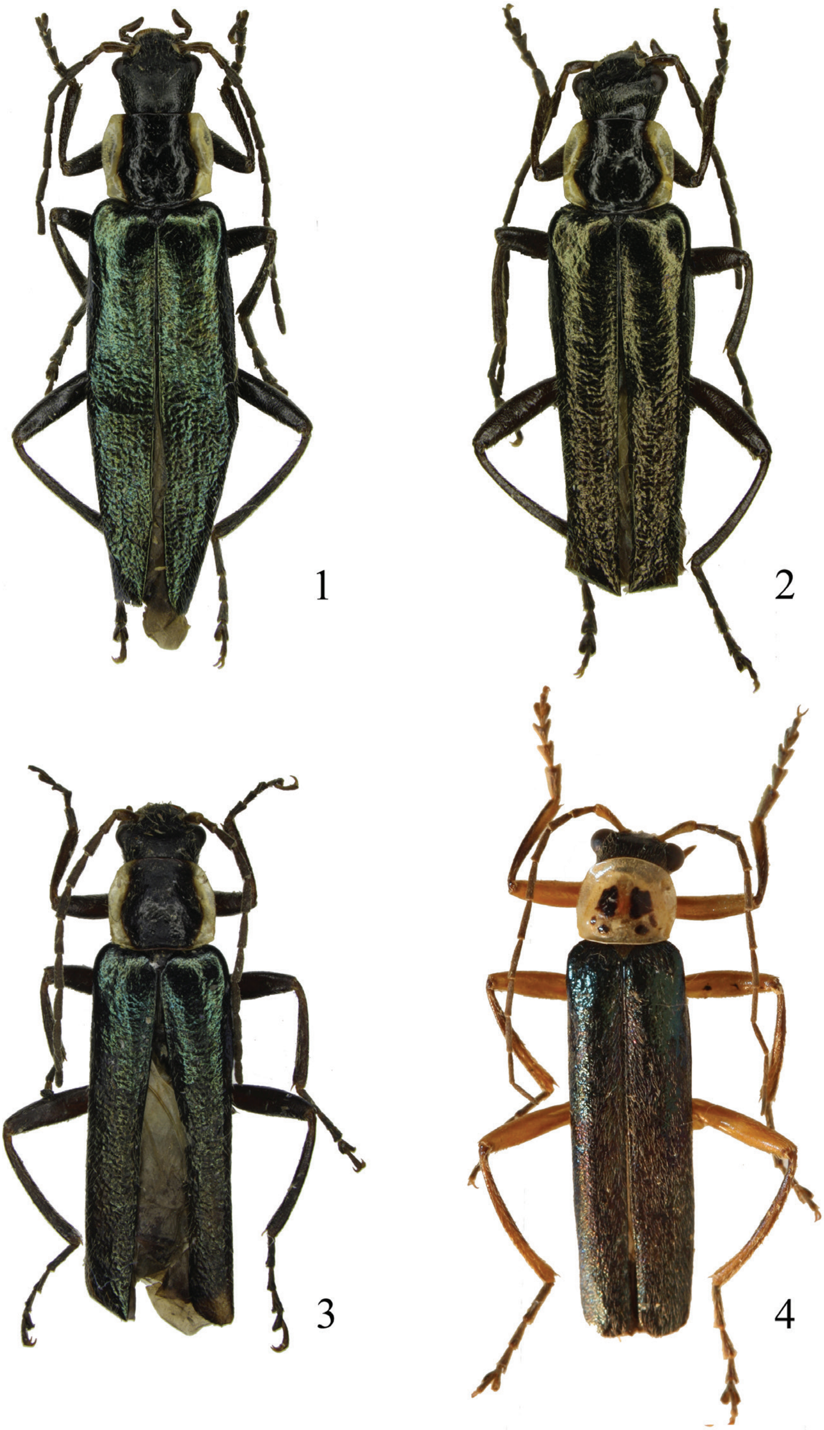
– All tarsal claws simple in female; aedeagus: conjoint dorsal plate of parameres each side with a small tooth near middle of apical margin on inner surface, lateroapical angles acutely dentated................................ ***T. wittmeri* sp. n.**

***Taiwanocantharis thibetanomima* (Wittmer, 1997)**

http://species-id.net/wiki/Taiwanocantharis_thibetanomima
Figs 1, 5–8

Cantharis (s.str.) *thibetanomima* Wittmer, 1997: 294, Figs. 151–153.
Taiwanocantharis thibetanomima: Švihla 2011: 5.

Type material examined. Holotype: 1 ♂ (NHMB): [h]“Sichuan, 2500m \ Emei Shan \ 29°35'N/103°11'E”, [h]“CHINA, \ 22/24.VI.1990”, [h] “Cantharis \ thibetanomima \ Wittm. \ det. W. Wittmer”, [p]“HOLOTYPUS”, [p]“CANTHARIDAE \ CANTH00004087”. Paratypes: 1 ♂ (NHMB): same data to the holotype, [p]“CANTHARIDAE \ CANTH00003067”; 1 ♀ (NHMB): same data, [p]“CANTHARIDAE \ CANTH00003209”; 1 ♀ (NHMB): same data, [p] “CANTHARIDAE \ CANTH00003565”; 1 ♂ (NHMB): [p]“CHINA / Sichuan



Figures 1–4. Male habitus, dorsal view: **1** *Taiwanocantharis thibetanomima* (Wittmer, 1997) **2** *T. wittmeri* sp. n. **3** *T. adentata* sp. n. **4** *T. parasatoi* sp. n.

\ 103.20el/29.30nw \ Mt. Emei 500-1200m \ 4.-18.V.1989 \ S. & J. Kolíáč leg.", [h]"thibetanomima", [p]"CANTHARIDAE \ CANTH00003497".

Additional material examined. CHINA: Sichuan: 1 ♂, 1 ♀ (IZAS): Emei Shan, 2100–3100m, 25.VI.1955, leg. B.R. Ou.

Redescription. Male (Fig. 1). Body black, except mandibles dark brown, antennomeres I–II brown on ventral sides, pronotum yellow, with a large black marking extending from anterior to posterior margin, elytra green, with strongly metallic shine.

Head rounded, surface matt on frons, densely punctate on vertex, eyes slightly protruding, head width acrossing eyes distinctly narrower than pronotum; terminal maxillary palpomeres nearly long-triangular, widest at basal one-third; antennae filiform, extending to elytral middle length, antennomeres II about 3 times longer than wide, III slightly longer than II, IV–XI each with a narrow, smooth longitudinal to oval groove nearly in middle of outer margin.

Pronotum wider than long, widest at anterior one-third, anterior margin straight, lateral margins sinuate, posterior margin bisinuate and narrowly bordered, anterior angles rounded, posterior angles slightly protruding, disc slightly convex at posterolateral parts, surface lustrous, slightly largely and sparsely punctate.

Elytra nearly parallel-sided, about 3 times longer than width at humeri, about 4 times of length of pronotum, dorsum finely punctate, lustrous at anterior one-third parts, roughly but shallowly rugoluse-lacunose on the rest.

Legs: all outer tarsal claws each with a triangular lobe at base, inner claws simple.

Aedeagus (Figs 5–7): ventral process of each paramere narrow, distinctly shorter than conjoint dorsal plate; conjoint dorsal plate with apical margin widely emarginated in middle, lateroapical angles obtusely dentated, each side with a large tooth near apical margin on inner surface; laterophyse adhered to median lobe, with apex bent towards middle, the portion around the bending corner with upper margin slightly protuberant and bent dorsally.

Female. Similar to male, but eyes smaller, terminal maxillary palpomeres shorter, nearly widest in middle, antennae shorter, extending to elytral one-third length, antennomeres IV–XI without any groove, pronotum wider, elytra with lateral margins slightly diverging posteriorly, abdominal sternite VIII (Fig. 8) largely emarginated in middle and slightly emarginated on both sides of posterior margin, the portion between middle and each lateral emarginations rounded at apex.

Body length: 9.0–11.0 mm; width: 2.0–2.5mm.

Distribution. China (Sichuan). Excluded from Yunnan province at the moment.

Remarks. In the study, the type series of this species were discovered to be plural and consist of two species. Except the true *T. thibetanomima*, which was located in Sichuan, China, the paratypes from Yunnan, China designated in the original publication belong to another unknown species described below, *T. wittmeri* sp. n. Besides, the photos of aedeagus provided by Wittmer (1997b) is not of *T. thibetanomima* but *T. wittmeri* sp. n. So it is necessary to redescribe and illustrate this species here.

Taiwanocantharis wittmeri **sp. n.**

http://zoobank.org/718F1778-CB50-4A92-AA39-74D0695B6AF7
http://species-id.net/wiki/Taiwanocantharis_wittmeri
Figs 2, 9–12

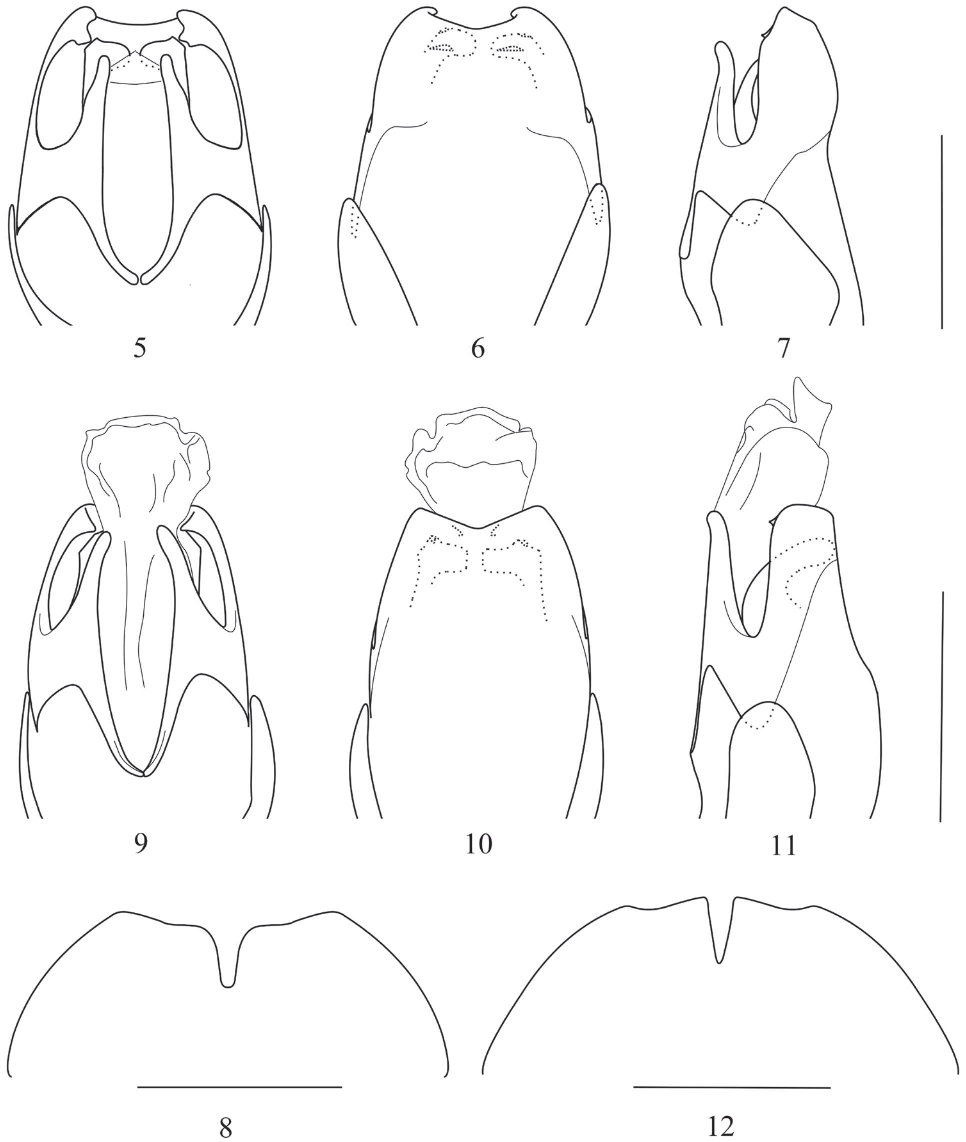
Cantharis (s.str.) *thibetanomima* Wittmer, 1997b: 294, Figs. 151–153, parte.

Type material. Holotype ♂ (NHMB): [p] "CHINA, Yunnan prov. \ 27°08'N 100°14'E, 2900 \ Yulongshan mts., -3500m \ BAISHUI 7.-12.VII.1990 \ Vít Kubáň leg.", [p] "CANTHARIDAE \ CANTH00003678". Paratypes: 1 ♀ (NHMB): same data to holotype, [p] "CANTHARIDAE \ CANTH00003695"; 1 ♀ (NHMB): same data, [p] "CANTHARIDAE \ CANTH00003057"; 1 ♀ (NHMB): same data, [p] "CANTHARIDAE \ CANTH00002059"; 1 ♂ (NHMB): [p] "YUNNAN, 23-24.JUN. \ YULONG Mts., 1993 \ 27.00N 100.12E \ Bolm lgt. 3200m", [p] "CANTHARIDAE \ CANTH00003523"; 1 ♀ (NHMB): [p] "YUNNAN, 24-26 May \ YULONG Mts., 1993 \ 27.01N 100.12E \ Bolm lgt. 3200m", [p] "CANTHARIDAE \ CANTH00003665"; 1 ♀ (IZAS): [p] "YUNNAN 3300-3500m \ 27.07N 100.13E 1993\ YULONGSHAN mts. 20- \ Vít Kubáň leg. -21/6.", [p] "IOZ(E) 217863"; 1 ♂ (IZAS): [p] "China N-YUNNAN \ 27°08'N 100°14'E \ Yulongshan mts. 2900- \ -3500m BAISHUI vill. \ lgt. D. Král 7-12/7'90", [p] "IOZ(E) 217864"; 1 ♀ (NHMB): [p] "China Yunnan 1-19.VII \ HEISHUI 27.13N 100.19E \ 35km N of Lijiang \ legit S. Beĉváŕ 1992", [p] "CANTHARIDAE \ CANTH00003632"; 1 ♂ (NHMB): [p] "CHINA: N. Yunnan \ 30km N of LIJIANG \ 3000m, 3.VII.1990 \ L. & M. Bocák. lgt.", [p] "CANTHARIDAE \ CANTH00004071"; 1 ♀ (NHMB): [p] "YUNNAN 2500-3100m \ 25.58N 100.21E 30/5 \ JIZUSHAN mts. -3/6 \ Vit Kubáň leg. 1993", [p] "CANTHARIDAE \ CANTH00003636"; 1 ♀ (NHMB): same data, [p] "CANTHARIDAE \ CANTH00003773"; 1 ♂ (NHMB): [p] "YUNNAN, 30 May-3 Jun \ JIZU MTS., 1993 \ 25.58N 100.21E \ Bolm lgt. 2800m", [p] "CANTHARIDAE \ CANTH00003608"; 1 ♀ (NHMB): same data, [p] "CANTHARIDAE \ CANTH00003804"; 1 ♀ (NHMB): [p] "YUNNAN 2000-2800m \ 25.11N 100.24E \ WEIBAOSHAN mts. \ W slope 25-28/6.92 \ David Král leg.", [p] "CANTHARIDAE \ CANTH00003651".

Description. Male (Fig. 2). Body black, except mandibles dark brown, antennomeres I–II brown on ventral sides, pronotum yellow, with a large black marking extending from anterior to posterior margin, elytra mixed green and bronze, with strongly metallic shine.

Head rounded, surface matt on frons, densely punctate on vertex, eyes slightly protruding, head width acrossing eyes distinctly narrower than pronotum; terminal maxillary palpomeres nearly long-triangular, widest at basal one-third; antennae filiform, extending to elytral middle length, antennomeres II about 3 times longer than wide, III slightly longer than II, IV–XI each with a narrow, smooth longitudinal to oval groove nearly in middle of outer margin.

Pronotum wider than long, widest at anterior one-third, anterior margin straight, lateral margins sinuate, posterior margin bisinuate and narrowly bordered, anterior an-



Figures 5–12. Aedeagus: (**5, 9** ventral view **6, 10** dorsal view **7, 11** lateral view) **8, 12** Abdominal sternite VIII of female, ventral view: **5–8** *Taiwanocantharis thibetanomima* (Wittmer, 1997) **9–12** *T. wittmeri* sp. n. Scale bars: 1 mm.

gles rounded, posterior angles nearly rectangular, not protruding, disc slightly convex at postero-lateral parts, surface lustrous, finely and sparsely punctate.

Elytra nearly parallel-sided, about 3 times longer than width at humeri, about 3.5 times of length of pronotum, dorsum finely punctate, lustrous at anterior one-third parts, roughly but shallowly rugoluse-lacunose on the rest.

Legs: all outer tarsal claws each with a triangular lobe at base, inner claws simple.

Aedeagus (Fig. 9–11): ventral process of each paramere narrow, nearly as long as conjoint dorsal plate; conjoint dorsal plate with apical margin triangularly emarginated in middle, lateroapical angles acutely dentated, each side with a small tooth near middle of apical margin on inner surface; laterophyse adhered to median lobe, with apex bent towards middle, the portion around the bending corner with upper margin slightly protuberant and bent dorsally.

Female. Similar to male, but eyes smaller, terminal maxillary palpomeres shorter, nearly widest in middle, antennae shorter, extending to elytral one-third length, antennomeres IV–XI without any groove, pronotum wider, elytra with lateral margins slightly diverging posteriorly, all tarsal claws simple, abdominal sternite VIII (Fig. 12) largely emarginated in middle and slightly emarginated on both sides of posterior margin, the portion between middle and each lateral emarginations tapered at apex.

Body length: 8.0–11.0mm; width: 2.0–2.5mm.

Diagnosis. This species is similar to *T. thibetanomima*, but can be distinguished from the latter by the following characters: all tarsal claws simple in female; aedeagus: ventral process of each paramere nearly as long as conjoint dorsal plate, conjoint dorsal plate with lateroapical angels acutely dentated, each side with a small tooth near middle of apical margin on inner surface; abdominal sternite VIII of female with the portions between middle and lateral emarginations tapered at apex.

Distribution. China (Yunnan).

Etymology. This species is named after the late distinguished taxonomist Dr. Walter Wittmer.

Remarks. This new species was described based on a part of the paratypes, which are located in Yunnan, China, of *T. thibetanomima*. What's noted, two paratypes provided with the information as "Yulongshan Mts., Baishui, 2900–3500m, 27°08'N, 100°14'E, 7.–12.VII.1990, 22.–24.VI.1993", according to the original publication by Wittmer (1997), can not found in the collection of NHMB. But four not three paratypes labeled as "Jizushan Mts., 2500–3100m, 25°58'N, 100°21'E, 30.V.–3.VI.1993" were found in NHMB, all of them were designated as the paratypes of *T. wittmeri* sp. n.

***Taiwanocantharis adentata* sp. n.**

http://zoobank.org/F6B46DF0-FD93-4F9A-ABDC-7018B5C87221
http://species-id.net/wiki/Taiwanocantharis_adentata
Figs 3, 13–16

Type material. Holotype ♂ (MHBU): CHINA: Gansu: Wenxian, Huangtuling, 2350m, 9.VII.2003, leg. Y.B. Ba & Y. Yu. Paratypes: 1 ♀ (MHBU): same data to holotype; 1 ♀ (MHBU): same data, 8.VII.2003. 1 ♂ (NHMB): [Sichuan]: Da Tsien Lou [Kangding], 3.VI.(18)93 (collector, hand-writing, hardly readable).

Description. Male (Fig. 3). Body black, except mandibles brown, antennomeres I–II brown on ventral sides, pronotum yellow, with a large black marking extending from anterior to posterior margin, elytra green, with strongly metallic shine.

Head rounded, surface matt on frons, densely punctate on vertex, eyes slightly protruding, head width acrossing eyes slightly narrower than anterior margin of pronotum; terminal maxillary palpomeres nearly long-triangular, widest at basal one-third; antennae filiform, extending to elytral middle length, antennomeres II about 3 times longer than wide, III slightly longer than II, IV–XI each with a narrow, smooth longitudinal to oval groove nearly in middle of outer margin.

Pronotum wider than long, widest at anterior one-third, anterior margin straight, lateral margins sinuate, posterior margin bisinuate and narrowly bordered, anterior angles rounded, posterior angles nearly rectangular, not protruding, disc slightly convex at postero-lateral parts, surface lustrous, finely and sparsely punctate.

Elytra nearly parallel-sided, about 3 times longer than width at humeri, about 4 times of length of pronotum, dorsum finely punctate, lustrous at anterior one-third parts, roughly but shallowly rugoluse-lacunose on the rest.

Legs: all outer tarsal claws each with a triangular lobe at base, inner claws simple.

Aedeagus (Figs 13–15): ventral process of each paramere narrow, slightly shorter than conjoint dorsal plate; conjoint dorsal plate with apical margin slightly emarginated in middle, lateroapical angles acutely dentated, without any tooth on inner surface; laterophyse adhered to median lobe, with apex bent towards middle, the portion around the bending corner with upper margin slightly protuberant and bent dorsally.

Female. Similar to male, but eyes smaller, terminal maxillary palpomeres shorter, nearly widest in middle, antennae shorter, extending to elytral one-third length, antennomeres IV–XI without any groove, pronotum wider, elytra with lateral margins slightly diverging posteriorly, abdominal sternite VIII (Fig. 16) largely emarginated in middle and slightly emarginated on both sides of posterior margin, the portion between middle and each lateral emarginations subrounded at apex.

Body length: 8.0–11.0 mm; width: 2.0–2.5mm.

Diagnosis. This species is similar to *T. thibetanomima*, but can be distinguished from the latter by the aedeagus: conjoint dorsal plate of parameres with lateroapical angles acutely dentated, without any tooth on inner surface.

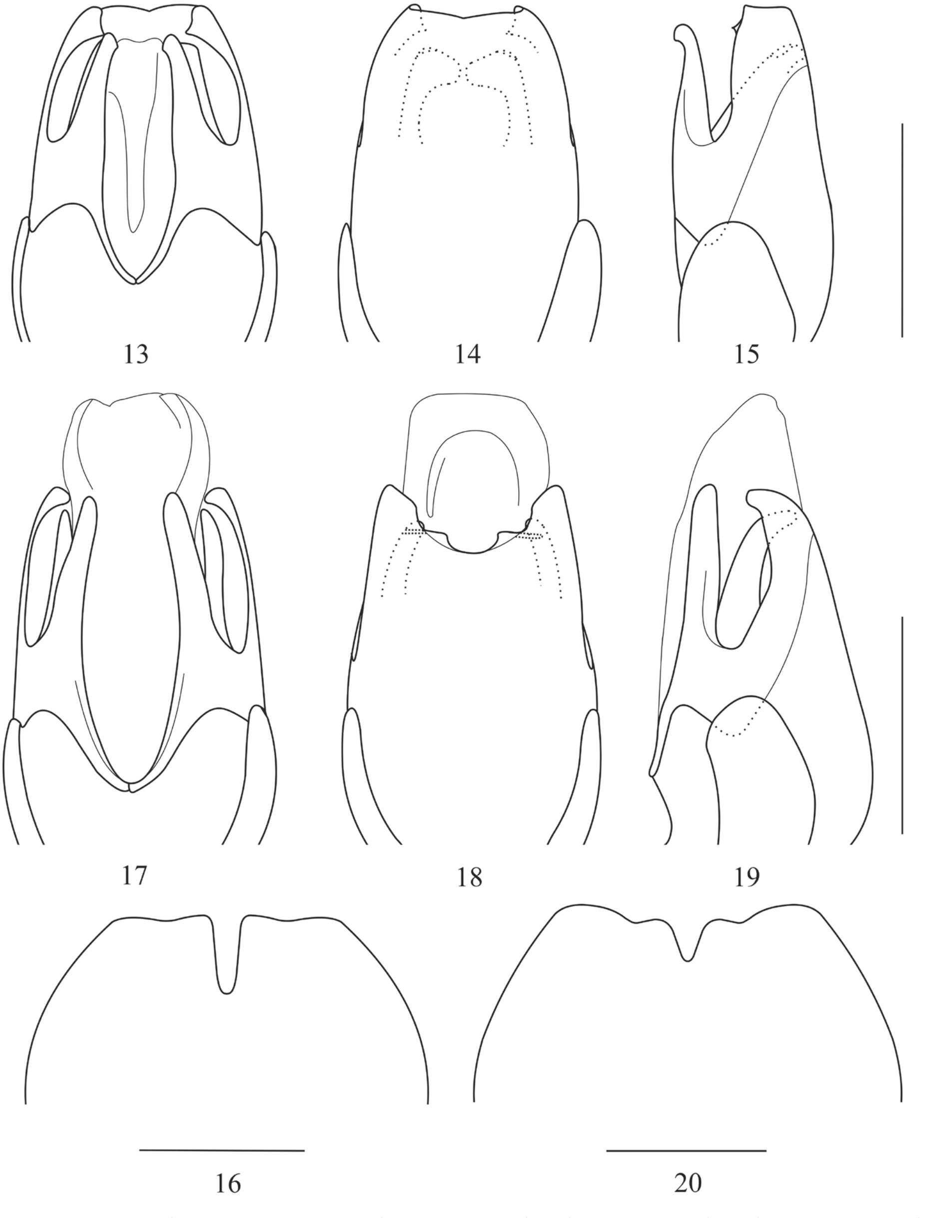
Distribution. China (Gansu, Sichuan).

Etymology. This specific name is derived from the Latin "*a-*" (none) + "*dentatus*" (toothed), referring to its conjoint dorsal plate of parameres without any tooth on inner surface.

Taiwanocantharis parasatoi sp. n.

http://zoobank.org/CD261DB4-3587-40AB-8343-CB2FF845B8D0
http://species-id.net/wiki/Taiwanocantharis_parasatoi
Figs 4, 17–20

Type material. Holotype ♂ (MHBU): CHINA: Guangxi: Wuming, Damingshan, 1100m, 27.V.2011, leg. H.Y. Liu. Paratypes: 2 ♂♂, 1 ♀ (MHBU): same data to holo-



Figures 13–20. Aedeagus: (**13, 17** ventral view **14, 18** dorsal view **15, 19** lateral view) **16, 20** Abdominal sternite VIII of female, ventral view: **13–16** *Taiwanocantharis adentata* sp. n. **17–20** *T. parasatoi* sp. n. Scale bars: 1 mm.

type; 2♂♂ (MHBU): same locality, 600–900m, 25.V.2011, leg. H.Y. Liu; 1 ♂, 1 ♀ (MHBU): same locality, 1230–1423m, 20.V.2011, leg. H.Y. Liu.

Description. Male (Fig. 4). Head black, mouthparts yellow, slightly darkened at terminal maxillary and labial palpomeres, mandibles dark brown, antennae black, antennomeres I–II yellow on ventral sides, pronotum yellow, disc with two central and four prebasal small black markings, scutellum yellow, elytra green, with strongly metallic shine, thorax and abdomen yellow on ventral sides, abdominal sternites II–VIII each side with a small round black marking, legs yellow, tibiae black, with apical parts yellow on ventral sides, tarsi black.

Head rounded, surface lustrous, densely punctate on vertex, eyes strongly protruding, width acrossing eyes slightly narrower than pronotum; terminal maxillary palpomeres nearly long-triangular, widest at basal one-third; antennae filiform, extending to elytral middle length, antennomeres II about 3 times longer than wide, III slightly longer than II, IV–XI each with a narrow, smooth longitudinal to oval groove nearly in middle of outer margin.

Pronotum distinctly wider than long, widest at anterior one-third, anterior margin arcuate, lateral margins slightly sinuate, posterior margin arcuate and narrowly bordered, anterior angles rounded, posterior angles subrounded, not protruding, disc slightly convex at postero-lateral parts, surface lustrous, finely and sparsely punctate.

Elytra nearly parallel-sided, about 4 times longer than width at humeri, about 5 times of length of pronotum, dorsum finely punctate, lustrous at humeral parts, roughly but shallowly rugoluse-lacunose on the rest.

Legs: slender, all outer tarsal claws each with a triangular lobe at base, inner claws simple.

Aedeagus (Figs 17–19): ventral process of each paramere slightly widened, nearly as long as conjoint dorsal plate; conjoint dorsal plate slightly bent ventrally at apex in lateral view, with apical margin roundly emarginated in middle, each side of the emargination triangularly protuberant, the protuberance extending laterally into a short ridge on inner surface and bent ventrally, lateroapical angles blunt-coniformly dentated; laterophyses normal and separated on both sides of median lobe, with apices rounded.

Female. Similar to male, but eyes smaller, terminal maxillary palpomeres shorter, nearly widest in middle, antennae shorter, extending to elytral one-third length, antennomeres IV–XI without any groove, elytra with lateral margins slightly diverging posteriorly, abdominal sternites II–VII each side with a small round black marking, VIII (Fig. 20) moderately emarginated in middle and slightly emarginated on both sides of posterior margin, the portion between middle and each lateral emarginations rounded at apex.

Body length: 12.0–14.0 mm; width: 2.0–3.0 mm.

Diagnosis. This new species is related to *T. satoi* (Wittmer, 1997a), but can be distinguished from the latter by the following characters: pronotum with posterior angles not protruding, disc with a large central and four small prebasal black markings; legs yellow at coxae, trochanters and femora, black at tibiae and tarsi; abdominal sternite VIII of female moderately emarginated in middle and slightly emarginated on both sides of posterior margin.

Distribution. China (Guangxi).

Etymology. This specific name is derived from the Greek prefix "*para-*" (similar), referring to its close relationship to *T. satoi*.

Taiwanocantharis drahuska (Švihla, 2004)

http://species-id.net/wiki/Taiwanocantharis_drahuska

Cordicantharis drahuska Švihla, 2004: 176, Figs 55–57, 198.
Cantharis (s.str.) *gansosichuana* Kazantsev, 2010: 154, Figs 2–4.
Taiwanocantharis drahuska: Švihla 2011: 5.
Taiwanocantharis gansosichuana: Švihla 2011: 5. **syn. n.**

Type material examined. *Cordicantharis drahuska*: Holotype: 1 ♂ (NMPC): [p]"China: Shaanxi, 2.-4.7.1998 \ Qing Ling Shan mts., 3500m \ Hou Zen Zi-Tai Bai \ Jindra, Trýzna & Šafránek lgt.", [p]"HOLOTYPUS \ Cordicantharis \ drahuska sp. n. \ V. Švihla det. 2003".

Cantharis (s.str.) *gansosichuana*: Holotype: 1 ♂ (SKCR): [p]"CHINA: S Gansu \ Tepo [Tewo] 2500-2800m \ 26-28/vi/2001 \ S. Kazantsev leg.", [p-h]"Cantharis \ gansosichuana \ sp. n. \ S. Kazantsev det. 2010", [p]"HOLOTYPUS \ S. Kazantsev des.".

Additional material examined. CHINA: Sichuan: 2 ♂♂, 1 ♀ (NMPC): Erlangshan Mts., 2600m, E Luding, 14.–16.VI.2003, leg. S. Murzin. Gansu: 1 ♂, 6 ♀♀ (HBUM): Wenxian, Huangtuling, 2350m, 9.VII.2003, leg. Yi-Bin Ba & Yang Yu; 1 ♀ (HBUM): same data, 8.VII.2003. Ningxia: 1 ♂ (HBUM): Heshangpu Forestry center, 1.–2.VII.2008, leg. X.P. Wang & X.L. Liu; 1 ♀ (HBUM): same data, 2100m, 5.–6.VII.2008; 2 ♂♂, 13 ♀♀ (HBUM): Jingyuan, Erlonghe, 3.–4. VII.2009, leg. X.P. Wang & X.L. Zhao; 4 ♀♀ (HBUM): same locality, 23.VI.2008, leg. Hong-Fan Ran; 2 ♀♀ (HBUM): same locality, 6.VII.2009, leg. S.Y. Zhou & X.J. Meng; 1 ♀ (HBUM): same locality, 6.VII.2009, leg. H.F. Ran & S.S. Zhang; 4 ♀♀ (HBUM): same locality, 23.VI.2008, leg. H.F. Ran; 1 ♂, 4 ♀♀ (HBUM): Jingyuan, Xixia Forestry center, 9.–10.VII.2009, leg. X.P. Wang & X.L. Zhao; 1 ♂, 3 ♀♀ (HBUM): same locality, 27.–28.VII.2008, leg. X.M. Li, H.F. Ran & Q.Q. Wu; 3 ♂♂, 8 ♀♀ (HBUM): same data, 15.–16.VII.2008; 1 ♂ (HBUM): same locality, 27.VII.2008, leg. F. Yuan; 2 ♀♀ (HBUM): Wanghuanan Forestry center, 20.VI.2008, leg. H.F. Ran; 1 ♀ (HBUM): same locality, 3.–4.VII.2009, leg. G.D. Ren & Y.W. Ba; 2 ♀♀ (HBUM): Jingyuan, Dongshanpo, 8.VII.2009, leg. H.F. Ran & S.S. Zhang; 1 ♀ (HBUM): Hongxia Forestry center, 25.VI.2008, leg. H.F. Ran; 1 ♂ (HBUM): Longde, Fengtai Forestry center, 29.–30.VI.2008, leg. X.M. Li, H.F. Ran & Q.Q. Wu.

Distribution. China (Sichuan, Gansu, Shaanxi, Ningxia). Newly recorded for Ningxia Hui Autonomous Region.

Remarks. It had been noted by Švihla (2011) that *T. gansosichuana* (Kazantsev, 2010) was possibly a junior synonym of *T. drahuska* (Švihla, 2004) without examining the types of the former species. During our study, the holotypes of the both nominal species and a large series of additional material at our disposal were examined, and no difference between them was discovered, thereby we suggest *T. drahuska* be synonymized with *T. gansosichuana*.

Taiwanocantharis dedicata **(Švihla, 2005)**

http://species-id.net/wiki/Taiwanocantharis_dedicata

Cantharis (s.str.) *dedicata* Švihla, 2005: 88, Figs 35–37.
Taiwanocantharis dedicata: Švihla 2011: 5.

Type material examined. Holotype: 1 ♂ (NMPC): [p]“Laos: Hua Phan prov. \ Ban Saluei, Mt. Phu Phan \ 20.13°N, 103.95°E, 1300-2000m \ F. & L. Kantner lgt. \ 6-17.v.2004”, [p]“HOLOTYPUS \ Cantharis (s.str.) \ dedicata sp. n. \ V. Švihla det. 2005”.

Additional material examined. CHINA: Yunnan: 2 ♂♂ (IZAS): Tengchong, Jietou town, Shaba, 1850m, 25.3926°N, 98.7035°E, 25.V.2006, leg. H.B. Liang & P. Hu.

Distribution. China (new record: Yunnan); Laos.

Taiwanocantharis malaisei **(Wittmer, 1989)**

http://species-id.net/wiki/Taiwanocantharis_malaisei

Cantharis malaisei Wittmer, 1989: 212, Figs. 5, 7.
Taiwanocantharis malaisei: Švihla 2011: 5.

Type material examined. Holotype: 1 ♂ (NHMB): [p]“N.E. BURMA \ Kambaiti, 7000ft \ 3/5 1934 \ R. Malaise”, [h]“Canthris \ malaisei \ Wittm. \ det. W. Wittmer”,[h]“HOLOTYPUS”, [p]“Naturhistorisches \ Museum Basel \ Coll. W. Wittmer”, [p]“CANTHARIDAE \ CANTH00003352”. Paratypes: 2 ♀♀ (NHMB): same data, 3. –7.V.1934; 1 ♀ (NHMB): same data, 12.IV.1934; 2 ♀♀ (NHMB): same data, 4.–8.VI.1934; 1 ♂, 1 ♀ (NHMB): same data, 2000m, 27.V.1934.

Additional material examined. CHINA: Yunnan: 1 ♀ (NHMB): Gaoligong mts., 2200–2500m, 24°57'N, 98°45'E, 8.–16.V.1995, leg. Vit Kubáň; 1 ♀ (CAS): Lushui County, Pianma Township, Gangfang, 1675m, 26.12070°N/098.57830°E, 16.V.2005, attracted to uv and mv lights at night, Stop# HBL-05-11, H. B. Liang collector [CASENT 1036703].

Distribution. China (new record: Yunnan); Myanmar.

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We are grateful to late Dr. Michel Brancucci (NHMB) not only for his providing a chance to the first author to visit and study in the Naturhistorisches Museum Basel for one year, but also for giving her a lot valuable suggestions in studying on the taxonomy of Cantharidae. Also, we thank Dr. Vladimír Švihla (NMPC), Dr. Sergey V. Kazantsev (Moscow, Russia) and Dr. David H. Kavanaugh (CAS) for their kind helps in accessing to the cantharid collections under their charge. The present study was supported by the National Natural Science Foundation of China (Nos. 31010103913, 31172135), the Knowledge Innovation of Chinese Academy of Sciences (Nos. KSCX2-EW-G-4, KSCX2-EW-Z-8), the Natural Science Foundation of Hebei Province (No. C2013201261) and a grant (No. O529YX5105) from the Key Laboratory of the Zoological Systematics and Evolution of the Chinese Academy of Sciences.

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RESEARCH ARTICLE

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Spatial distribution of fifty ornamental fish species on coral reefs in the Red Sea and Gulf of Aden

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Abstract

The spatial distribution of 50 ornamental fish species from shallow water habitats on coral reefs were investigated using visual census techniques, between latitudes 11–29°N in the Red Sea, in Jordan, Egypt, Saudi Arabia, and Yemen, and in the adjacent Gulf of Aden in Djibouti. One hundred eighteen transects (each 100×5 m) were examined in 29 sites (3–8 sites per country). A total of 522,523 fish individuals were counted during this survey, with mean abundance of 4428.2 ± 87.26 individual per 500 m^2 transect. In terms of relative abundance (RA), the most abundant species were Blue green damselfish, *Chromis viridis* (RA=54.4%), followed by Sea goldie, *Pseudanthias squamipinnis* (RA= 34.7), Whitetail dascyllus, *Dascyllus aruanus* (RA= 2.6%), Marginate dascyllus, *Dascyllus marginatus* (RA= 2.0), Red Sea eightline flasher *Paracheilinus octotaenia* (RA=1.0), and Klunzinger's wrasse, *Thalassoma rueppellii* (0.7%). The highest number of species (S) per 500 m^2 transect was found on reefs at the latitude 20° in Saudi Arabia (S=21.8), and the lowest number of species was found at the latitude 15° in Djibouti (S=11.11). The highest mean abundance (8565.8) was found on reefs at latitude 20° in Saudi Arabia and the lowest mean abundance (230) was found on reefs at latitude 22°, also in Saudi Arabia. Whereas, the highest Shannon-Wiener Diversity Index was found in reefs at the latitude 22° (H`=2.4) and the lowest was found in reefs at the latitude 20° (H`=0.6). This study revealed marked differences in the structure of ornamental fish assemblages with latitudinal distribution. The data support the presence of two major biogeographic groups of fishes in the Red Sea and Gulf of Aden: the southern Red Sea and Gulf of Aden group and the group in the northern and central Red Sea. Strong correlations were found between live coral cover and the number of fish species, abundance and Shannon-Wiener Diversity indices, and the strength of these correlations varied among the reefs. A conclusion was done that environmental differences among the reefs and the habitats investigated were important components of abundance variations and species diversity of ornamental fish along latitudinal gradients in the Red Sea and the Gulf of Aden.

Keywords
Fish community structure, coral reef fishes, Aquarium fishes, Biogeographical affinities, Red Sea and Gulf of Aden

Introduction

Coral reefs are valuable and important ecosystems. They are among the most productive and diverse of all-natural ecosystems, and they are often called «the tropical rain forests of the sea» (Bourilere and Harmelin 1989). Coral reefs have many functions, amongst which is the provision of a variety of habitats for a wealth of organisms. Fishes are a dominant group of coral reef fauna, in terms of both their biomass and diversity. They are the most visible and important mobile component in the coral reefs (Letourneur et al. 1999). Reef ecosystems provide fishes with shelter, feeding, spawning and nursery grounds. Pollution, destructive fishing, over-fishing, coral bleaching, tourism development and other stresses and activities threaten these valuable ecosystems.

While the Red Sea fish fauna is taxonomically quite well known (Randall 1992, Goren and Dor 1994, Khalaf 2004) compared with other parts of the tropical Indo-Pacific Ocean, the community structure of shore fishes has been less well investigated (Khalaf and Kochzius 2002). Despite a long tradition of taxonomical work (e.g. Forsskal 1775, Klunzinger 1884), few studies have been published on the general community structure of the Red Sea shore fishes (Bouchon-Navaro 1980, Ben-Tuvia et al. 1983, Rilov and Benayahu 2000, Khalaf and Kochzius 2002, Alwany and Stachowitsch 2007) and these studies cover a small range of spatial distribution. Most species of near-shore fishes in the Red Sea associate with coral reefs, although some occur in sea grasses, sandy areas, and other near-shore habitats (UNEP 1997). The present study was carried out through the Sustainable Use and Management of Living Marine Resources component of the Strategic Action Programme for the Red Sea and Gulf of Aden (SAP) executed by The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) between 1999 and 2003. The study was conducted at coral reef sites to assemble comparative regional data on the distribution of fifty ornamental fish species at latitudinal (11–29°N) spatial scales. The main objectives of the study were to assess the community structure, and biogeographic affinities of Red Sea coral reef fishes that are collected for the aquarium trade.

Material and methods

Study area

The study was conducted at coral reef sites at latitudes between 11–29°N along the coasts of Jordan, Egypt, Saudi Arabia, Yemen in the Red Sea and just outside the Red Sea in the Gulf of Aden, for Djibouti (Fig. 1).

Figure 1. Map of the Red Sea and Gulf of Aden. Squares indicate the coral reef sites examined in the present study.

Visual census

We selected 50 ornamental reef fish species that occur in shallow water habitats on coral reefs only. Based on the information collected from fishermen and Government authorities in member countries of (PERSGA), most of the sites and depths in Egypt, Saudi Arabia and Yemen were selected in sites used by collectors of the ornamental fishes. Whereas, the sites in Jordan and Djibouti were collection of ornamental fishes did not take place was carried out in coral reef sites. The abundance of each species was surveyed along the coasts of Jordan, Egypt, Saudi Arabia, Yemen and Djibouti using a visual census technique by SCUBA divers, as described in English et al. (1994). The visual census technique is a widely used method for ecological studies of fishes on coral reefs. However, differences in skill levels and techniques of observers can be a source of imprecision and/or bias (Thompson and Mapstone 1997). Therefore, only underwater fish counting performed by the first author was used to avoid this type of bias in the present study. A total of 118 transects, each 100m length × 5m width (500m^2) were performed at 29 sites (3–6 transects per site except at Ras Mohamed two transects instead of three at 2–4 m depth were surveyed due to the strong

Table 1. Information on 29 sampling sites along the Jordanian, Egyptian, Saudi Arabian, Yemeni and Djibouti coasts, Red Sea and Gulf of Aden; n=number of transects examined; date of fish counts given for each sampling depth, and position of each site in latitude N and longitude E shown. NR=not recorded. Note: in Yemen, Djibouti, and at some sites in Saudi Arabia, only transects at 2–4m depth were examined.

Country	Latitude	Site	n	2–4m	n	5 m depth	n	10 m depth	N	E	Total No. of transects
Jordan	JO 29°	Marine Science Station			3	26/7/2002	3	26/7/2002	29°26.276, 34°58.275		18
		Visiting Center			3	25/7/2002	3	25/7/2002	NR	NR	
		Tourist Camp			3	24/7/2002	3	24/7/2002	29°26.276, 34°58.275		
Egypt	EG 27°	Noksh			3	11/7/2002	3	11/7/2002	27°46.723, 34°02.915		31
		Mahmoudat			3	12/7/2002		12/7/2002	27°44.460, 34°08.881		
		Manar Dolphin			3	13/7/2002	3	13/7/2002	27°42.303, 34°07.133		
		Elli			3	14/7/2002	3	14/7/2002	27°47.334, 33°53.227		
		Zorab			5	16/7/2002		16/7/2002	27°50.146, 34°00.230		
		Ras Mohamad			2	15/7/2002	3	15/7/2002	27°43.886, 34°15.663		
Saudi Arabia	SA 22°	Bostek/Thoal					3	2/11/2002	22°19.647, 39°02.350		6
		Thoal- Awjam			3	2/11/02			22°19.648, 39°02.351		
	SA 21°	Alkabeera			3	30/10/2002	3	27/10/2002	21°41.581, 39°00.741		21
		Bayada			3	28/10/2002			NR	NR	
		South Batch Bayada			3	30/10/2002	3	29/10/2002	21°44.602, 38°57.798		
		Al-Sagheera			3	31/10/2002			21°39.721, 38°58.850		
		Al-Kherq			3	31/10/2002			21°43.039, 38°59.253		
	SA 20°	Alleeth			3	3/11/2002	3	3/11/2002	20°06.326, 40°13.030		6
Yemen	YE 15°	Kadaman	3	8/10/2002					15°33.949, 42°13.585		18
		Kamaran	3	5/10/2002					15°16.593, 42°36.192		
		Tekfash	3	7/10/2002					15°41.979, 42°23.654		
		Quish	3	7/10/2002					15°41.084, 42°28.110		
		Al-murk	3	8/10/2002					NR	NR	
		Al-Badi	3	9/10/2002					NR	NR	
Djibouti	DJ 12°	Gehere	3	17/10/2002					12°16.662, 43°22.926		3
	DJ 11°	Khor Ambado	3	13/10/2002					11°35.780, 43°01.985		15
		Maskali	3	14/10/2002					11°42.937, 43°09.246		
		Musha	3	14/10/2002					11°44.669, 43°12.440		
		Tajoura	3	15/10/2002					11°46.245, 42°56.860		
		Arta Plaga	3	16/10/2002					11°35.394, 42°49.981		
		Total n	36		49		33				118

water currents occurred during the period of study, Table 1). At each site, a visual census was conducted along three transects, in most cases on the shallow reef slope (4–5 m) and also three transects on the deep reef slope (8–10m). Divers then swam along the transects and recorded individuals of the 50 selected fish species within 2.5 m either side, and 3 m above the transect line for a duration of 25–30 minutes. Fish identification in the field was checked using published guides (Myers 1991, Randall 1992, Smith and Heemstra 1986, Khalaf and Disi 1997). The common name of fishes indicated in this study were after Froese and Pauly 2000 (FishBase 2013). All latitude numbers are for north latitudes.

Surveys of the benthic habitat were carried out by assistants from Saudi Arabia and Yemen. The line-point intercept method was used with the tape stretched taut 200 points recorded per 100-m transect. From this point-intercept data, the percentage cover was calculated of live hard coral, live soft coral, dead coral, coral rock, sand, rubble, macro algae, algal turf, sponge, and others as described by Edwards (2002).

Statistical analysis

Abundance of fishes was described by relative abundance (RA) and frequency of appearance (FA) following Khalaf et al. (2006). RA was calculated as: (pooled average abundance of species *i* at each depth and site / pooled average abundance of all species at each depth and site) × 100. FA was determined as: (number of transects in which species *i* was present / total number of transects) X 100. Species richness (number of species), and Shannon-Weiner species diversity were calculated using PRIMER-E (Polymouth Marine Laboratory, UK, 2000). Multivariate analysis of the data such as cluster analysis was performed using the same software. Analysis of a linear regression test used to examine the relationship between hard coral (HC) and soft coral (SC) vs. species richness (S), fish abundance (N), Shannon-Weiner Diversity Index (H´) as described by Sokal and Rohlf (1981) and implemented using STAT VEIW computer software.

Results

Benthic habitat

Fig. 2 shows the percentage cover of substrate types for various latitudes along the Red Sea and Gulf of Aden.

Jordan

Latitude 29°

Along the Jordanian Gulf of Aqaba coast, the highest hard live coral cover was 47%, occurring at the Visitor Center at 10 m depth. The average live hard coral cover across all sites in Jordan was 27%. The highest soft coral cover was at the Visitor Center at 5 m depth, and the average among all Jordanian sites was 6%.

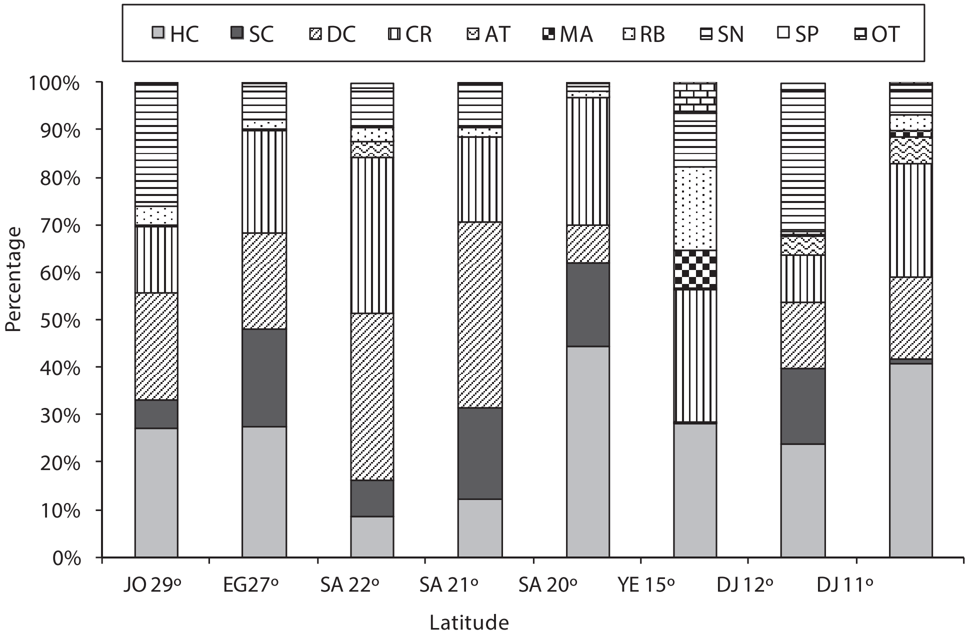

Figure 2. Percent cover (%) for substrate types at all latitudes [(JO=Jordan, EG=Egypt, SA= Saudi Arabia, YE=Yemen, DJ=Djibouti), where (HC=Hard coral, SC=Soft coral, DC=Dead coral, CR=Coral rock, AT=Algal turf, MA=Macroalgae, RB=Rubble, SN=Sand, SP=Sponge, OT=Others)].

Egypt

Latitude 27°

Along the Egyptian coast, the highest hard coral cover was 41.2%, found at both Noksh (5 m depth) and at Mahmoudat (5 m depth). The average of hard coral cover at all Egyptian sites was 27.6%. The highest soft coral cover was 47.8% at Fanar Dolphin and Ras Mohammed respectively, both at 10 m depth. The average soft coral cover at all sites in Egypt was 20.6%.

Saudi Arabia

Latitude 22°

At latitude 22°, the highest hard coral cover was 14%, occurring at Thowal-Awjam at 4 m depth. The average hard live coral at all sites at this latitude was 8.8%. The highest soft coral cover was 5.5% in Thoal-Bostek, at 10 m deep, and the average soft coral cover at all sites at this latitude was 7.7%.

Latitude 21°

The highest hard live coral cover was 35.5% at Bayada, in the deep transect. The average hard live coral cover at all sites was 12.4%. The highest soft coral cover was 81.5% at Alkabeera at 4m deep, and the average soft coral cover at all sites was 19.2%.

Latitude 20°

The highest hard coral cover was 52.5% at Alleeth in shallow transects. The average hard live hard coral in all transects was 44.4%. The highest soft coral cover was 32.0%, and the average of all transects was 17.5%.

Yemen

Latitude 15°

The highest hard coral cover along the Yemeni Red Sea Coast was 40.5% at Tekfash. The average live hard coral cover at all sites was 26.2%. The highest soft coral was 0.3% at Tekfash. The average soft coral cover at all sites was 0.1%.

Djibouti

The below sites were in the Gulf of Aden.

Latitude 12°

The highest hard coral cover was 32.5% recorded at Gehere in shallow transects. The average hard live coral cover at all sites was 23.8%. The highest soft coral cover was 17.5% recorded at Gehere in shallow transects. The average of soft coral cover at all sites was 15.8%.

Latitude 11°

The highest live hard coral cover was 71.0% at Tadjoura in shallow transects. The lowest hard live coral cover was 14.0% at Maskali in shallow transects. The highest soft coral cover was 2.5% at Musha. The average soft coral cover at all transects was 3.4%.

The overall mean percentage cover for both hard and soft coral (HC and SC combined) from highest to lowest was as follows: The highest was 61.9% total coral cover at latitude 20° along the Saudi Arabia coast, then 48.2% at latitude 27° along the Egyptian coast, 44.1 and 39.7 at latitude 11 and 12 ° respectively, 33.3% at latitude 29° along the Jordanian coast, 31.6 at Latitude 21 at Saudi Arabia coast, 26.3% at latitude 15° at the Yemeni coast, and the lowest combined total coral cover was 16.4% at latitude 22° along the Saudi Arabia coast.

Fish assemblages and community indices

Dominant taxa and fish community structure

Jordan

Latitude 29°

A total of 29,485 fishes were counted along the 18 transects examined at latitude 29°. The mean fish abundance ranged from 475 individuals per transect on the Tourist Camp reef at 5 m depth, to 3,117 individuals per transect on the Visitor Center reef at 5 m depth. The mean fish abundance across all transects was 1,638 individuals per transect. Of the 50 fish species considered, only 35 were observed at Jordanian sites. The number of species observed ranged from 23 at 10m depth at the Tourist Camp, to 30 at 5m depth at the Marine Science Station, with an average of 19.6 species per transect (Fig. 3). In terms of relative abundance (RA) on Jordanian reefs, the 5 most abundant fish species examined was the Sea goldie, *Pseudanthias squamipinnis* (Peters, 1855) (RA= 40.7%), followed by Blue green damselfish, *Chromis viridis* (Cuvier, 1830) (RA= 27.5%), Whitetail dascyllus, *Dascyllus aruanus* (Linnaeus, 1758) (RA= 7.7%), Red Sea eightline flasher, *Paracheilinus octotaenia* Fourmanoir, 1955 in Roux-Estève and Fourmanoir 1955 (RA=7.3%), and Marginate dascyllus, *Dascyllus marginatus* (Rüppell, 1829) (RA= 6.8%). Together, these five species made up 90% of the abundance of the 50 fish species examined (Table 2).

In terms of frequency of appearance, the most common species were *P. squamipinnis*, *D. aruanus*, *D. marginatus*, Twoband anemonefish, *Amphiprion bicinctus* Rüppell, 1830, Eritrean butterflyfish *Chaetodon paucifasciatus* Ahl, 1923 (100% each), *C. viridis*, Fourline wrasse, *Larabicus quadrilineatus* (Rüppell, 1835), Green birdmouth wrasse, *Gomphosus caeruleus* Lacepède, 1801, and Yellowbreasted wrasse, *Anampses twistii* Bleeker, 1856 (94.4% each) (Table 3).

Egypt

Latitude 27°

A total of 196,379 fish individuals were counted along 32 transects which were examined at the latitude 27°. The mean abundance ranged from 310 individuals at Mahmoudat at 10 m depth, to 13,358 individuals per transect at Fanar Al-Dolphin at 5m depth. The mean fish abundance of all transects was 6,334 individuals per transect. Of the 50 fish species considered, only 43 were reported from Egyptian sites. The number of species observed ranged from 26 at Mahmoudat (10 m depth) to 34 at Al-Noksh (9 m depth), with a mean of 20.6 species per transect (Fig. 3).

In terms of relative abundance (RA) on Egyptian reefs, the most abundant species was *P. squamipinnis* (RA= 84.6%), followed by *C. viridis* (RA= 10.4%); these two species made up 95% of all the fishes recorded in Egypt (Table 2).

In terms of frequency of appearance (FA), the most common species was, Bluestreak cleaner wrasse *Labroides dimidiatus* (Valenciennes, 1839 in Cuvier and Valenciennes 1839) at 94.%, followed by Blacktail butterflyfish, *Chaetodon austriacus* Rüppell, 1836 and Klunzinger's wrasse, *Thalassoma rueppellii* (Klunzinger, 1871) (90%, each); other common species were *G. caeruleus*, Threadfin butterflyfish,*Chaetodon auriga* Forsskål, 1775 (87%, each), Blackside hawkfish, *Paracirrhites forsteri* (Schneider, 1801 in Bloch and Schneider 1801) (84%), and *C. paucifasciatus* (81%) (Table 3).

Saudi Arabia

Latitude 22°

A total of 1,380 fishes were counted along the 6 transects performed in Saudi Arabia at latitude 22°N. Fish abundance ranged from 145 individuals per transect in Bostek/Thoal at 10 m deep, to 297 individuals per transect in Bostek/Thoal at 10 m deep. The mean fish abundance in all transects was 230 fish per transect. Of the 50

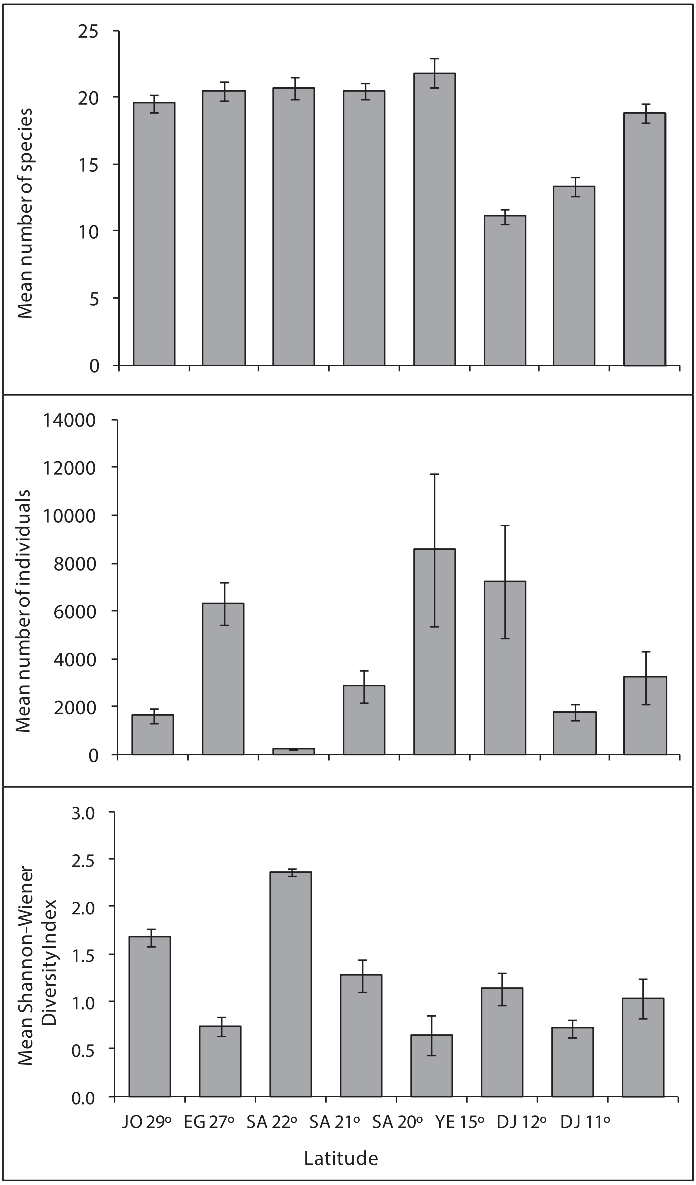

Figure 3. Mean number of fish species, mean number of individuals, and mean Shannon-Wiener Diversity Index in coral reef along the Jordan latitude 29°; Egypt latitude 27°; Saudi Arabia latitude 22, 21, 20°; Yemen 15° and Djibouti latitude 12, 11°.

species considered, only 35 were reported from this latitude, with a mean of 20.7 species per transect (Fig. 3).

In terms of relative abundance (RA), the most abundant fish species was *P. sqamipinnis* (RA= 16. 7%), followed by Sohal surgeonfish *Acanthurus sohal* (Forsskål, 1775) (RA= 12.4%), *L. quadrilineatus* (RA= 12.3), *G. caeruleus* (RA= 6.9), and Sunrise dot-

Table 2. Relative abundance in % of fish individuals per 500m² transect along reefs at JO= Jordan latitude 29°; EG=Egypt latitude 27°; SA=Saudi Arabia latitude 22, 21, 20°; YE=Yemen 15° and DJ=Djibouti latitude 12, 11°. (TRA indicates total relative abundance per family).

Fish scientific name	**Fish common name**	**JO 29°**	**EG 27°**	**SA 22°**	**SA 21°**	**SA 20°**	**YE 15°**	**DJ 12°**	**DJ 11°**	**Total RA**
Scorpaenidae										0,01
Pterois miles	Devil firefish	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Pterois radiata	Radial firefish	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,01
Serranidae										34,71
Pseudanthias squamipinnis	Sea goldie	40,7	84,6	16,7	3,9	1,5	0,0	0,0	0,0	34,71
Pseudochromidae										0,28
Pseudochromis flavivertex	Sunrise dottyback	0,0	0,0	6,7	0,0	0,0	0,0	0,0	0,0	0,03
Pseudochromis fridmani	Orchid dottyback	0,8	0,4	0,9	0,2	0,1	0,0	0,0	0,0	0,23
Pseudochromis springeri	Blue-striped dottyback	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,02
Chaetodontidae										0,96
Chaetodon auriga	Threadfin butterflyfish	0,0	0,2	1,2	0,1	0,0	0,0	0,0	0,0	0,10
Chaetodon austriacus	Blacktail butterflyfish	0,5	0,2	2,3	0,2	0,0	0,0	0,0	0,0	0,13
Chaetodon fasciatus	Diagonal butterflyfish	0,1	0,1	1,3	0,1	0,0	0,0	0,0	0,1	0,06
Chaetodon larvatus	Hooded butterflyfish	0,0	0,0	1,2	0,1	0,2	0,8	0,2	0,4	0,27
Chaetodon lineolatus	Lined butterflyfish	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,00
Chaetodon melannotus	Blackback butterflyfish	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,03
Chaetodon melapterus	Arabian butterflyfish	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,2	0,02
Chaetodon mesoleucos	White-face butterflyfish	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,01
Chaetodon paucifasciatus	Eritrean butterflyfish	1,5	0,1	0,0	0,1	0,0	0,0	0,0	0,0	0,14
Chaetodon semilarvatus	Bluecheek butterflyfish	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,1	0,03
Chaetodon trifascialis	Chevron butterflyfish	0,0	0,1	0,0	0,0	0,0	0,0	0,1	0,1	0,07
Chaetodon vagabundus	Vagabond butterflyfish	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,1	0,01
Heniochus acuminatus	Pennant coralfish	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Heniochus intermedius	Red Sea bannerfish	0,1	0,0	3,4	0,1	0,0	0,1	0,1	0,3	0,10
Pomacanthidae										0,18
Pomacanthus asfur	Arabian angelfish	0,0	0,0	1,7	0,0	0,0	0,1	0,1	0,1	0,06
Pomacanthus imperator	Emperor angelfish	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Pomacanthus maculosus	Yellowbar angelfish	0,0	0,0	0,5	0,0	0,0	0,3	0,1	0,1	0,08
Pygoplites diacanthus	Regal angelfish	0,0	0,0	0,7	0,1	0,0	0,0	0,0	0,1	0,04
Pomacentridae										59,39
Amphiprion bicinctus	Twoband anemonefish	1,5	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,12
Chromis viridis	Blue green damselfish	27,5	10,4	0,0	73,9	92,3	88,8	83,8	90,8	54,40
Dascyllus aruanus	Whitetail dascyllus	7,7	0,2	0,6	17,3	0,1	0,3	0,0	0,4	2,61
Dascyllus marginatus	Marginate dascyllus	6,8	0,3	0,0	0,0	0,1	5,8	0,0	0,1	1,95
Dascyllus trimaculatus	Threespot dascyllus	0,4	0,0	0,0	0,1	0,1	1,0	0,0	0,0	0,30
Cirrhitidae										
Paracirrhites forsteri	Blackside hawkfish	0,0	0,1	0,3	0,3	0,0	0,0	0,0	0,0	0,08
Labridae										3,45
Anampses twistii	Yellowbreasted wrasse	0,6	0,1	0,5	0,1	0,0	0,0	0,0	0,0	0,09
Bodianus anthioides	Lyretail hogfish	0,1	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,02
Cheilinus lunulatus	Broomtail wrasse	0,0	0,0	1,3	0,0	0,0	0,0	0,0	0,0	0,04
Coris aygula	Clown coris	0,0	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,03
Gomphosus caeruleus	Green birdmouth wrasse	0,5	0,2	6,9	0,6	0,2	0,0	1,2	0,5	0,26
Labroides dimidiatus	Bluestreak cleaner wrasse	0,1	0,2	3,6	0,2	0,0	0,0	0,2	0,1	0,12

Fish scientific name	**Fish common name**	**JO 29°**	**EG 27°**	**SA 22°**	**SA 21°**	**SA 20°**	**YE 15°**	**DJ 12°**	**DJ 11°**	**Total RA**
Larabicus quadrilineatus	Fourline wrasse	0,4	0,1	12,3	0,2	0,4	1,6	4,1	1,7	0,74
Novaculichthys taeniourus	Rockmover wrasse	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Paracheilinus octotaenia	Red Sea eightline flasher	7,3	0,3	1,1	0,0	3,9	0,1	0,0	0,7	0,98
Thalassoma rueppellii	Klunzinger's wrasse	2,6	1,2	6,1	0,7	0,2	0,0	0,0	0,0	0,72
Thalassoma lunare	Moon wrasse	0,0	0,0	5,6	0,2	0,2	0,6	7,6	1,5	0,45
Acanthuridae										0,88
Acanthurus sohal	Sohal surgeonfish	0,0	0,7	12,4	0,3	0,3	0,2	0,4	0,5	0,43
Naso lituratus	Orangespine unicornfish	0,0	0,1	2,9	0,1	0,1	0,0	0,0	0,8	0,14
Zebrasoma veliferum	Sailfin tang	0,1	0,1	6,4	0,5	0,0	0,0	0,0	0,2	0,14
Zebrasoma xanthurum	Yellowtail tang	0,3	0,1	0,9	0,2	0,0	0,0	1,2	1,0	0,17
Balistidae										0,04
Balistapus undulatus	Orange-lined triggerfish	0,0	0,0	0,8	0,1	0,0	0,0	0,0	0,0	0,03
Balistoides viridescens	Titan triggerfish	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,00
Rhinecanthus assasi	Picasso triggerfish	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,01
Ostraciidae										0,00
Ostracion cubicus	Yellow boxfish	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,00
Tetraodontidae										0,01
Arothron diadematus	Masked puffer	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,01

tyback *Pseudochromis flavivertex* Rüppell, 1835 (RA=6.7), these five species accounted for 54.93 % of all fish species recorded from this latitude (Table 2).

In terms of frequency of appearance (FA), the most common species were Sailfin tang *Zebrasoma veliferum* (Bloch, 1795), Hooded butterflyfish *Chaetodon larvatus* Cuvier, 1831, *Heniochus intermedius* Steindachner, 1893, *L. dimidiatus*, *L. quadrilineatus* and *G. caeruleus* (FA= 100%, each) (Table 3).

Latitude 21°

A total of 60,096 fishes were counted along the 21 transects performed in Saudi Arabia at latitude 21°. Fish abundance ranged from 116 individuals per transect in Alkabeera site at 4 m deep to 9,480 individuals per transect in South Batch Bayada at 10 m deep. The mean fish abundance in all transects was 2861.7 individuals per transect. Of the 50 species considered, only 40 were reported from this latitude, with a mean of 20.5 species per transect (Fig. 3).

In terms of relative abundance (RA), the most abundant fish species was *C. viridis* (RA=73.9%), followed by *D. aruanus* (RA=17.3%), and *P. sqamipinnis* (RA= 3.9%). These three species accounted 95.04 % of all fish species recorded from this latitude (Table 2).

In terms of frequency of appearance (FA), the most common species were *G. caeruleus* and *L. dimidiatus*, (FA= 100%, each) followed by *C. austriacus* (FA=95.5%), Diagonal butterflyfish *Chaetodon fasciatus* Forsskål, 1775 and *P. forsteri* (FA= 90.5%, each) (Table 3).

Latitude 20°

A total of 51,395 fishes were counted along the 6 transects performed in Saudi Arabia at latitude 20°. Fish abundance ranged from 1278 individuals per transect in Alleeth at

Table 3. Frequency of appearance in % of fish individuals per 500m² transect along reefs at JO= Jordan latitude 29°; EG=Egypt latitude 27°; SA=Saudi Arabia latitude 22, 21, 20°; YE=Yemen 15° and DJ=Djibouti latitude 12, 11°.

Fish species	JO 29°	EG 27°	SA 22°	SA 21°	SA 20°	YE 15°	DJ 12°	DJ 11°
Scorpaenidae								
Pterois miles	16,7	29,0	0,0	0,0	0,0	0,0	0,0	0,0
Pterois radiata	22,2	29,0	0,0	0,0	16,7	0,0	0,0	20,0
Serranidae								
Pseudanthias squamipinnis	100,0	80,6	50,0	33,3	83,3	0,0	0,0	0,0
Pseudochromidae								
Pseudochromis flavivertex	0,0	0,0	50,0	19,0	0,0	22,2	0,0	0,0
Pseudochromis fridmani	88,9	74,2	50,0	47,6	33,3	0,0	0,0	0,0
Pseudochromis springeri	61,1	25,8	0,0	0,0	0,0	0,0	0,0	0,0
Chaetodontidae								
Chaetodon auriga	11,1	87,1	83,3	66,7	33,3	0,0	0,0	0,0
Chaetodon austriacus	83,3	90,3	100,0	95,2	33,3	0,0	0,0	0,0
Chaetodon fasciatus	72,2	74,2	66,7	90,5	50,0	16,7	33,3	66,7
Chaetodon larvatus	0,0	3,2	100,0	76,2	100,0	100,0	100,0	100,0
Chaetodon lineolatus	0,0	9,7	16,7	4,8	0,0	0,0	0,0	0,0
Chaetodon melannotus	27,8	41,9	0,0	33,3	0,0	0,0	0,0	13,3
Chaetodon melapterus	0,0	0,0	0,0	0,0	0,0	0,0	100,0	93,3
Chaetodon mesoleucos	0,0	0,0	0,0	23,8	16,7	22,2	0,0	66,7
Chaetodon paucifasciatus	100,0	80,6	0,0	57,1	16,7	0,0	0,0	0,0
Chaetodon semilarvatus	0,0	45,2	16,7	33,3	50,0	50,0	33,3	73,3
Chaetodon trifascialis	11,1	74,2	0,0	52,4	0,0	5,6	33,3	33,3
Chaetodon vagabundus	0,0	0,0	0,0	0,0	0,0	0,0	100,0	73,3
Heniochus acuminatus	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6,7
Heniochus intermedius	44,4	67,7	100,0	14,3	100,0	83,3	100,0	93,3
Pomacanthidae								
Pomacanthus asfur	0,0	0,0	66,7	0,0	83,3	94,4	33,3	86,7
Pomacanthus imperator	5,6	19,4	0,0	0,0	16,7	5,6	33,3	0,0
Pomacanthus maculosus	0,0	22,6	66,7	0,0	83,3	100,0	100,0	80,0
Pygoplites diacanthus	5,6	54,8	66,7	14,3	100,0	0,0	0,0	80,0
Pomacentridae								
Amphiprion bicinctus	100,0	45,2	33,3	47,6	83,3	11,1	0,0	26,7
Chromis viridis	94,4	54,8	0,0	71,4	100,0	55,6	100,0	93,3
Dascyllus aruanus	100,0	22,6	33,3	61,9	66,7	16,7	0,0	46,7
Dascyllus marginatus	100,0	19,4	0,0	0,0	33,3	50,0	0,0	20,0
Dascyllus trimaculatus	44,4	16,1	0,0	4,8	33,3	11,1	0,0	13,3
Cirrhitidae								
Paracirrhites forsteri	0,0	83,9	33,3	90,5	16,7	0,0	0,0	0,0
Labridae								
Anampses twistii	94,4	77,4	33,3	66,7	50,0	0,0	0,0	53,3
Bodianus anthioides	61,1	29,0	50,0	14,3	16,7	0,0	0,0	0,0
Cheilinus lunulatus	22,2	64,5	83,3	14,3	66,7	72,2	33,3	53,3
Coris aygula	27,8	67,7	16,7	14,3	0,0	5,6	0,0	0,0
Gomphosus caeruleus	94,4	87,1	100,0	100,0	100,0	22,2	100,0	93,3
Labroides dimidiatus	66,7	93,5	100,0	100,0	100,0	27,8	100,0	66,7
Larabicus quadrilineatus	94,4	74,2	100,0	76,2	100,0	100,0	100,0	100,0
Novaculichthys taeniourus	0,0	0,0	0,0	4,8	16,7	0,0	0,0	0,0

Fish species	**JO 29°**	**EG 27°**	**SA 22°**	**SA 21°**	**SA 20°**	**YE 15°**	**DJ 12°**	**DJ 11°**
Paracheilinus octotaenia	55,6	9,7	33,3	0,0	83,3	5,6	0,0	33,3
Thalassoma rueppellii	100,0	90,3	83,3	85,7	83,3	0,0	0,0	0,0
Thalassoma lunare	22,2	48,4	100,0	81,0	83,3	100,0	100,0	100,0
Acanthuridae								
Acanthurus sohal	0,0	32,3	66,7	71,4	100,0	50,0	66,7	53,3
Naso lituratus	5,6	41,9	50,0	71,4	50,0	5,6	0,0	6,7
Zebrasoma veliferum	44,4	48,4	100,0	47,6	83,3	44,4	0,0	86,7
Zebrasoma xanthurum	88,9	41,9	33,3	47,6	16,7	22,2	66,7	100,0
Balistidae								
Balistapus undulatus	50,0	29,0	83,3	76,2	50,0	0,0	0,0	40,0
Balistoides viridescens	0,0	3,2	33,3	14,3	16,7	0,0	0,0	13,3
Rhinecanthus assasi	0,0	19,4	0,0	42,9	16,7	5,6	0,0	0,0
Ostraciidae								
Ostracion cubicus	27,8	3,2	16,7	4,8	0,0	5,6	0,0	0,0
Tetraodontidae								
Arothron diadematus	11,1	32,3	66,7	19,0	16,7	0,0	0,0	0,0

10 m deep, to 20,038 individuals per transect in Alleeth at 5 m deep. The meanfish abundance of all transects was 8565.8 individuals per transect. Out of the 50 species considered, only 40 were reported from this latitude, with a mean of 21.8 species per transect (Fig. 3).

In terms of relative abundance (RA), the most abundant fish species was *C. viridis* (RA=92.32%), followed by *P. octotaenia* (RA=3.86%), and *P. sqamipinnis* (RA= 1.53%). These three species accounted for 97.71 % of all fish species recorded from this latitude (Table 2).

In terms of frequency of appearance (FA), the most common species were *A. sohal, C. larvatus, H. intermedius, G. caeruleus*, *L. dimidiatus*, *L. quadrilineatus,* Regal angelfish *Pygoplites diacanthus* (Boddaert, 1772) and *C. viridis* (FA= 100%, each) (Table 3).

Yemen

Latitude 15°

A total of 129,932 fishes were counted during the 18 transects that were performed at latitude 15°. The mean fish abundance ranged from 95 individuals per transect at Al-Murk at 5 m deep, to 24,906 individuals per transect at Quish at 4m depth. The average fish abundance calculated from all transects was 7,218 individuals per transect. Of the 50 ornamental fish species considered, only 28 were reported from the Yemeni sites. The number of species observed ranged from 11 at Al-Murk (4 m depth) to 18 at both Quish and Al-Badi Island (shallow depth), with a mean of 11.1 species per transect (Fig. 3).

In terms of relative abundance (RA), the most abundant species was *C. viridis*. This species accounted for 88.5% of the fish abundance recorded at Kamaran, 79.1% at Tekfash, 93.3% at Quish and 85.3% at Al-Badi.

The mean relative abundance for *C. viridis* in all transects was 88.8%. The second most abundant fish species was *D. marginatus* accounting for 4.1%, 14.1%, 3.1% and 8.7% of fish abundance from Kamaran, Tekfash, Quish and Al-Badi respectively. The mean relative fish abundance for *D. marginatus* in all transects was 5.8%. This was followed by *L. quadrilineatus* (average 1.6%) and *C. larvatus* (average 0.8%). These four species made up 99% of the 28 fish species which were counted (Table 2).

In terms of frequency of appearance (FA), the most common fish species were Yellowbar angelfish *Pomacanthus maculosus* (Forsskål, 1775), Moon Wrasse *Thalassoma lunare* (Linnaeus, 1758), *L. quadrilineatus*, and *C. larvatus* (100%, each), followed by *Pomacanthus asfur* (Forsskål, 1775) (94.0%) and *H. intermedius* (83.3%) (Table 3).

Djibouti

Latitude 12°

A total of 5,368 fishes were counted in the 3 transects that were examined at latitude 12°. Fish abundance ranged from 1164 fishes in Gehere at 4 m depth, to 2408 in Gehere at 4 m depth. The mean fish abundance of all transects was 1789.3 individuals per transect. Of the 50 species considered, only 18 were reported from this latitude, with a mean of 13.3 species per transect (Fig 3).

In terms of relative abundance (RA), the most abundant fish species was *C. viridis* (RA=83.8%), followed by *T. lunare* (RA= 7.6%), and *L. quadrilineatus* (RA= 4.1%). These three species accounted 95.51 % of all fish species recorded from this latitude (Table 2).

In terms of frequency of appearance (FA), the most common species were *C. larvatus*, Arabian butterflyfish *Chaetodon melapterus* Guichenot, 1863, Vagaband butterflyfish *Chaetodon vagabundus* Linnaeus, 1758, *H. intermedius*, *G. caeruleus*, *L. dimidiatus*, *L. quadrilineatus, T. lunare*, *P. maculosus*, and *C. viridis* (100%, each) (Table 3).

Latitude 11°

A total of 48,488 fishes were counted along the 15 transects that were examined in Djibouti at latitude 11°. Fish abundance ranged from 181 fishes in Khor Ambado at 7 m depth, to 16,609 in Maskali at 5 m depth. The mean fish abundance of all transects was 3232.5 individuals per transect. Of the 50 species considered, only 33 were reported from this latitude, with a mean of 18.8 species per transect (Fig 3).

In terms of relative abundance (RA), the most abundant fish species was *C. viridis* (RA= 90.81%), followed by *L. quadrilineatus* (RA= 1.70%), and *T. lunare* (RA= 1.47%) (Table 2). These three species accounted for 93.98 % of all fish species recorded from this latitude.

In terms of frequency of appearance (FA), the most common species were Yellowtail tang *Zebrasoma xanthurum* (Blyth, 1852), *C. larvatus*, *L. quadrilineatus* and *T. lunare* (100%, each), followed by *C. melapterus*, *H. intermedius*, *G. caeruleus* and *C. viridis* (93.30%, each), see Table 3.

All Latitudes

A total of 522,523 fish individuals were counted in the 118 transects that were examined at all latitudes (Jordan 29°, Egypt 27°, Saudi Arabia 22°, 21° and 20°, Yemen 15°, Djibouti 12° and 11°). The mean fish abundance in all transects was 4428.2 ±87.26 individuals per transect.

In terms of relative abundance (RA), the most abundant fish species was *C. viridis* (RA=54.4%), followed by *P. squamipinnis* (RA= 34.7), *D. aruanus* (RA= 2.6%), *D. marginatus* (RA= 2.0), *P. octotaenia* (RA=1.0) and *T. rueppellii* (0.7%). These six species accounted for 95.47% of all fish species recorded during this study (Table 2). Number of species, number of individuals, and Shannon-Wiener diversity in sites along the Jordanian, Egyptian, Saudi Arabia, Yemeni and Djiboutian reefs are shown in Figure 3. Of the 50 fish species counted during this study, the highest number of species (S) was found at latitude 20° on Saudi Arabian reefs (S= 21.8), and the lowest at latitude 15° in Yemen (S= 11.11). The highest mean fish abundance was found on reefs at latitude 20° in Saudi Arabia (8565.8), followed by latitude 15° in Yemen (AA=7218), whereas the lowest number of individuals was found on reefs at latitude 22° in Saudi Arabia (AA= 230). The highest mean Shannon-Wiener diversity Index was found in Saudi Arabia at latitude 22° (H`= 2.4), followed latitude 29° in Jordan, whereas the lowest was found at latitude 20° in Saudi Arabia (H`= 0.6) (Fig. 3). Table 4 shows mean fish abundance for the 50 ornamental fish species at all latitudes.

Fish families

Figures 4, 5 and 6 illustrate differences in the mean fish abundance per 500 m^2 transect, according to latitudinal distribution among the 50 ornamental fish species. These belong mainly to the following fish families: [Fig. 4. I. Acanthuridae (4 species), II. Balistidae (3 species), III. Chaetodontidae (14 species), IV. Pomacanthidae (4 species)[; [Fig. 5. V. Pomacentridae (5 species), VI. Pseudochromidae (3 species), VII. Cirrhitidae (one species), VIII. Serranidae (one species) IX. Labridae (11 species)]; and Fig. 6. X. Scorpaenidae (2 species), XI. Ostraciidae (one species), XII. Tetraodontidae [(one species)] that are utilized by the aquarium trade in the region.

Acanthuridae (Surgeonfishes)

Of the 12 species of surgeonfish's reported from the Red Sea, only 4 species are important in the ornamental fish trade, therefore only *A. sohal,* Orangespine unicornfish *Naso lituratus* (Forster, 1801 in Bloch and Schneider 1801), *Z. veliferum* and *Z. xanthurum* were counted. *A. sohal* were abundant along Egyptian latitude 27° followed by Saudi Arabian latitude 22°. *N. lituratus* were abundant along the Djiboutian reefs at latitude 11° (Fig 4). *Z. veliferum* were abundant along the Saudi Arabian reefs at latitudes 22 and 21°. Whereas, *Z. xanthurum* were most abundant along the Djiboutian reefs at latitudes 11 and 12°. Triggerfishes had the lowest number of individuals.

Balistidae (Triggerfishes)

This family had the lowest number of individuals of all fish families examined here. Out of the 10 triggerfishes reported from the Red Sea, only Ornage-lined triggerfish *Balistapus undulatus* (Park, 1797), Titan triggerfish *Balistoides viridescens* (Bloch &

Table 4. Mean fish abundance in percentage (%, ± SE) per $500m^2$ transect along reefs at JO= Jordan latitude 29°; EG=Egypt latitude 27°; SA=Saudi Arabia latitude 22, 21, 20°; YE=Yemen 15° and DJ=Djibouti latitude 12, 11°.

Fish species	**JO 29°**	**EG 27°**	**SA 22°**	**SA 21°**	**SA 20°**	**YE 15°**	**DJ 12°**	**DJ 11°**
Scorpaenidae								
Pterois miles	0.2 ±0.1	0.6 ±0.2	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Pterois radiata	0.4 ±0.2	0.5 ±0.1	0.0 ±0.0	0.0 ±0.0	0.2 ±0.2	0.0 ±0.0	0.0 ±0.0	0.3 ±0.2
Serranidae								
Pseudanthias squamipinnis	666.2 ±156.2	5356.2 ±896.0	38.3 ±21.2	111.4 ±51.4	130.8 ±59.6	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Pseudochromidae								
Pseudochromis flavivertex	0.0 ±0.0	0.0 ±0.0	15.3 ±7.1	0.5 ±0.3	0.0 ±0.0	3.3 ±1.8	0.0 ±0.0	0.0 ±0.0
Pseudochromis fridmani	13.3 ±2.9	26.1 ±8.3	2.0 ±0.9	4.7 ±1.5	7.8 ±6.5	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Pseudochromis springeri	2.3 ±0.6	2.5 ±1.8	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Chaetodontidae								
Chaetodon auriga	0.2±0.1	13.6 ±4.9	2.8 ±0.7	3.0 ±0.8	0.7 ±0.4	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Chaetodon austriacus	8.2 ±1.6	10.7 ±1.5	5.3 ±1.3	6.5 ±0.8	2.2 ±1.4	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Chaetodon fasciatus	2.2 ±0.6	3.6 ±0.7	3.0 ±1.3	3.1 ±0.5	0.8 ±0.4	0.4 ±0.3	0.7 ±0.7	2.7 ±0.7
Chaetodon larvatus	0.0 ±0.0	0.1 ±0.1	2.7 ±0.7	1.9 ±0.4	17.5 ±4.3	58.1 ±12.2	3.3 ±0.7	13.3 ±2.6
Chaetodon lineolatus	0.0 ±0.0	0.2 ±0.1	0.3 ±0.3	0.1 ±0.1	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Chaetodon melannotus	0.6 ±0.2	3.1 ±0.9	0.0 ±0.0	2.2 ±1.4	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.3 ±0.2
Chaetodon melapterus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	7.3 ±1.2	7.1 ±1.3
Chaetodon mesoleucos	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.6 ±0.2	0.3 ±0.3	0.9 ±0.6	0.0 ±0.0	1.7 ±0.4
Chaetodon paucifasciatus	24.5 ±2.3	7.2 ±1.2	0.0 ±0.0	2.3 ±0.6	0.3 ±0.3	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Chaetodon semilarvatus	0.0 ±0.0	1.5 ±0.4	0.2 ±0.2	0.7 ±0.2	1.8 ±0.9	2.1 ±0.8	1.3 ±1.3	2.5 ±0.6
Chaetodon trifascialis	0.2 ±0.1	9.2 ±1.5	0.0 ±0.0	1.0 ±0.3	0.0 ±0.0	0.6 ±0.6	1.3 ±1.3	2.2 ±1.0
Chaetodon vagabundus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	6.0 ±1.2	2.3 ±0.6
Heniochus acuminatus	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0	0.1 ±0.1
Heniochus intermedius	1.1 ±0.3	2.8 ±0.4	7.8 ±2.00	2.6 ±0.4	3.5 ±0.6	8.2 ±2.1	2.7 ±0.7	9.6 ±3.9
Pomacanthidae								
Pomacanthus asfur	0.0 ±0.0	0.0 ±0.0	3.8 ±1.5	0.0 ±0.0	3.7 ±1.1	9.8 ±1.8	1.7 ±1.7	4.2 ±0.7

Fish species	**JO 29°**	**EG 27°**	**SA 22°**	**SA 21°**	**SA 20°**	**YE 15°**	**DJ 12°**	**DJ 11°**
Pomacanthus imperator	0.1 ±0.1	0.3 ±0.1	0.0 ±0.0	0.0 ±0.0	0.2 ±0.2	0.1 ±0.1	0.3 ±0.3	0.0 ±0.0
Pomacanthus maculosus	0.0 ±0.0	0.4 ±0.1	1.2 ±0.5	0.4 ±0.4	1.7 ±0.5	20.2 ±3.9	2.0 ±0.6	2.2 ±0.6
Pygoplites diacanthus	0.2 ±0.2	1.3 ±0.3	1.5 ±0.8	4.3 ±0.8	2.3 ±0.3	0.0 ±0.0	0.0 ±0.0	4.1 ±0.9
Pomacentridae								
Amphiprion bicinctus	25.2 ±2.0	2.8 ±1.4	0.8 ±0.5	1.2 ±0.3	1.7 ±0.6	0.1 ±0.1	0.0 ±0.0	1.3 ±0.7
Chromis viridis	450.0 ±158.6	657.6 ±209.2	0.0 ±0.0	2114.3 ±582.7	7908.3 ±3192.2	6411.1 ±2248.9	1500.0 ±346.4	2935.3 ±1093.6
Dascyllus aruanus	125.7 ±32.7	10.7 ±5.00	1.3 ±0.9	494.o ±185.3	10.3 ±7.8	24.0 ±17.8	0.0 ±0.0	12.53 ±6.2
Dascyllus marginatus	111.8 ±24.2	17.4 ±7.8	0.0 ±0.0	0.0 ±0.0	5.8 ±4.2	420.9 ±124.2	0.0 ±0.0	2.7 ±1.5
Dascyllus trimaculatus	7.2 ±2.9	0.8 ±0.4	0.0 ±0.0	1.7 ±1.2	9.5 ±7.1	72.9 ±72.8	0.0 ±0.0	1.3 ±1.1
Cirrhitidae								
Paracirrhites forsteri	0.0 ±0.0	6.4 ±1.1	0.7 ±0.4	9.5 ±1.7	0.2 ±0.7	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Labridae								
Anampses twistii	9.8 ±1.7	7.0 ±1.1	1.2 ±0.8	2.7 ±0.6	1.2 ±0.7	0.0 ±0.0	0.0 ±0.0	1.0 ±0.3
Bodianus anthioides	2.0 ±0.6	1.6 ±0.6	1.0 ±0.5	0.2 ±0.1	0.8 ±0.8	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Cheilinus lunulatus	0.3 ±0.2	2.1 ±0.4	3.0 ±1.1	0.4 ±0.3	1.5 ±0.6	3.5 ±0.1	0.3 ±0.3	1.6 ±0.9
Coris aygula	0.3 ±0.1	4.7 ±1.1	0.3 ±0.3	0.2 ±0.1	0.0 ±0.0	0.1 ±0.1	0.0 ±0.0	0.0 ±0.0
Gomphosus caeruleus	8.3 ±1.6	13.1 ±2.1	15.8 ±1.7	15.8 ±1.9	14.3 ±3.7	0.4 ±0.2	21.0 ±10.6	15.7 ±3.5
Labroides dimidiatus	1.7 ±0.5	11.0 ±1.5	8.3 ±1.6	6.4 ±0.7	4. 0 ±0.7	0.4 ±0.2	3.0 ±1.0	2.9 ±0.9
Larabicus quadrilineatus	6.8 ±1.1	3.9 ±0.7	28.3 ±7.2	6.0 ±1.7	34.8 ±4.5	114.6 ±21.7	73.7 ±25.7	55.1 ±6 .0
Novaculichthys taeniourus	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.90 ±0.90	0.17 ±0.17	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
Paracheilinus octotaenia	119.9 ±44.8	17.1 ±9.6	2.5 ±1.7	0.0 ±0.0	330.8 ±144.00	5.6 ±5.6	0.0 ±0.0	21.1 ±9.7
Thalassoma rueppellii	42.0 ±4.4	78.7 ±23.5	14.0 ±3.7	19.8 ±3.9	13.7 ±5.9	0.0 ±0.0	0.0 ±0.0	0.0 ±0.0
Thalassoma lunare	0.8 ±0.4	2.6 ±0.7	12.8 ±3.2	6.3 ±1.3	17.7 ±7.7	44.4 ±8.2	135.3 ±5.4	47.6 ±8.4
Acanthuridae								
Acanthurus sohal	0.0 ±0.0	41.4 ±21.7	28.5 ±13.5	8.9 ±1.8	26.5 ±8.3	10.8 ±5.3	8.0 ±4.2	15.0 ±5.8
Naso lituratus	0.1 ±0.1	4.2 ±1.7	6.7 ±4.1	4.1 ±0.9	4.3 ±2.4	1.4 ±1.4	0.0 ±0.0	27.3 ±27.3
Zebrasoma veliferum	1.1 ±0.3	4.9 ±1.5	14.8 ±8.3	13.00 ±9.5	4.2 ±1.9	3.1 ±1.1	0.0 ±0.0	6.6 ±1.3
Zebrasoma xanthurum	4.1 ±0.5	3.7 ±1.5	2.0 ±1.6	6.3 ±4.0	0.3 ±0.3	1.3 ±0.7	21.3 ±13.7	32.1 ±6.4

Fish species	**JO 29°**	**EG 27°**	**SA 22°**	**SA 21°**	**SA 20°**	**YE 15°**	**DJ 12°**	**DJ 11°**
Balistidae								
Balistapus undulatus	0.8 ±0.3	0.9 ±0.3	1.8 ±0.7	2.9 ±0.6	1.2 ±0.7	0.0 ±0.0	0.0 ±0.0	0.7 ±0.3
Balistoides viridescens	0.0 ±0.0	0.0 ±0.0	0.3 ±0.2	0.1 ±0.1	0.3 ±0.3	0.0 ±0.0	0.0 ±0.0	0.1 ±0.1
Rhinecanthus assasi	0.0 ±0.0	0.5 ±0.2	0.0 ±0.0	1.4 ±0.4	0.2 ±0.2	0.1 ±0.1	0.0 ±0.0	0.00 ±0.00
Ostraciidae								
Ostracion cubicus	0.5 ±0.3	0.0 ±0.0	0.5 ±0.5	0.1 ±0.1	0.0 ±0.0	0.1 ±0.1	0.0 ±0.0	0.00 ±0.00
Tetraodontidae								
Arothron diadematus	0.1 ±0.1	2.1 ±1.3	0.8 ±0.3	0.2 ±0.1	0.2 ±0.2	0.0 ±0.0	0.0 ±0.0	0.00 ±0.00

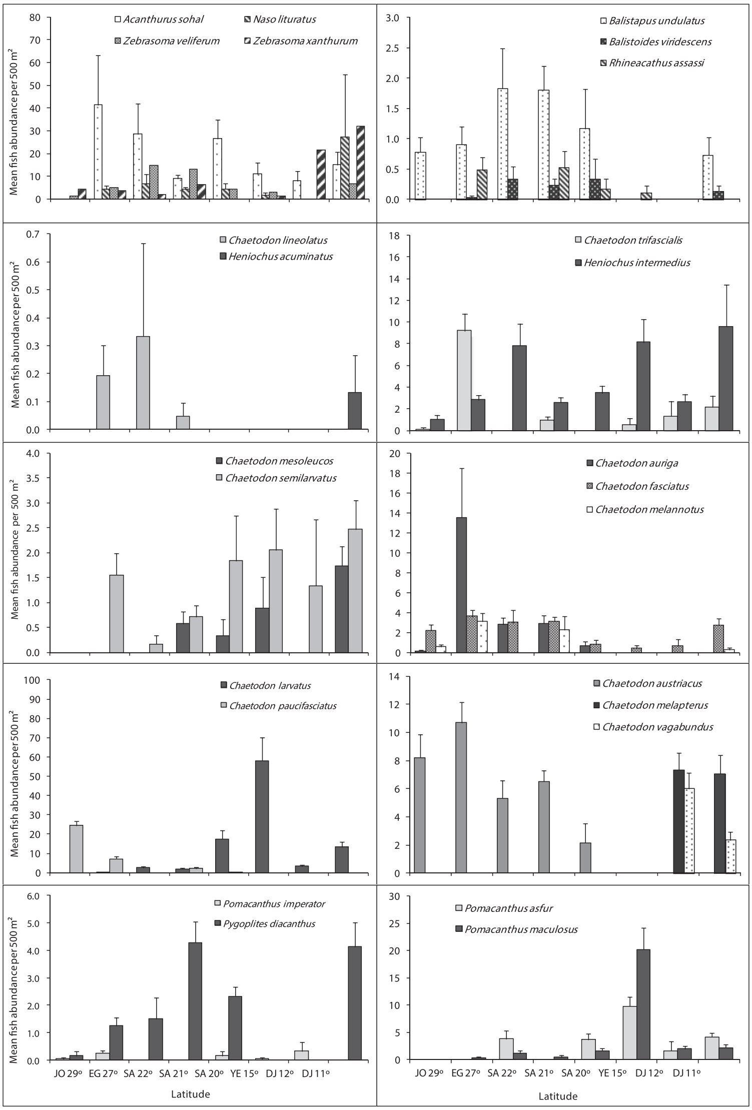

Figure 4. Differences in mean fish abundance per 500 m² transect according to latitudinal distribution for the families: Acanthuridae (*A. sohal, N. lituratus, Z. veliferum* and *Z. xanthurum)*, Balistidae (*B. undulates*, *B. viridescens*, and *R. assassin)*, Chaetodontidae (*C. lineolatus, H. acuminatus, C. mesoleucos, C. semilarvatus, C. auriga, C. fasciatus, C. melannotus, C. larvatus, C. paucifasciatus, C. austiacus*, *C. trifascialis, H. intermedius, C. melapterus*, and *C. vagabundus*), and Pomacanthidae (*P. asfur*, *P. imperator*, *P. maculosus* and *P. diacanthus*).

Schneider, 1801), and Picasso triggerfish *Rhinecanthus assasi* (Forsskål, 1775) were counted due to their importance in the aquarium trade. Geographical trends indicated that *B. undulates* and *B. viridescens* were more abundant along the Saudi Arabian reefs at Latiudes 22, 21 and 20° but *R. assassi* did not show any clear geographical trend (Fig. 4).

Chaetodontidae (Butterflyfishes)

Out of the 17 butterflyfishes known from the Red Sea, this study indicates the presence of 14 species. Geographical trends were observed in almost all butterflyfish species (Fig. 4). *C. austiacus* and *C. paucifasciatus* were most abundant along the reefs at latitudes 29 and 27°. These two species were not recorded in latitudes 15, 12 and 11°. On the other hand, *C. auriga*, *C. fasciatus* and *Chaetodon lineolatus* Cuvier, 1831 in Cuvier and Valenciennes were most abundant along the Egyptian and Saudi Arabia at latitudes 27, 22, and 21°. *C. larvatus* was most abundant along the Saudi Arabia and Yemen reefs at latitudes 20 and 15°. There were 3 butterflyfish species *C. melapterus*, *C. vagabundus*, and Pennant coralfish *Heniochus acuminatus* (Linnaeus, 1758) exist only at the Djiboutian reefs at latitudes 12 and 11°. The distributional pattern for all butterflyfish species is shown in Fig. 4.

Pomacanthidae (Angelfishes)

This family had the second lowest number of individuals of the fish families examined here. Out of the 7 species of angelfish recorded from the Red Sea, only 4 species (*P. asfur*, Emperor angelfish, *Pomacanthus imperator* (Bloch, 1787), *P. maculosus,* and *P. diacanthus*) that are used in the aquarium fish trade in the Red Sea were found. Latitude 15° exhibited the highest number of individuals for angelfish species, particularly for *P. asfur* and *P. maculosus*. Whereas, the reefs at the latitude 29° had the lowest number of individuals. Geographical trends were clear for some species like *P. asfur* which is the most abundant angelfish at the latitudes 15° but did not reach the northern Red Sea at the reefs between latitudes 29 and 27°. The distributional pattern for angelfish species is shown in Fig. 4.

Psudochromidae (Dottybacks)

Out of the 12 dottybacks fishes known from the Red Sea, only 3 species of importance in ornamental fish trade were counted. The 3 of them were not reported along the Djiboutian reefs. Bluestriped dottyback *Pseudochromis springeri* Lubbock, 1975 preferred the north, and it was found only along the Jordanian and Egyptian reefs at latitudes 29 and 27°. Whereas, Orchid dottyback *Pseudochromis fridmani* Klausewitz, 1968 extended to reach reefs at latitude 15°. The distributional pattern for Dottybacks is shown in Fig. 4.

Pomacentridae (Damselfishes)

Damselfishes had the highest number of individuals at all studied sites. Out of 35 damselfishes known from the Red Sea, only 5 species that are mostly used in the aquarium trade in the region were counted. *C. viridis* was the most dominant species of the damselfish family on Red Sea reefs. Geographical distribution of the clownfish *A. bicinctus* revealed that it prefers the Jordanian and Egyptian reefs at latitude 29° and 27°. The distributional pattern for damselfishes is shown in Fig. 5.

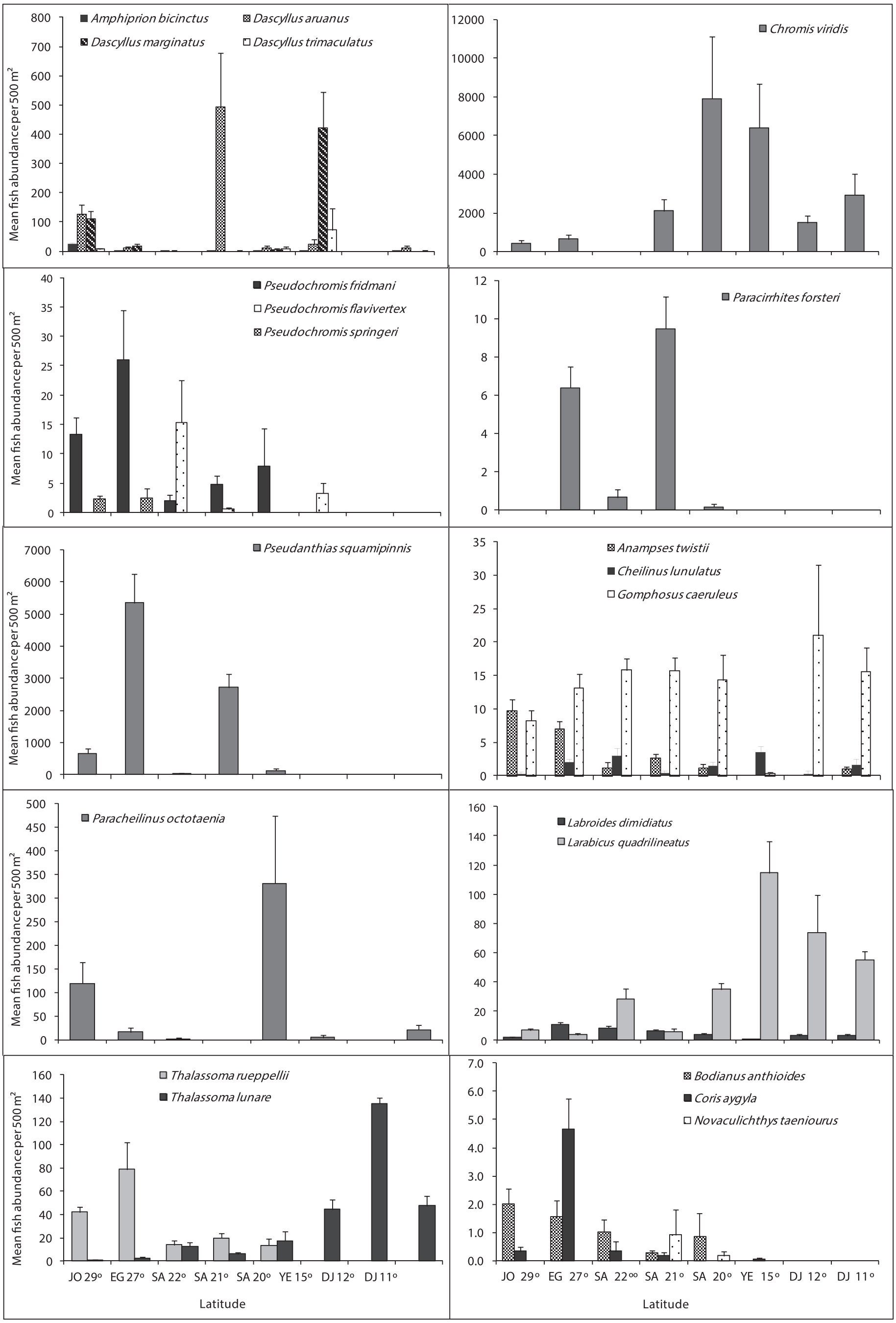

Figure 5. Differences in mean fish abundance per 500 m² transect according to latitudinal distribution for the fish species belonging mainly to families: Pomacentridae (*A. bicinctus, D. aruanus, D. marginatus, D. trimaculatus*, and *C. viridis*), Pseudochromidae (*P. fridmani, P. flavivertex* and *P. springeri*), Cirrhitidae (*P. forsteri*), Serranidae (*P. squamipinnis*), and Labridae (*A. twistii, C. lunulatus, G. caeruleus, P. octotaenia, L. dimidiatus, L. qudrilineatus, T. rueppellii, T. lunare, B. anthioides, C. aygula* and *N. taeniourus*).

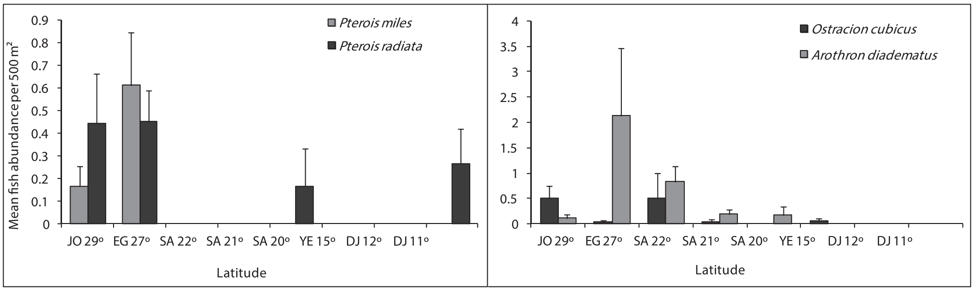

Figure 6. Differences in mean fish abundance per 500 m² transect according to latitudinal distribution for the fish species belonging to the family Scorpaeinidae (*P. miles, P. radiata*), Ostraciidae (*O. cubicus*), and Tetraodontidae (*A. diadematus*).

Labridae (Wrasses)

Out of the 64 wrasses reported from the Red Sea, only 11 species that are used mostly in the aquarium fish trade were counted. *T. rueppellii*, *Bodianus anthioides* (Bennett, 1832), *Coris aygula* Lacepède, 1801 and *A. twistii* were most abundant along the reefs in latitudes 29 and 27°; they were rare or not recorded along the Yemeni and Djiboutian reefs at latitudes 15, 12 and 11°. However, *T. rueppellii* and *B. anthioides* were restricted to the northern and central Red Sea. On the other hand, *T. lunare* was most abundant in the south at latitudes 15, 12 and 11°. The cleaner wrasse *L. dimidiatus* was most abundant along the reefs in latitudes 27, 22° and *L. qudrilineatus* on the other side was most abundant along the reefs at latitudes 15, 12 and 11°. The distributional pattern for wrasses is presented in Fig. 5.

Serranidae (Groupers)

Only *P. squampinnis* belonging to the subfamily Anthininae was counted during this study. The counts indicated that this species was most abundant along the reefs at latitudes 27 and 29° respectively and it was not reported from the Yemeni and Djiboutian reefs at latitudes 15, 12 and 11° (Fig. 5).

Cirrhitidae (Hawkfishes)

P. forsteri did not show a geographical trend in its distribution, except that it was not recorded in reefs at latitudes 29°, 15, 12 and 11° (Fig. 5).

Ostracidae (Boxfishes)

The distributional patterns for the boxfish, *Ostracion cubicus* Linnaeus, 1758, are shown in Fig. 6. It was abundant along the Jordanian reefs at latitude 29° and Saudi Arabia 22° reefs. It was either rare or not reported in other studied sites.

Tetraodontidae (Pufferfishes)

Arothron diadematus (Rüppell, 1829) is of importance in the fish aquarium trade in the region, and the number of individuals were very low. This species was not reported in the southern Red Sea and Gulf of Aden (Fig. 6).

Scorpaenidae (Scorpionfishes)

Two species *Pterois miles* (Bennett, 1828) and *Pterois radiata* Cuvier, 1829 in Cuvier and Valenciennes 1829 belonging to this family were counted; *Pterois miles* was reported only on Jordanian and Egyptian reefs. Whereas, *P. radiata* reached to Djiboutian waters, but both species were present in very low numbers. The distributional pattern for both species is shown in Fig. 6.

Correlation of fish community pattern with benthic habitat

The simple regression procedure of the Stat View software was used to correlate the fish community patterns such as species richness, average fish abundance (N), and Shannon-Wiener Index (H`) to benthic habitat (Table 5). The maximum regression correlation between hard coral cover and fish species richness (r=0.9060) was at reefs in latitude 12° followed by latitude 22°. Whereas, the strongest correlation with average fish abundance (r=0.554) was at reefs in latitude 20°, followed by latitude 15°. Reefs in latitude 20° also exhibited the highest regression correlation with Shannon-Wiener

Table 5. Regression correlation (r) analysis of fish community pattern vs. hard coral (simple regression); mean fish abundance (N), species richness (number of species) and Shannon-Wiener Index (H`) at reefs at various latitudes along the Red Sea and Gulf of Aden * if $p < 0.05$ significant correlation.

Latitude	Number of species	Number of Individuals	Shannon-Wiener diversity H′
29°	**0,257**	**0,378**	**0,219**
	p=0.305	*p=0.121*	p=0.385
27°	**0,395**	**0,354**	**0,451**
	p=0.028*	*p*=0.051	*p*=0.01*
22°	**0,179**	**0,473**	**0,118**
	p=0.733	*p*=0.343	*p*=0.807
21°	**0,415**	**0,447**	**0,2**
	p=0.613	*p*=0.042*	*p*=0.385
20°	**0,767**	**0,554**	**0,758**
	p=0.075	*p*=0.254	*p*=0.080
15°	**0,663**	**0,221**	**0,584**
	p=0.003*	*p*=0.375	*p*=0.011
12°	**0,906**	**0,431**	**0,448**
	p=0.278	*p*=0.716	*p*=0.711
11°	**0,02**	**0,305**	**0,071**
	p=0.944	*p*=0.268	*p*=0.793

Table 6. Regression correlation (r) analysis of fish community pattern vs. soft coral (simple regression); mean fish abundance (N), species richness (number of species) and Shannon-Wiener Index (H`) at reefs at various latitudes along the Red Sea and Gulf of Aden. * if p <0.05 significant correlation.

Latitude	Number of species	Number of Individuals	Shannon-Wiener diversity H′
29°	**0,329**	**0,311**	**0,445**
	p=0.183	p=0.209	p=0.064
27°	**0,122**	**0,355**	**0,564**
	p=0.509	p=0.050*	p=0.001*
22°	**0,338**	**0,276**	**0,484**
	p=0.513	p=0.598	p=0.330
21°	**0,342**	**0,475**	**0,422**
	p=0.128	p=0.030	p=0.0.056
20°	**0,237**	**0,095**	**0,758**
	p=0.650	p=0.862	p=0.897
15°	**0**	**0**	**0**
	p=1.000	p=1.000	p=1.000
12°	**0,19**	**0,984**	**0,99**
	p=0.880	p=0.115	p=0.120
11°	**0,336**	**0,114**	**0,33**
	p=0.220	p=0.685	p=0.229

diversity (r=0.7582), followed by latitude 15° (Table 5). However, the highest correlation between soft coral and species richness was (r=0.3420) at latitude 21°, followed by latitude 22° (Table 6). Whereas, the maximum regression correlation with average fish abundance was found (r=0.9838) at latitude 12°, followed by latitude 21°. Reefs at Latitude 12° exhibited the highest regression correlation with Shannon-Wiener diversity (r=0.9869), followed by latitude 20°.

Biogeography

Cluster analysis revealed that two primary groups of sites can be distinguished from the data (Fig. 7): Group A is divided into two sub-groups gathering the sites from Djibouti and Yemen with about 58% similarity: sub-group (A1) incorporates sites in Djibouti latitudes 12 and 11° with about 70% similarity (A2) incorporates sites in the country of Yemen (latitude 15°) with about 63% similarity, and sub-group. Group (B) is divided into 3 sub-groups gathering the sites in Jordan, Egypt and Saudi Arabiawith 71% similarity: subgroup (B1) incorporates the sites in Jordan latitude (29°) with about 82% similarity, subgroup (B2) incorporates most of the sites in Egypt at latitudes 27 and some sites in Saudi Arabia at latitudes (20, and 21°) with about 82% similarity.,and subgroup (B3) incorporates the sites is Saudi Arabia at latitudes (21 and 22°) with about 75% similarity. These two main groups (A and B) are connected together with about 52% similarity. The data clearly show that ornamental fish communities in the Red Sea and Gulf of Aden fall into two distinct biogeographical groups.

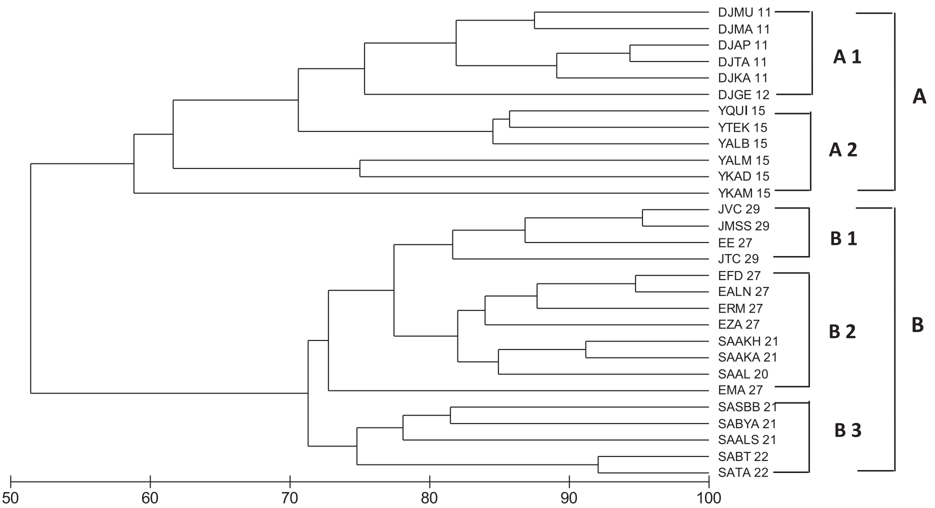

Figure 7. Cluster analysis of relationships between ornamental fish assemblages (Bray-Curtis similarity) from different countries in the Red Sea and Gulf of Aden region. Country Key: J29°= sites at latitude at 29° on the Jordanian coast, JMSS 29= Marine Science Station, JTC 29= Tourist Camp, JVC= Visitor Center; E27°= sites at latitude 27° in Egypt, EALN 27= AL-Noksh, EMA 27= Mahmoudat, EFD 27= Fanar Dolphin, EE 27= Elli, ERM 27= Ras Mohamad, EZA 27= Zorab; SA22, SA21 and SA20° = sites at latitudes on the Saudi Arabia coast, SATA 22= Thoal- Awjam, SABT 22= Bostek/Thoal, SAAKA 21= Alkabeera, SABYA 21= Bayada, SASBB 21= South Batch Bayada, SAALS 21= Al-Sagheera, SAAKH 21= Al-Kherq, SAAL 20= Alleeth; Y15°= sites at latitude along the Yemeni coast, YKAD 15= Kadaman, YKAM 15= Kamaran, YTEK 15= Tekfash, YQUI 15= Quish, YALM 15= Al-murk, YALB 15= Al-Badi; Dj11 and Dj12° =sites at latitudes 11 and 12° along the Djiboutian coast, DJGE 12= Gehere, DJKA 11= Khor Ambado, DJMA 11= Maskali, DJMU 11= Musha, DJTA 11= Tajoura, DJAP 11= ArtaPlaga.

One of the groups characterizes the northern and central Red Sea, whilst the other is in the southern Red Sea and Gulf of Aden.

Discussion

A new and updated checklist of fishes of the Red Sea has recorded a total of 1078 species belonging to 154 families (Golani and Bogorodsky 2010). From this list, a total of 50 fish species used for aquarium trade were investigated during the present study. A database for aquarium fish stocks was established during this intensive survey, and is housed at PERSGA office Jeddah, Saudi Arabia.

This study revealed marked differences in the structure of ornamental fish assemblages with latitude. The presence-absence data for the fifty ornamental fish species used in the aquarium trade in the region support the presence of two main biogeographic gradients in the Red Sea and Gulf of Aden: a south Red Sea and Gulf of Aden latitudinal gradient, and a gradient along the north and central Red Sea. Latitudinal gradients in water quality (temperature, salinity, plankton production) may cause in part this north-south variation in fish community structure. There are marked changes in the structure of coral reef fish communities moving from north to the south within the Red Sea. Carter and Prince (1981) concluded that gradual changes in salinity and temperature could generate abrupt boundaries for species distributions. Differences in environmental tolerance among species could mean that some are better adapted to conditions prevailing in the south than those further north or vice-versa. Factors in the physical environment including irradiance, salinity, temperature, pressure, nutrients and wastes all influence the distribution of organisms in the sea. The ability of an organism to tolerate changes in these physical environmental factors plays a major role in determining the organism's distribution in the marine environment (Karlenskint et al. 2008). There are strong gradients from north to south in surface water temperature (approx. 6-8 °C), salinity (5–7 ppt), nutrient concentration and turbidity in the Red Sea (Gordeyeva 1970, Morcos 1970, Morley 1975, Edwards and Head 1987, Weikert 1987).

The gradient observed during this study could also be due to different types of habitat available in the different sites, as well as their different amounts of coral cover, which could produce more or less favorable conditions for the development of juvenile fishes (availability of food, food supply, substrate complexity with different coral cover, etc.). This study identified major differences in the faunal composition and relative abundance in almost all of the fish families investigated. They included the studied species of triggerfishes (Balistidae), surgeonfishes (Acanthuridae), butterflyfishes (Chaetodontidae), angelfishes (Pomacanthidae), damselfishes (Pomacentridae), Wrasses (Labridae), dottybacks (Pseudochromidae) and *P. squamipinnis* in the family grouperfishes (Serranidae). Similar results were obtained by (Ormond and Edwards 1987; Roberts and Ormond 1987; Roberts et al. 1992). Sheppard et al. (1992) indicated that there are marked differences among the different regions of the Red Sea in fish species richness, assemblage composition and species abundances. Brokovich et al. (2006) reported a strong correlation between fish assemblages and the different types of habitats at the northern tip of the Gulf of Aqaba. Similar results were also reported by Khalaf and Kochzius (2002).

The fish fauna of the Djiboutian coast is shared with the Indian Ocean and the Red Sea. However, in terms of species composition, the Red Sea influence dominates, especially in areas near to Bab el Mandeb (Barrat and Medeley, 1990). A biogeographic analysis of the Indian Ocean coral fauna based on presence/absence of species revealed a clear pattern of faunal relationships between the Red Sea, Southern Arabia and the Indian Ocean (Khalaf and Kochzius 2002). Habitat strongly influences which species are able to live in a particular place. There are considerable differences in reef structure and coral assemblages from north to south within the Red Sea. In the south, reef structures becomes shallow with macroalgal dominated frameworks (Yemen and Djibouti). In the far south there are few areas of hard substrata, and these are mainly coralline-algal reefs covered with dense growth of the brown algae Sargassum and Turbinaria (Khalaf, personal observation).

A review of the literature describing fish habitat correlations from various regions presents a convincing positive relationship between habitat structural complexity and reef fish diversity in the Caribbean (Risk 1972, Luckhurst and Luckhurst 1978) and in the Great Barrier Reef (McCormick 1994). The strength of this correlation however, may vary among reef types. Percent of live branching or massive coral, substratum diversity and complexity have several times been identified as important predictors of the diversity of reef fish assemblages (Talbot 1965, Talbot and Goldman 1972, Luckhurst and Luckhurst 1978, Bouchon-Navaro and Bouchon 1989). This study supports the above mentioned studies, and shows that a number of fish species occupy different latitudes. Species varied in their abundances from reef to reef, and adjacent reefs supported different groups of species. As a general conclusion, we suggest that differences among reefs and habitats were among important components of variability in the number of fishes and species of ornamental fishes along the Red Sea and Gulf of Aden.

The high numbers of the clownfish *A. bicinctus* along the Jordanian reefs at latitude 29° compared to other reefs in other latitudes is perhaps due the availability of the sea anemone hosts *Entacmaea quadricolor* and *Heteractis crispa* (Huebner et al. 2012). Chadwick and Arvedlund (2005) proposed that *H. crispa* may serve as nursery habitats for *A. bicinctus* because they host more juvenile fish than does *E. quadricolor*, and Huebner et al. (2012) further documented this relationship using field experiments. The present study revealed that *A. bicinctus,* which is an endemic species to the Red Sea and Gulf of Aden, was a common and abundant species in the northern Red Sea, less common in the central Red Sea and rare or not present in the southern Red Sea and Gulf of Aden. These patterns may be due in part to the distributional and abundance patterns of the above host anemones, but detailed surveys of these anemones need to be conducted throughout the Red Sea to further test these ideas.

Two of the 3 species that belong to the family of dottybacks, Pseudochromidae i.e., *P. springeri* and *P. fridmani* were endemic to the Red Sea (Randall 1992), and both of them were not found along the Yemeni and Djiboutian reefs. The third species *P. flavivertex* which is endemic to the Red Sea and Gulf of Aden (Randall 1992) was recorded in all latitudes except at latitudes 12 and 11° along the Djiboutian reefs during this investigation. A total of 14 butterflyfishes are reported from the Red Sea, of which seven are endemic or range no further than the Gulf of Aden (Randall, 1992). In the present study, 14 species of butterflyfishes have also been reported. Butterflyfish assemblages in the southern Red Sea differ from that in the north (Righton et al. 1996). Other differences occur among butterflyfish. For example, *C. paucifasciatus* is abundant in the Gulf of Aqaba and Gulf of Suez but absent or rare in the southern Red Sea. However, *C. larvatus* is a dominant species in the south but rare in the northern Red Sea and Gulf of Suez and absent entirely from the Gulf of Aqaba. On the other hand, there are some species such as *H. acuminatus*, *C. melapterus* and *C. vagabundus* that are present along the Djiboutian reefs but are not reported in the Red Sea. The results presented in this study demonstrate that there are many differences between the reef fish fauna of the northern and central Red Sea, from that of the southern Red Sea and Gulf of Aden. For example, *P. sqamipinnis* dominated fish assemblages in the northern Red Sea along the Jordanian and Egyptian coasts, whereas *C. viridis* dominated fish assemblages in the central Red Sea, along the Saudi Arabia coast at both latitudes 20 and 21°, and in the Gulf of Aden.

During this survey, *C. viridis* was the most abundant species in the Red Sea and Gulf of Aden. This species dominated the reefs at latitudes 21, 20, 15, 12 and 11°. Similar results were reported at Nuweiba (Ben-Tuvia, 1983), at Djiboutian reefs (Barrat and Medley 1990), at Sanganeb atoll (Krupp et al. 1993), and in Eritrean reefs (Daw et al. 2001). *C. viridis* usually forms large aggregations and is found associated with large heads of *Acropora* corals that provide shelter from predators and a nocturnal retreat. Thus, these distributional patterns for this fish may indicate a higher abundance of large *Acropora* corals on southern than northern reefs in this region. The second most abundant species was *P. squamipinnis*, which dominates the reefs at latitudes 29, 27 and 22°. Similar findings were recorded at the Japanese Garden reef site at Eilat (Rilov and Benayahu 2000), at Nuweiba (Ben-Tuvia et al. 1983), at Sanganeb Atoll (Krupp et al. 1993), and on Jordanian reefs (Khalaf and Kochzius 2002). This species occurs usually in small to very large aggregations around rock or coral heads. These two species feed on plankton above rich beds of live coral (Khalaf and Disi 1997). These patterns indicate the importance of live coral cover, reef rugosity, and availability of plankton in the distribution of these reef fishes.

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DATA PAPER

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CLIMBER: Climatic niche characteristics of the butterflies in Europe

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Abstract

Detailed information on species' ecological niche characteristics that can be related to declines and extinctions is indispensable for a better understanding of the relationship between the occurrence and performance of wild species and their environment and, moreover, for an improved assessment of the impacts of global change. Knowledge on species characteristics such as habitat requirements is already available in the ecological literature for butterflies, but information about their climatic requirements is still lacking. Here we present a unique dataset on the climatic niche characteristics of 397 European butterflies representing 91% of the European species (see Appendix). These characteristics were obtained by combining detailed information on butterfly distributions in Europe (which also led to the 'Distribution Atlas of Butterflies in Europe') and the corresponding climatic conditions. The presented dataset comprises information for the position and breadth of the following climatic niche characteristics: mean annual temperature, range in annual temperature, growing degree days, annual precipitation sum, range in annual precipitation and soil water content. The climatic niche position is indicated by the median and mean value for each climate variable across a species' range, accompanied by the 95% confidence interval for the mean and the number of grid cells used for calculations. Climatic niche breadth is indicated by the standard deviation and the minimum and maximum values for each climatic variable across a species' range. Database compilation was based on high quality standards and the data are ready to use for a broad range of applications.

It is already evident that the information provided in this dataset is of great relevance for basic and applied ecology. Based on the species temperature index (STI, i.e. the mean temperature value per species), the community temperature index (CTI, i.e. the average STI value across the species in a community) was recently adopted as an indicator of climate change impact on biodiversity by the pan-European framework supporting the Convention on Biological Diversity (Streamlining European Biodiversity Indicators 2010) and has already been used in several scientific publications. The application potential of this database ranges from theoretical aspects such as assessments of past niche evolution or analyses of trait interdependencies to the very applied aspects of measuring, monitoring and projecting historical, ongoing and potential future responses to climate change using butterflies as an indicator.

Keywords
Climate change, climate warming, CTI, global change, global warming, modelling, risk, trend, STI, Europe, butterflies, Lepidoptera, Papilionidae, Pieridae, Lycaenidae, Riodinidae, Nymphalidae, Hesperiidae

Introduction

Global change seriously threatens biodiversity at all organisational levels ranging from genetic diversity, performance and occurrence of single species, taxonomic, phylogenetic and functional diversity of communities and species assemblages to properties of whole ecosystems including the provision of ecosystem services for human well-being (Lavergne et al. 2010; Parmesan 2006; Potts et al. 2010; Schröter et al. 2005). But species are not equally at risk when facing global change (e.g. Settele et al. 2008). In the context of climate change, several species-specific ecological characteristics have been identified to determine vulnerability, including diets, habitat requirements, ecological specialisation and plasticity and the ecological characteristics of interacting species (Heikkinen et al. 2010; Pöyry et al. 2009; Schweiger et al. 2012; Visser 2008; Warren et al. 2001). Thus, good knowledge of the ecological characteristics relevant for the reaction of species and communities to particular drivers of global change is needed, which can then be utilised as powerful indicators for conservation planning and action.

One of the most important ecological characteristics to assess how species react to climate change obviously is the climatic niche. While knowledge on particular species characteristics such as habitat requirements is already available for some species groups, crucial publicly available information about climatic requirements is still lacking for the majority of the species. Here we present a unique dataset on climatic niche characteristics of 397 (91%) butterfly species in Europe, which have been shown to be particularly sensitive to changing climates (Hill et al. 2002; Settele et al. 2008; Warren et al. 2001). Based on projections of future suitable climatic conditions, Settele et al. (2008) showed that under the assumption of unlimited dispersal 7% of the European butterflies are at an extremely high or very high risk (i.e. a loss of more than 95% and 85%, respectively of their current range size until 2080), 6% are at high risk (>70% loss) and 18% are at risk (>50% loss; Fig. 1). However, the more realistic assumption of no dispersal (in the given amount of time) projected 33% of the butterflies to be at an extremely high or very high risk, 26% to be at high risk and 19% to be at risk (Fig. 1).

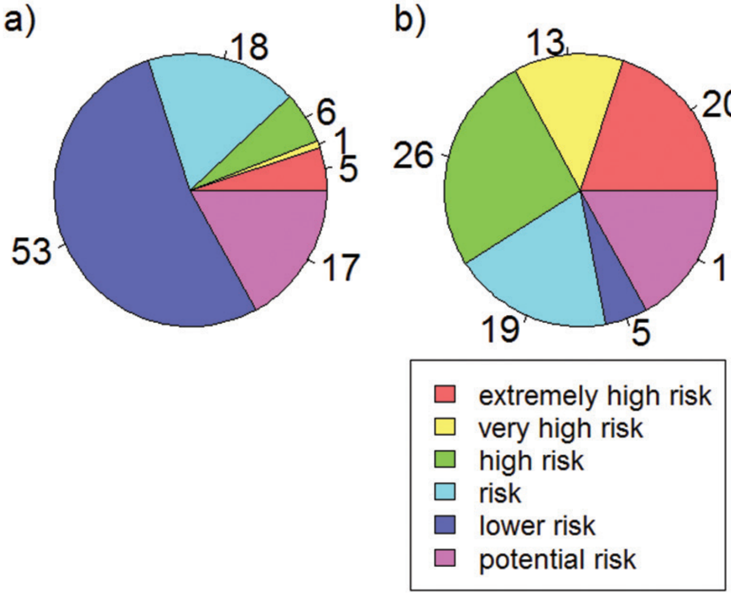

Figure 1. Proportion of species (%) with different climatic risk status after Settele at al. (2008) assuming full dispersal (**a**) and no dispersal capacity (**b**).

Based on detailed data on the distribution of European butterflies, which also led to the 'Distribution Atlas of European Butterflies' (Kudrna 2002), the 'Climatic Risk Atlas of European Butterflies (Settele et al. 2008) and the 'Distribution Atlas of Butterflies in Europe' (Kudrna et al. 2011), we extracted measures of climatic conditions (indicating niche breadth and position) within the distributional range of each species. As a consequence of this approach, users of this dataset should be aware that the provided measures refer to the realised climatic niche and not to the fundamental niche (sensu Hutchinson 1957; but see discussion in Araújo and Guisan 2006). The extracted measures reflect two primary properties of climate, energy and water, which are known to affect butterfly species performance and distributions as a consequence of physiological limitations (Buckley et al. 2011; Roy et al. 2001). Most of these measures are quite independent from each other and cover different aspects of the climatic niche (Fig. 2).

By combining a comprehensive database on the distribution of European butterflies with publicly available climatic data in combination with a constantly high level of quality control at crucial steps of the data generation, CLIMBER represents a unique and ready-to-use dataset for a broad variety of potential applications. Analysis of phylogenetic signals in the climatic niche characteristics, for instance, can be used to assess past niche evolution which can lead to projections of potential future risks in the face of rapid climate change (for a comparable analysis for birds see Lavergne et al. 2013). Also, analyses relating climatic niche properties to other species traits can be helpful to assess interdependencies of different ecologi-

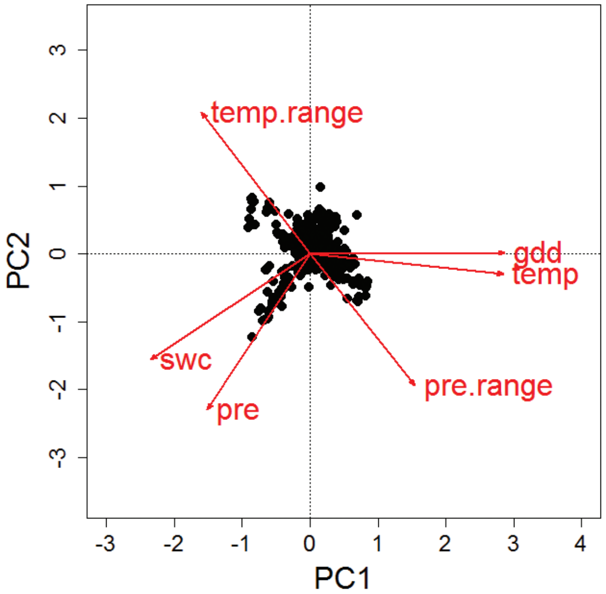

Figure 2. Results from a principal component analysis of the species-specific mean values of six different climate variables. Mean values per species have been calculated based on the observed records per 50 km × 50 km CGRS grid cell across a species' European distribution. PC1 explained 58% and PC2 32% of the variability. Niche characteristics according to annual temperature (temp) and growing degree days until August (gdd) are highly correlated. Also, the two measures of water availability, annual precipitation (pre) and soil water content (swc) show some similarity, while the indicators of annual range in precipitation (pre.range) and temperature (temp.range) are negatively correlated. In spite of these similarities, aspects of energy, water and their annual variability can be assessed independently with a choice of at least three of the indicators.

cal characteristics, as has been done recently for birds and their temperature and habitat preferences (Barnagaud et al. 2012). So far the most powerful application of climatic niche characteristics provided in this dataset comes from the 'species temperature index' (STI). The STI is simply the mean temperature value per species across its range. Based on the STI, the 'community temperature index' (CTI) has been suggested as a powerful and robust tool to measure the response of local communities to temperature change (Devictor et al. 2008; Devictor et al. 2012a; Devictor et al. 2012b). The CTI is calculated as the average STI value across the species or specimens in a community and has been used to analyse the temporal response to climate warming of local bird and butterfly communities across Europe. One striking result of this study was the detection of time lag effects in the community response to climate warming and that these lag effects differed between the two species groups (Devictor et al. 2012a).

STI values for European butterflies can be of great value for governmental and non-governmental conservation organisations (Van Swaay et al. 2010; Van Swaay et al. 2008). Based on the STI, the CTI was recently adopted as an indicator of climate change impact on biodiversity by the pan-European framework supporting the Convention on Biological Diversity (Streamlining European Biodiversity Indicators 2010; http://ec.europa.eu/environment/nature/knowledge/eu2010_indicators). Thus, STI and corresponding CTI values can perfectly complement and enrich the analysis of all kind of butterfly monitoring schemes. To address the fact that temperature is not the only changing climatic factor or aspect of the climatic niche, we think that the additionally provided climatic niche characteristics concerning water availability and annual climatic variability can help to enrich the landscape of target-specific analyses and indicators (Fig. 2). By providing public access to this dataset, we hope to contribute to improvements of the scientific understanding of how climate change affects species and communities and to improve monitoring and conservation actions for climate change mitigation.

Metadata

For the description of the metadata we followed the standards suggested by Michener et al. (1997) in a slightly modified way.

Title

CLIMBER: Climatic niche characteristics of the butterflies in Europe

Contributors

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Geographic, temporal and taxonomic coverage

Geographic coverage and spatial resolution

Climatic niche characteristics are provided for all butterfly species occurring within a European window of 11°W–32°E longitude and 34°N–72°N latitude (Fig. 3). Resolution of butterfly distribution and corresponding climate data used to calculate climatic niche characteristics corresponds to the 50 km × 50 km Common European Chorological Grid Reference System (CGRS; http://www.eea.europa.eu/data-and-maps/data/common-european-chorological-grid-reference-system-cgrs).

The geographic window excludes data from the Atlantic islands under European administration (the Azores, Madeira and Canary Islands) as well as Cyprus and Iceland. Due to low levels of recording, data from Belarus, Ukraine, Moldova, and Russia were also excluded. Additionally, no climate data were available for two species with extremely local distributions on the Pontine Islands and the Greek island of Nissiros. These restrictions led to the exclusion of 38 of the European butterfly species listed in Kudrna et al. (2011), but confined to these regions (Table 1).

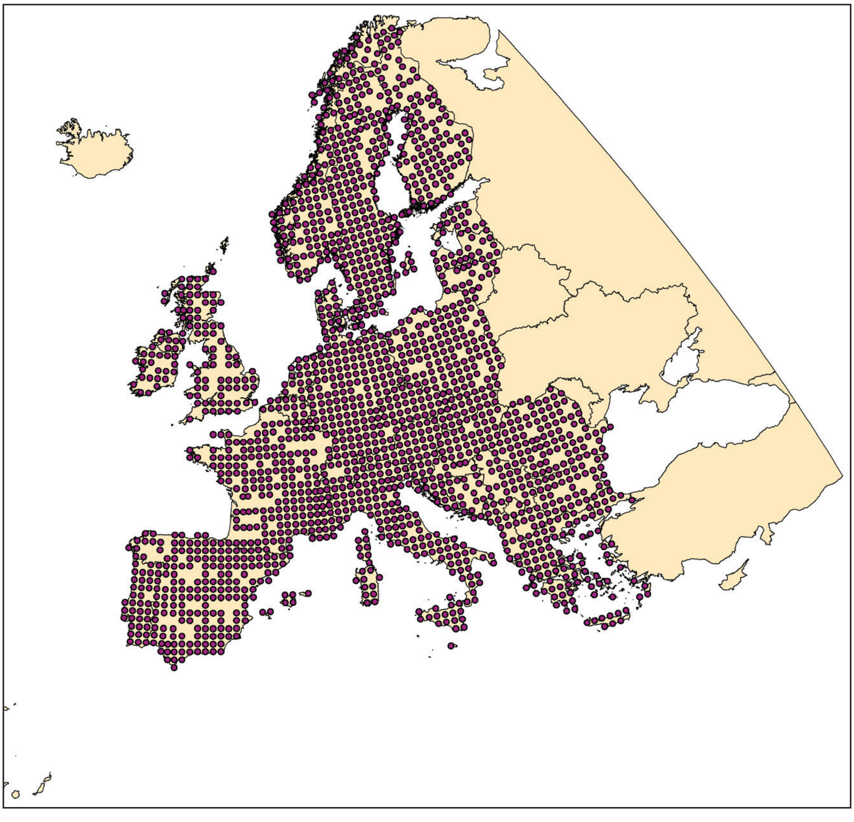

Figure 3. Geographic coverage used for the calculation of the climatic species characteristics. Purple dots indicate 50 km × 50 km CGRS grid cells with available species records.

Table 1. Species occurring in Europe and listed in Kudrna et al. (2011) but not considered for the assignment of climatic niche characteristics in this database.

Species	European range
Azanus ubaldus (Stoll, 1782)	Canary Islands
Catopsilia florella (Fabricius, 1775)	Canary Islands
Chazara persephone (Hübner, [1805])	Ukraine
Chilades galba (Lederer, 1855)	Cyprus
Cigaritis acamas (Klug, 1834)	Cyprus
Cyclyrius webbianus (Brulle, 1839)	Canary Islands
Euchloe eversi Stamm, 1963	Canary Islands
Euchloe grancanariensis Acosta, 2008	Canary Islands
Euchloe hesperidum Rothschild, 1913	Canary Islands
Glaucopsyche paphos Chapman, 1920	Cyprus
Gonepteryx cleobule (Hübner, 1825)	Canary Islands
Gonepteryx eversi Rehnelt, 1974	Canary Islands
Gonepteryx maderensis Felder, 1863	Madeira
Gonepteryx palmae Stamm, 1963	Canary Islands
Hipparchia azorina (Strecker, 1899)	Azores
Hipparchia bacchus Higgins, 1967	Canary Islands
Hipparchia cypriensis (Holik, 1949)	Cyprus
Hipparchia gomera Higgins, 1967	Canary Islands
Hipparchia maderensis (Bethune-Baker, 1891)	Madeira
Hipparchia sbordonii Kudrna, 1984	Pontine Islands
Hipparchia tamadabae Owen & Smith, 1992	Canary Islands
Hipparchia tilosi (Manil, 1984)	Canary Islands
Hipparchia wyssii (Christ, 1889)	Canary Islands
Hypolimnas misippus (Linnaeus, 1764)	Canary Islands
Maniola cypricola (Graves, 1928)	Cyprus
Maniola halicarnassus Thomas, 1990	Nissiros Island
Neolycaena rhymnus (Eversmann, 1832)	Ukraine
Pararge xiphia (Fabricius, 1775)	Madeira
Pararge xiphioides Staudinger, 1871	Canary Islands
Pieris cheiranthi (Hübner, 1808)	Canary Islands
Pieris wollastoni Butler, 1866	Madeira
Polyommatus corydonius (Herrich-Schäffer, 1852)	Ukraine
Polyommatus damocles (Herrich-Schäffer, 1844)	Ukraine
Polyommatus damone (Eversmann, 1841)	Ukraine
Pseudochazara euxina (Kusnezov, 1909)	Ukraine
Thymelicus christi Rebel, 1894	Canary Islands
Tomares callimachus (Eversmann, 1848)	Ukraine
Vanessa vulcania (Godart, 1819)	Canary Islands & Madeira

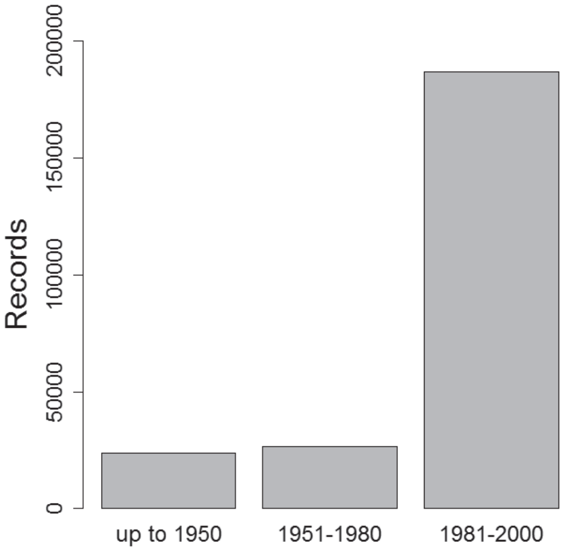

Figure 4. Temporal availability of records and corresponding sampling intensity. Only the period of 1981–2000 has been considered in CLIMBER.

Temporal reference period

Only butterfly distribution data from the period of 1981 to 2000 were considered due to low sampling intensity in earlier periods (Fig. 4) and to minimize errors due to ongoing range shifts as a response to recent climate change.

Taxonomy

Taxonomic ranks

Phylum: Arthropoda
Subphylum: Hexapoda
Class: Insecta
Order: Lepidoptera
Superfamily: Papilionoidea (sensu Regier et al. 2013; Wahlberg et al. 2013)
Families: Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, Riodinidae
Common name: butterflies

Taxonomic coverage

The taxonomic coverage spans all butterfly species within the selected geographic window (397 species) and represents 91% of all European species (Fig. 5). Thirty-eight

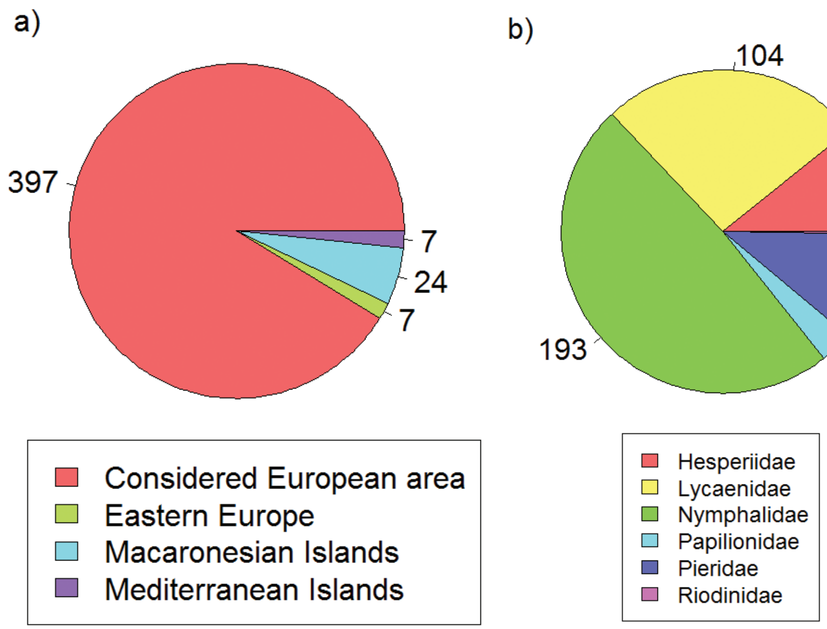

Figure 5. Taxonomic coverage according to the entire European butterfly fauna (**a**) and families (**b**). Values indicate number of species.

Table 2. Corrected species names (cf. Tshikolovets 2011) in comparison to Kudrna et al. (2011).

Corrected species names
Anthocharis damone Boisduval, 1836
Apatura metis Freyer, 1829
Argynnis elisa Godart, 1823
Aricia morronensis Ribbe, 1910
Cacyreus marshalli Butler, 1898
Colias aurorina Herrich-Schäffer, 1850
Erebia ottomana Herrich-Schäffer, 1847
Maniola chia Thomson, 1987
Maniola halicarnassus Thomson, 1990
Melitaea asteria Freyer, 1828
Melitaea varia Meyer-Dür, 1851
Pararge xiphioides Staudinger, 1871
Plebejus trappi (Verity, 1927)
Pseudochazara amymone Brown, 1976
Pseudochazara orestes Prins & Poorten, 1981

species from less well sampled Eastern European countries, Atlantic and small Mediterranean islands have not been considered (Fig. 5a). The taxonomy of European butterfly species follows Kudrna et al. (2011). Erroneous use of brackets around authors' names was corrected in 15 cases (cf. Tshikolovets 2011; Table 2).

Aricia artaxerxes (Fabricius, 1793) and *Aricia montensis* Verity, 1928 are treated in CLIMBER as distinct species with parapatric distributions (see Sanudo-Restrepo et al. 2013). The latter species is confined to the Iberian Peninsula and North Africa.

For the local Macedonian endemic *Pseudochazara amymone* Brown, 1976 no data were available for the considered time period. After its first discovery in Greece in 1975, the species was not reliably recorded again until its recent rediscovery in Southern Albania (Eckweiler 2012). According to Eckweiler (2012), *P. amymone* should be considered a subspecies of *Pseudochazara mamurra* (Herrich-Schäffer, [1846]), which is widespread in the Middle East.

The following species in our database actually comprise records of more than one species, most of which were recognized only recently, and are difficult or impossible to distinguish without genitalia examination or molecular methods.

- *Carcharodus alceae* (Esper, 1780) probably contains data of the sibling species *Carcharodus tripolinus* (Verity, 1925) from the Southern Iberian Peninsula, differing only in genitalia characters.
- *Leptidea sinapis* (Linnaeus, 1758) is a complex of three sibling species, and includes data of *Leptidea juvernica* Williams, 1946, and *L. reali* Reissinger, 1990 (Dincă et al. 2011b; Dincă et al. 2013). Whereas *L. sinapis* can be separated by their genitalia, the other two taxa can only be separated from each other by molecular characters. *L. reali* seems to replace *L. juvernica* in SW Europe, and both occur largely in sympatry with *L. sinapis*.
- *Lycaena tityrus* (Poda, 1761) includes data of *Lycaena bleusei* Oberthür, 1884 from Central Spain and Central Portugal, which appears to be a distinct species according to unpublished molecular data.
- *Melitaea athalia* (Rottemburg, 1775) includes the Southwest European *Melitaea nevadensis* Oberthür, 1904 (syn. *celadussa* Fruhstorfer, 1910) which might only be a subspecies of the former. Molecular data are inconclusive regarding the taxonomic status of these parapatric taxa.
- *Melitaea phoebe* (Goeze, 1779) recently turned out to be a complex of at least two largely sympatric species with distinctive larval colouration, and our data probably include records of *Melitaea ornata* Christoph, 1893 (syn. *telona* Fruhstorfer, 1908 and *emipunica* Verity, 1919) (see Toth et al. 2013; Toth and Varga 2011; Tshikolovets 2011).
- *Polyommatus icarus* (Rottemburg, 1775) includes data of *Polyommatus celina* (Austaut, 1879), which was recognized as a distinct species from North Africa and the Canary Islands by molecular methods (Wiemers et al. 2010), but also occurs in Southern Spain, and appears to replace *P. icarus* in the Balearic Islands, Sardinia, and Sicily (Dincă et al. 2011a).
- *Pontia daplidice* (Linnaeus, 1758) includes the data of the sibling species *Pontia edusa* (Fabricius, 1777), a parapatric taxon, which can only be distinguished by molecular methods (Geiger and Scholl 1982; John et al. 2013; Wiemers unpubl.).

Methods

Butterfly distribution data

Climatic niche characteristics of the butterflies in Europe are based on their European distribution. Butterfly distributions were available from about 7000 georeferenced localities and about 200,000 database records. These records were stored in a database and constituted also the basis for 'The Distribution Atlas of European Butterflies' (Kudrna 2002) and, as an updated version, for the 'Distribution Atlas of Butterflies in Europe' (Kudrna et al. 2011; Fig. 6). The data are owned by the Helmholtz Centre for Environmental Research (and thus by the originators of CLIMBER). To avoid problems of occasional undersampling and imprecise geo-reference of some locations at the local scale, we re-sampled the localities to 1720 CGRS grid cells at a 50 km × 50 km resolution. Distribution data refer to the period of 1981–2000 and cover the abovementioned European window of 11°W–32°E longitude and 34°N–72°N latitude. We also provide an estimation of species range sizes by the number of grid cells used for calculating the climatic species characteristics.

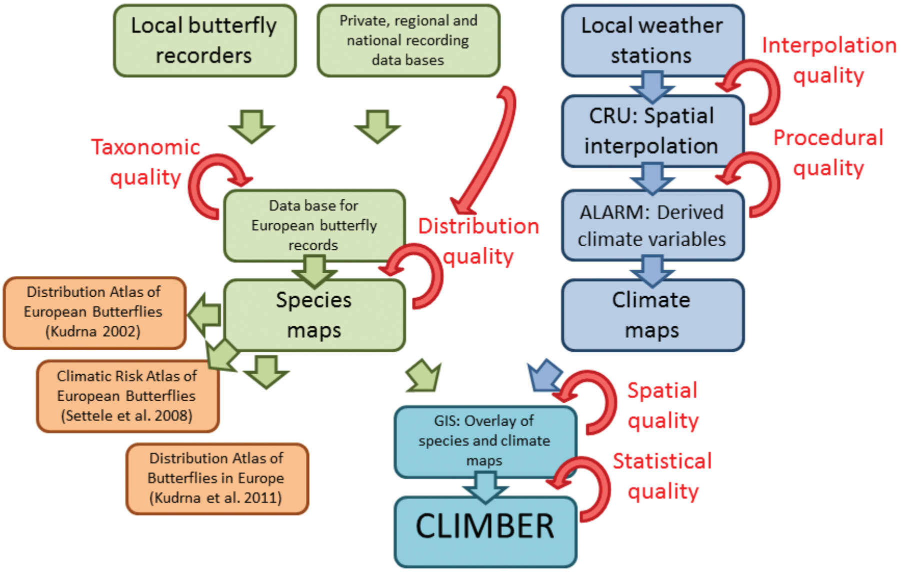

Figure 6. Work flow and data sources for the generation of CLIMBER. Butterfly distribution data are based on a database which combines information from local recorders and private, regional and national databases. Thereof, species distributional maps have been developed. Together with maps of original and derived climate variables, based on interpolated data from local weather stations, species distribution-climate relationships have been assessed in a GIS. Based on these relationships several statistics describing the climatic characteristics of 397 European butterfly species have been developed and stored in CLIMBER. Several steps of quality control ensure a high level of data accuracy. CRU; Climate Research Unit, University of East Anglia (http://www.cru.uea.ac.uk/). ALARM; EU, FP6 project 'Assessing Large Scale Risks for Biodiversity with Tested Methods' (http://www.alarmproject.net/climate/climate/).

Climate data

We used monthly, interpolated climate data (publicly available at http://www.alarm-project.net/climate/climate), originally provided via the ALARM project (Settele et al. 2012; Settele et al. 2005; Spangenberg et al. 2012) at a 10 arcmin grid resolution (Mitchell et al. 2004; New et al. 2000) and aggregated them to the CGRS grid (Fig. 6). For a detailed description of the climate data see Fronzek et al. (2012). The following basic climatic variables were used to assess aspects of the climatic niche: mean annual temperature (°C), range of annual temperature (°C), annual precipitation sum (mm), range of annual precipitation (mm), accumulated growing degree days with a base temperature of 5°C until February, April, June and August and soil water content for the upper horizon (0.5 m). Different time periods for calculating accumulated growing degree days enable the consideration of different phenologies and phenological aspects in the analysis of the climatic species characteristics. We do not provide growing degree days for periods ending later than August because these values are highly correlated with mean annual temperature in any case. Soil water content originated from the dynamic vegetation model LPJ-GUESS (Hickler et al. 2009; Hickler et al. 2004) which provides a process-based representation of the water balance in terrestrial ecosystems. According to the time period of the butterfly distribution data, we used averaged values for the period 1971–2000 for the climate data.

Calculation of the climatic niche characteristics

Climatic niche characteristics were calculated per butterfly species according to the climatic conditions across their respective ranges, i.e. across all grid cells in which a particular species occurs (see Devictor et al. 2012a; Schweiger et al. 2012; Van Swaay et al. 2010; Van Swaay et al. 2008; Fig. 6). The dataset comprises information for the position and breadth of the climatic niche. Niche position is indicated by the median and mean value for each climate variable across a species' range, accompanied by the 95% confidence interval for the mean. Niche breadth is indicated by the standard deviation and the minimum and maximum values for each climatic variable across a species' range.

Data verification

Several steps of quality control ensure a high level of data accuracy (Fig. 6). During the step of compiling butterfly records for Europe, taxonomic experts addressed problems of potential misidentification, synonymy and the taxonomic concept. Once the species distribution maps had been produced, internal and external control ensured the elimination of obviously wrong records (species outside their natural range). Climate data are based on original climate variables from the Climate Research Unit (CRU) of the University of East Anglia and derived climate variables generated by the ALARM project. Both, CRU and ALARM ensured a high level of internal and external quality control. Data quality for the calculation of the climatic niche characteristics for each butterfly species is high (about 200,000 records for butterfly distribution; well recognised and commonly accepted climate data). Additionally, we provide the number of grid cells which have been used to calculate the climatic species characteristics and the standard deviation to assess uncertainty of the measures.

Data status and accessibility

Status

Data set version: v1.3
Latest update: 18.10.2013.
Metadata status: Metadata are complete and stored with the data.

Accessibility

Copyright restrictions: None.
Proprietary restrictions: This dataset is freely available for non-commercial scientific use.
Citation: Data users must cite this Data Paper properly in any publication that results from an analysis using the provided data as a whole or in parts as: Schweiger O, Harpke A, Wiemers M, Settele J (2013). CLIMBER: Climatic niche characteristics of the butterflies in Europe. ZooKeys 367: 65–84. doi: 10.3897/zookeys.367.6185
In addition to the Data Paper the resource should be cited as: Helmholtz Centre for Environmental Research - UFZ (2013). CLIMBER: Climatic niche characteristics of the butterflies in Europe. 397 records, Online at http://ipt.pensoft.net/ipt/resource.do?r=climber, version 1.3 (released on 3/12/2013), Resource ID: GBIF key: http://www.gbif.org/dataset/e2bcea8c-dfea-475e-a4ae-af282b4ea1c5, Data Paper ID: doi: 10.3897/zookeys.367.6185
Collaboration: Data users might consider collaboration and/or co-authorship with the data owners.
Storage location: http://ipt.pensoft.net/ipt/resource.do?r=climber

Data structure

Dataset file

File name: CLIMBER.v.1.3.csv
Size: 398 rows, 67 columns; 183kB.

Format and storage mode: ASCII csv, semicolon-delimited; decimal separator: '.'.
Header information: First row provides variable names.
Alphanumeric attributes: Mixed.
Special characters: Missing values are indicated by NA.

Variable definition

Climatic niche characteristics are based on nine climate variables (Table 3). All climate variables represent average values for the period of 1971–2000. Seven statistics are available for each climate variable (Table 4).

We also provide an estimation of species range size (range.size) to assess the number of grid cells used for calculating the climatic species characteristics. For a detailed description of swc see section Climate data. Annual measures are calculated over full 12 month periods, while accumulated growing degree days have been calculated for four periods from January to February, April, June and August to cover a variety of phenological aspects and life cycle stages.

Species range refers to the distributional range according to the 50 km × 50 km CGRS grid cells in which a species was recorded.

Data anomalies

Missing values: NA indicates that a species was only present in one grid cell and thus 95% confidence intervals and standard deviation could not be calculated.

Table 3. Climatic variables used for the assessment of climatic niche characteristics of the butterflies in Europe.

Name	Definition	Unit	Interpretation
range.size	Distributional range size as number of occupied grids	Grid cells	Sample size
temp	Mean annual temperature	°C	Temperature (STI)
range.ann.temp	Annual range in monthly temperature (warmest month - coldest month)	°C	Continentality
precip	Annual precipitation sum	mm	Precipitation
range.ann.precip	Annual range in monthly precipitation sum (wettest month - driest month)	mm	Oceanity
gdd.feb	Accumulated growing degree days above 5°C from January to February	°C	Temperature corrected for metabolic activity preconditions
gdd.apr	Accumulated growing degree days above 5°C from January to April	°C	Temperature corrected for metabolic activity preconditions
gdd.june	Accumulated growing degree days above 5°C from January to June	°C	Temperature corrected for metabolic activity preconditions
gdd.aug	Accumulated growing degree days above 5°C from January to August	°C	Temperature corrected for metabolic activity preconditions
swc	Soil water content of the upper horizon (0.5 m)	No unit (0-1)	Water availability

Table 4. Statistics available for each climate variable describing the niche position and breadth for the butterflies in Europe.

Name	Definition	Interpretation
mean	Mean value of climate variable across the species' range	'Optimal' climatic conditions; niche position
ci.95.low	Lower 95% confidence interval for the mean	Uncertainty of the mean
ci.95.up	Upper 95% confidence interval for the mean	Uncertainty of the mean
min	Minimum value of the climate variable across the species range	Lower climatic limit
max	Maximum value of the climate variable across the species range	Upper climatic limit
sd	Standard deviation of the climate variable across the species range	Niche breadth

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Publications based on this dataset

Devictor V, Van Swaay C, Brereton T, Brotons L, Chamberlain D, Heliölä J, Herrando S, Julliard R, Kuussaari M, Lindstöm A, Reif J, Roy DB, Schweiger O, Settele J, Stefanescu C, Van Strien A, Van Turnhout C, Vermouzek S, WallisDeVries MF, Wynhoff I, Jiguet F (2012a) Differences in the climatic debts of birds and butterflies at a continental scale. Nature Climate Change 2: 121–124. doi: 10.1038/nclimate1347

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Appendix

Database of the climatic niche characteristics of the butterflies in Europe (CLIMBER). (doi: 10.3897/zookeys.367.6185.app) File format: Comma-separated values file (csv).

Citation: Schweiger O, Harpke A, Wiemers M, Settele J (2013) CLIMBER: Climatic niche characteristics of the butterflies in Europe. ZooKeys 367: 65–84. doi: 10.3897/zookeys.367.6185 Resource ID: GBIF key: http://www.gbif.org/dataset/e2bcea8c-dfea-475e-a4ae-af282b4ea1c5 doi: 10.3897/zookeys.367.6185.app