**Clunio boudouresquei sp. n. and Thalassosmittia ballestai sp. n., Two Tyrrhenian marine species occurring in Scandola Nature Reserve, West Corsica (Diptera: Chironomidae)**

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**Abstract**

*Clunio boudouresquei* sp. n. and *Thalassosmittia ballestai* sp. n. are diagnosed and described based on associated material of male adults, pharate male adults and pupal exuviae recently collected in the marine littoral zone of Scandola Nature Reserve (Cala Litizia, Punta Palazzu, Focolara Bay, West Corsica). While *C. boudouresquei* sp. n. is described as male and female adults and pupal exuviae, *T. ballestai* sp. n. is described only as male adult and pupal exuviae. On the basis of some atypical characters found in the male adult and pupal exuviae, both *C. boudouresquei* sp. n. and *T. ballestai* sp. n. appear to belong to a local Tyrrhenian element. Biological cycles of both new species are closely related to alternation between marine and terrestrial ecological conditions, which are strongly reinforced during spring tides of lunar rhythms. Larval stages of both new species are typically marine shore dwellers of the intertidal zone along seacoasts of the Tyrrhenian sub-region, where the biological and ecological quality of marine coastal habitats are being seriously damaged by various anthropogenic activities. In the latter sites, the *Lithophyllum byssoides* (Lamarck) Foslie pavements (trottoirs, encorbellements) are actually threatened by the massive proliferation of Sea Mussels (Mytilidae), which predominate when changes in water quality and level of pollution become increasingly high. The two new species are considered as pertinent biological indicators of the marine coastal habitats around the Tyrrhenian Region, in particular, those delimited by the mid-littoral large bio-constructions of the red calcified alga *L. byssoides*, where the larvae of *C. boudouresquei* sp. n. are exclusively confined. Such threatened species are considered biogeographic Tyrrhenian representatives and indicators of global warming and local climate change in the region, particularly to a rising sea level. Comments on the taxonomic position, ecology and geographical distribution of the new species are given.

**Introduction**

Recent investigations of marine chironomids conducted in the protected area of Scandola Nature Reserve (West Corsica), allowed us to sample fully developed pharate, adults, pupae and pupal exuviae of two new species, which belong to the genera *Clunio* Haliday, 1855 and *Thalassosmittia* Strenzke & Remmert, 1957. The two new species (*C. boudouresquei* sp. n. and *T. ballestai* sp. n.) were previously reported by Moubayed-Breil et al. (2013) and Moubayed-Breil & Ashe (2012) as, *Clunio* sp. 1 and *Thalassosmittia* sp. 1. Worldwide the genus *Clunio* is known from all geographic regions, while *Thalassosmittia* is restricted the Neotropical, Nearctic, Palaearctic and Afrotropical regions. Data on the taxonomy and geographical distribution of known valid species of these two genera from Europe and some neighbouring areas show that there are about 25 species for the genus *Thalassosmittia* and about 10 species for the genus *Clunio* (Saunders 1928; Storá 1936; Tokunaga 1936; Strenzke & Remmert 1957; Strenzke 1960; Saether 1969; Morley & Ring 1972; Neumann 1976; Saether 1977; Heimbach 1978; Michailova 1980a, 1980b; Coffman et al. 1986; Cranston et al. 1989; Langton 1991; Wang & Saether 1993; Neumann et al. 1997; Sasa & Suzuki 1999a, 1999b; Yamamoto 2004; Langton & Pinder 2007; Tasdemir 2010; Saether & Andersen 2011; Ashe & O’Connor 2012; Kaiser & Heckel 2012; Saether & Spies 2013; Andersen & Pinho 2014; Moubayed-Breil & Ashe 2012; Andersen et al. 2013; Moubayed-Breil et al. 2013; Moubayed-Breil & Ashe 2016; Yamamoto et al. 2019). Consequently, the description of *C. boudouresquei* sp. n. and *T. ballestai* sp. n. increases worldwide the total number of described species to 26 for the genus *Thalassosmittia* and to...
In this paper, *Clunio boudouresquei* sp. n. and *T. ballestai* sp. n. are described and diagnosed based on associated material recently collected in the marine littoral zone of Scandola Nature Reserve (Focolara Bay) located in western Corsica. While *Clunio boudouresquei* sp. n. is described as male and female adults and pupal exuviae, *T. ballestai* sp. n. is described only as male adult and pupal exuviae. On the basis of some atypical characters found in the male adult (shape of head, palpomeres, apodemes, tergite IX, inferior volsella, gonostylus) and pupal exuviae (distribution pattern of armament on tergites and sternites), *Clunio boudouresquei* sp. n. and *T. ballestai* sp. n. appear to belong, each to a local Tyrrhenian marine element.

Larval stages of both new species are typically marine shore dwellers of the intertidal zone along seacoasts, where dense populations are often reported. In particular, those of *Clunio boudouresquei* sp. n. are exclusively confined to the intertidal habitats delimited by the mid-littoral large bio-constructions (pavements, ‘trottoirs’) of the ‘long-living’ red calcified alga *Lithophyllum byssoides* (Lamarck) Foslie, which are locally present in both western Corsica (Punta Palazzu) and southern France. In addition, the latter pristine habitats are considered to be microrefugia for a well-diversified biocoenosis including marine and semi-terrestrial taxa/species. The two new species are considered as pertinent indicators of the environmental quality of seacoasts around the Tyrrhenian Region (insular and continental Provinces), where changes in biological and ecological conditions of the intertidal zone are presumably being the result of human activities and global warming in this region.

**Material and methods**

Material composed of adults, pharate adults and pupal exuviae belonging to both *Clunio boudouresquei* sp. n. and *T. ballestai* sp. n. was collected using standard methods: troubleau net for the benthos (larvae and pupae) and individuals floating on the surface of the water; Brundin drift nets towed behind a boat for pharates, pupae and drifted pupal exuviae; sweep net for flying adults. Additional inorganic material composed of plastics (micro- + macroplastics) and pellet tar (0.5-5 to 10-15 mm), was also collected during the fieldwork, which were especially of great interest for useful comments on both biological and ecological quality of environment. Male adults were preserved in 80-85% ethanol, then cleared of musculature in 90% lactic acid (head, thorax, abdomen and anal segment) for 60 to 80 minutes; this can be left overnight at room temperature without any detrimental effect or damage. The specimens were checked under a binocular microscope after 20 minutes in lactic acid to determine how the clearing was progressing. When clearing was complete the specimens were washed in two changes of 70% ethanol to ensure that all traces of lactic acid were removed.

The studied material was mounted in polyvinyl lactophenol. Before the final slide mountings of the type and paratype material in dorsal view, the hypopygium including tergite IX and anal point, the gonocoxite and the gonostylus, were viewed ventrally and laterally to examine and draw from both sides all the necessary details of the species. In particular, the ventral view of hypopygium was illustrated when the anal point and tergite IX were removed. For a better examination of the specific features and more accurate description of the various taxonomic details of the pupa, the pupal abdomen was mounted not only in dorsal and ventral view, but separately in lateral view, which facilitates proper examination and illustration of all the relevant taxonomic characters. The proximal part of the abdomen and the halteres of the male adult were preserved in 85% ethanol for an eventual DNA analysis. Morphological terminology and measurements follow those of Saether (1980), Langton (1991) and Langton & Pinder (2007) for the imagines and pupal exuviae. Taxonomic remarks on some related known species from Europe with comments on the ecology and geographical distribution of the two new species are given.

**Description**

*Clunio boudouresquei* Moubayed-Breil, sp. n.

*Clunio* sp. 1, in Moubayed-Breil & Ashe (2012), Moubayed-Breil et al. (2013).

[http://zoobank.org/3B0274A6-5460-4D84-8028-2BF8903468B9](http://zoobank.org/3B0274A6-5460-4D84-8028-2BF8903468B9)

**Material examined**

Holotype. France, West Corsica, Scandola Nature Reserve, Focolara Bay, Cala Litizia, bioconstructions of the red calcified marine alga *L. byssoides* of Punta Palazzu locality (Fig. 10), 42° 21′ 25″ N, 8° 34′ 0″ E; 1 male pharate adult, leg. J. Moubayed-Breil, 03.VI.2015. Locality No. 31 in Moubayed-Breil & Ashe (2012); locality No. 30 in Moubayed-Breil et al. (2013). Marine water temperature: 10-12°C (min.), 22-24°C (max.).

Paratypes (all leg J.M-B.): 2 male adults, 1 female adult, 6 pupal exuviae (4 males and 2 females), same locality as for holotype, 03.VI.2015.
Holotype (mounted on 1 slide) and 2 pupal exuviae (1 male and 1 female) are deposited in the collections of the Zoologische Staatssammlung München (ZSM), Munich, Germany. Additional paratypes are deposited in the senior author’s collection.

**Diagnostic characters**

Based on some characters found in the male adult (vertex with lateral projections, typical morphology of inferior volsella and both basal and caudal apodemes, presence of megaseta on gonostylius), *C. boudouresquei* sp. n. appears to belong to a local Tyrrhenian marine element. However, this new species can be distinguished from other European *Clunio* species by the blow listed characters.

**Male adult:** Vertex with two lateral triangular projections; antenna 10-segmented, last flagellomere longer than the 3 preceding segments; sensilla chaetica present on tibia and ta1 of PI-PIII; tergite VIII with a distinct elongate ellipse-like ridge located antero-medially, midline area with 6 short setae; apical expansion of tergite IX distinctly convex at apex; caudal apodeme with 5-6 curved claw-like tubercles; inferior volsella wider at base and narrowing distally; gonostylius unusually bearing a black fingernail-like megaseta, apex ending with a single finger-like tubercle.

**Female adult:** Eyes densely haired, temporals 2 including 1 inner and 1 outer vertical; clypeus semi-circular, bare; antenna 7-segmented, last flagellomere elongated, segments 6 and 7 each with 1 tubular sensilla chaetica; palpomere 2, globular, with 3 sensilla clavata distally and 1 long fine seta; tarsomere ta1 of PI and PII is half long as ta1 of PIII; tergite VIII with a distinct elongate ellipse-like ridge located anteriorly, midline area with 6 short setae; apical expansion of tergite IX distinctly convex at apex; caudal apodeme with 5-6 curved claw-like tubercles; inferior volsella wider at base and narrowing distally; gonostylius unusually bearing a black fingernail-like megaseta, apex ending with a single finger-like tubercle.

**Pupal exuviae:** Antero-median area of frontal apotome and thorax with wrinkles; frontal setae present on distal part of frontal apotome; dorcocentrales Dc1-Dc6 and Dc2-Dc6 located close together; anterior transverse rows of spines interrupted on tergite II; posterior transverse rows of hooks present on sternites V-VII.

**Etymology:** The new species is named ‘boudouresquei’ in honour of our colleague Ch-Fr. Boudouresque (University of Sciences, Luminy, Marseille), who is still active in studying the biology and ecology of the Mediterranean marine flora and fauna including those of the protected area of Scandola Nature Reserve. As he always did in past, he keeps working on developing projects to preserve the marine protected area of Scandola Nature Reserve, which represents a precious and valuable inheritance area.

**Male adult**

(n = 5, 2 pharates; Figs 1c-h, 2a-d, 3a-b)

Total length 2.70-2.90 mm. Wing length 1.35-1.40 mm, TL/WL = 2-2.10. General colouration contrasting brown to dark brown. Head and antennae dark brown; thorax contrasting light brown to brown with dark brown mesonotal stripes; wing pale translucent; legs brown to dark brown; tergites I-VII brownish, tergite VIII and anal distinctly contrasting light brown to dark brown.

Head. Eyes sub-circular without dorso-median extension, densely hairy with long and short pin-like hairs; hairs absent on inner lateral eye margin, outer posterior margin lacking setae. Vertex (Fig. 1c, dorsal; Fig. 1d, ventral) with 2 triangular lateral expansions; temporals 2 consist only of 2 outer verticals, postorbitals absent. Antenna 10-segmented, about 500 µm long, lacking plumose; segment 1-2 (Fig. 1e), segment 1 globular, segment 2 145 µm long, linearly elongated; segment 2-9 globular, nearly sub-equal (30-40 µm long); ultimate flagellomere (Fig. 1f) 105 µm long, about 40 µm maximum width, as longer than the 3 preceding segments, thumb-like shaped; sensilla chaetica present on segments 1 to 8; antennal groove reaching segment 2; AR 0.27. Palp (Figs 1g-h) 2-segmented, lacking sensilla clavata; left palpomer 1-2 respectively 25 and 55 µm long, palpomere 2 ending with a long finger-like expansion; right palpomers 1-2 (Fig. 1h), first one indistinct, second one sub-rectangular to square-like shaped, side about 25-30 µm long. Clypeus semi-circular and bare. Thorax. Antepronotum (Fig. 1c) weakly developed with joined lobes. Antepronotals 3; acrostichals 4-5 starting close to antepronotum; dorcocentrales 5 in 1 row; prealars 2; scutellum with 8 setae. Wing. Brachium with 1 seta; number of setae on veins: R, 7; R2-3, 6-7; remaining veins and squama bare. Legs. Femur of PI-PIII broad (100-110 µm maximum width); tibial spurs distinctly conspicuous and curved at apex, length (µm): PI, 40; PII, 65; PIII, 55. Tarsomeres ta1 and ta4 of PI and PII (45 and 40 µm long) shorter than tarsomere ta0 (75 and 65) as in Table 1; SV of PII (9.48) is much higher than in PI and PII. Sensilla chaetica present on tibia and tarsomere ta0 of PI-
Figure 1. Male and female adults of *Clunio* spp. Male adult. Head in dorsal and ventral view of: a-b) *C. marinus*; c-d) *C. boudouresquei* sp. n.: e) antenna, segments 1-3; f) segments 8-9 and last flagellomere; g) palp, left and right (h). Female adult of *C. boudouresquei* sp. n.: i) segment 6 and last flagellomere; j) palp. Male adult. Segment 9 and last flagellomere of: k) *C. boudouresquei* sp. n.; l) *C. marinus*. Male adult. Palp of: m) *C. sp. 2*; n) *C. marinus*.

PIII. Length (µm) and proportions of prothoracic (PI), mesothoracic (PII) and metathoracic (PIII) legs as in Table 1.

Abdomen. Hypopygium in dorsal and ventral view as in Figs 2a-b (Fig. 2a, dorsal; Fig. 2b, ventral, with tergite IX removed). Laterosternite absent. Tergite VIII with a distinct elongate ellipsoidal ridge located antero-medially, midline area bearing 6 short setae (3 on each side). Tergite IX is *Clunio*-type, without anal point; dorsal side (Fig. 2a) densely covered with macrotrichia-like setae in reclinate pattern (orally directed), postero-median area with about 40 short setae about 15 µm long; ventral side (Fig. 3b) with a semi-circular posterior lamella covered with macrotrichia. Ventral side
of hypopygium (Fig. 1b) includes 4 distinct apodemes (basal, axial, lateral and caudal) which can be detailed as: basal apodeme (= sternapodeme) 140 µm maximum width, T-like shaped (Figs 1b, 3a) with anterior side concave (occasionally convex as in Fig. 3c); axial apodeme about 320 µm long, ending with a bi-lobed semi-circular apical expansion (Figs 2a, 3b); lateral apodeme (= phallopodeme) 250 µm long, inwardly bent distally; caudal apodeme (Fig. 2b) distinctly branched on each lateral side, composed of 2 connected parts, basal one is a rectangular brush-like shaped, posterior one consists of 5-6 grouped claws of typical structure. Gonoxoxite about 600 µm long, 250 µm maximum width, distal inner area with dense group of long and short setae; inferior volsella 220 µm long, 15-20 µm width medially, located distally, conical and densely covered with short and upwardly directed setae. Gonostylus (Figs 2c-d) inversed triangle-like shaped, arched with acute posterior angle and projecting backwards posteriorly; thicker at base, much thinner in median and distal parts; length (in µm of sides): basal one about 20, concave one 25, convex one 17; apical angle (Fig. 2d) with 1 single characteristic finger-like tubercle; crista dorsalis well-developed, consists of 2 unequal lobes occupying the entire length of gonostylus; megaseta tooth-like shaped and conspicuous, nearly as high as wide (12-15 µm), represents an unusual character in the genus Clunio.

**Female adult**

(n = 2, 1 pharate; Figs 1i-j, 4a-e)

Small sized species. Total length 1.65-1.70 mm. General shape is Clunio female-type. Colouration as in the male adult except for the thorax, which is less dark. Antennae light brown; legs brownish with blackish claws. Abdominal tergites and anal segment contrasting brown to dark brown. Head. Eyes densely hairy, sub-circular without dorso-median extension, hairs absent on inner lateral eye margin, outer posterior margin lacking setae. Temporals 2, including 1 inner and 1 outer vertical. Clypeus semi-circular, bare. Antenna 7-segmented, about 200 µm long; last flagellomere (Fig. 1i) 60 µm long, elongated and lobe-like; segments 6 and 7 each with 1 tubular sensilla chaetica; antennal groove reaching segment 2; AR 0.43. Palp (Fig. 1j) 2-segmented; segment 1, indistinct; palpomere 2, globular about 20 µm long bearing 3 sensilla clavata distally and 1 long fine seta. Thorax. Chaetotaxy indistinct. Legs. Tibia of PI, PII and PIII nearly equal (185, 180, 185 µm long); length (µm) of tibial spurs of: PI, 40; PII, 65; PIII, 5. Tarsomeres ta1-ta5 of PI and PII equal in size as in Table 2; tarsomeres ta1, ta2, ta3 of PI and PIII are globular and equal in size (40 µm each long); tarsomere ta3 of PI and PII (40 µm long) is half long as ta1 of PIII (85 µm). Femur of PI is much wider (90 µm) than in PII-PIII (70 and 60); tibia of PII is wider (55 µm) than in PI and PII (45 µm each); tarsomere ta1 of PII and PIII (40 µm long) is half long as ta1 of PIII (85 µm). Femur of PI is much wider (90 µm) than in PII-PIII (70 and 60); tibia of PII is wider (55 µm) than in PI and PII (45 µm each); tarsomere ta1 of PII and PIII (40 µm long) is half long as ta1 of PIII (85 µm). Femur of PI is much wider (90 µm) than in PII-PIII (70 and 60); tibia of PII is wider (55 µm) than in PI and PII (45 µm each); tarsomere ta1 of PII and PIII (40 µm long) is half long as ta1 of PIII (85 µm). Femur of PI is much wider (90 µm) than in PII-PIII (70 and 60); tibia of PII is wider (55 µm) than in PI and PII (45 µm each); tarsomere ta1 of PII and PIII (40 µm long) is half long as ta1 of PIII (85 µm).

**Abdomen.** Anal segment (dorsal, Fig. 4a; ventral, Fig. 4b) 280 µm long, 260 µm maximum width at base, 130 µm wide at caudal part. Genitalia in dorsal and ventral view as illustrated in Figs 4b-e. Notum about 140 µm long with separate rami; on each side the rami are connected to a sternal

| Table 1. Male adult of Clunio boudouresquei sp. n. Length (µm) and proportions of prothoracic (PI), mesothoracic (PII) and metathoracic (PIII) legs. |
|---|---|---|---|---|---|---|---|
|   | fe  | ti  | ta1 | ta2 | ta3 | ta4 | ta5 | LR  | BV  | SV  | BR  |
| PI | 475 | 615 | 160 | 50  | 45  | 40  | 75  | 0.26| 5.95| 6.81| 0.90|
| PII| 555 | 555 | 200 | 95  | 115 | 55  | 70  | 0.36| 3.91| 5.55| 0.75|
| PIII| 610 | 575 | 125 | 50  | 45  | 40  | 65  | 0.22| 6.55| 9.48| 0.80|

| Table 2. Female adult of Clunio boudouresquei sp. n. Length (µm) and proportions of prothoracic (PI), mesothoracic (PII) and metathoracic (PIII) legs. |
|---|---|---|---|---|---|---|---|
|   | fe  | ti  | ta1 | ta2 | ta3 | ta4 | ta5 | LR  | BV  | SV  | BR  |
| PI | 245 | 185 | 40  | 25  | 20  | 15  | 40  | 0.22| 4.7  | 10.75| 0.80|
| PII| 260 | 180 | 40  | 25  | 20  | 15  | 40  | 0.22| 4.8  | 11  | 0.85|
| PIII| 270 | 185 | 85  | 35  | 40  | 20  | 45  | 0.46| 3.86| 5.35| 0.90|
axial apodeme. Sternite VIII with 22-24 setae (11-12 on each side of the notum). Gonapophysis VIII (Figs 4b-d): dorsomesal lobe (Fig. 4d) convex medially and projecting in both proximal and apical parts; ventrolateral lobe directed downwards, broader basally and narrowing posteriorly; apodeme lobe (left, Fig. 4c) distinctly swollen in its postero-median part. Presence of 2 stout inwardly directed setae on each side of gonapophysis VIII between base of sternite VIII and ventrolateral lobe. Seminal capsules 70 µm long, 40 µm maximum width, sub-oval and well-sclerotized medially. Spermathecal ducts with loops and separate openings. Tergite IX (Fig. 4e) egg-like shaped, markedly divided, with 20-22 setae (10-11 on each side). Gonocoxite (Figs 4a-b) weekly developed but widely extended, bearing 8-9 setae. Cercus (Fig. 4b) sub-rectangular, normally developed and projecting upwards.

Pupal exuviae
(n = 10, 7 males and 3 females; Figs 5a, 5c, 5e-f)
Total length 2.85-3.15 mm. Colouration contrasting dark brown to yellow brown, wrinkles present on antero-median area of frontal apotome and tho-
Figure 3 a-f). Male adult of *Clunio* spp. Axial apodeme and distal part of tergite IX of: a-b) *C. boudouresquei* sp. n.; c-d) *C. mediterraneus*; e-f) *C. sp. 1*.

Figure 4. Female adult of *Clunio boudouresquei* sp. n. a) tergites VIII-IX with gonocoxites, dorsal; b) genitalia with gonapophysis VIII, sternite VIII, seminal capsule, gonocoxite, tergite IX and cercus; c) apodeme lobe; d) dorsomesal lobe; e) tergite IX, dorsal.
rax; abdomen and anal segment brownish. Cephalothorax. Frontal apomere broadly trapezoidal, frontal setae about 40 µm long, inserted postero-medially, distance between frontal setae 50 µm. Median anteropronalts nearly subequal (30-35 µm long), lateral anteropronalts absent; preconneals sub-equal, about 50 µm long, insertion arranged I, triangle. Dorsocentrals Dc1-Dc2 and Dc3-Dc4 located close together; Dc4 sub-equal (about 10-15 µm long), Dc1 and Dc3 sub-equal (about 40 µm long); distance (in µm) between: Dc1 to Dc2 30, Dc2 to Dc4 80, Dc3 to Dc4 10.

Abdomen. Armament, chaetotaxy, distribution pattern of shagreen and details of armament on tergites and sternites II-VII as in Figs 5a, 5c, 5e-f. Tergite I and sternites I-III bare, sternite IV occasionally with 1-2 rows of small spines (Fig. 5a). Conjunctives of tergites III-VII and sternites V-VII with one transverse row of hooks, which are smaller on sternites, conjunctive on segment VIII composed only of short posteriorly directed spines. Antero-median transverse rows of spines present on tergites II-VII, sparsely present and interrupted medially on tergite II, becoming denser and more extensive on tergites III-VI. Pedes spurii A and B absent; apophyses on tergites and sternites absent. Number and distribution pattern of lateral setae on segments I-VIII: 2 on segment I; 2/3 on II-VII; 3 on VIII. Anal segment is Clunio-type, genital sac 490-500 µm long, 70 µm maximum width, ending each with 1 pointed tubercle.

Larva
Known but not described.

Differential diagnosis
Male adult and pupal exuviae of C. boudouresquei sp. n. are compared to those of known Clunio species from seaboards of Europe and neighbouring areas, based on material collected by the senior author in Corsica, continental France, Italy, Spain except for Bulgaria (Varna seashores, leg. P. Michailova). Some relevant specific features found in the male adult and pupal exuviae will easily separate the new species from other members of Clunio by the following combination of characters:

Male adult: Frontal area of head bearing 2 apical projections (Figs 1c-d), is differently shaped in C. marinus (Figs 1a-b); last flagellomere narrowed apically (Fig. 1f), is widely clubbed in C. mediterraneus (Fig. 1k) and linearly curved in C. sp. 1 (Fig. 1l); typical long finger-like expansion of left palp (Fig. 1g), is absent in both C. sp. 2 (Fig. 1m) and C. marinus (Fig. 1n); caudal apodeme composed of basal brush-like and 5-6 apical claws (Fig. 2h), is lacking basal brush and less branched apically in C. mediterraneus (Fig. 2e); megaseta present on gonostylus (Fig. 2c), is absent in C. mediterraneus (Fig. 2i) and C. marinus (Fig. 2h); apex of gonostylus with only one single finger-like tubercle (Figs 2e-d), while consists of several unequal tubercles in both C. sp. 1 (Fig. 2g) and C. marinus (Figs 2h-i); basal and apical parts of axial apodeme (Figs 3a-b), are differently shaped in C. mediterraneus (Figs 3c-d and C. sp. 1 (Figs 3e-f).

Male pupal exuviae: Transverse row of hooks present on sternites V-VII (Figs 5a, 5e-f), only present on sternites V-VI in C. mediterraneus (Figs 5b, 5g-h); anteromedian rows of spines on tergite II interrupted medially and sparse (Fig. 5c), is continuous and more dense in C. mediterraneus (Fig. 5d).

Ecology and remarks
The immature stages of Clunio spp. are typically marine dwellers of the intertidal zone along the littoral and mid-littoral zones of rocky shores, sometimes in association with populations of Mytilus spp. In some species (in particular those associated with Lithophyllum beds) the emergence of the adults is synchronized with the lunar cycle (Neumann 1976, Neumann et al. 1997, Kaiser & Heckel 2012). The biological cycle (reproduction and emergence) of C. boudouresquei sp. n. is closely related to the typology of the intertidal zone including alternation between submerged marine habitats and terrestrial ecological conditions, which are strongly reinforced during spring tides of lunar rhythms (new and full moon).

The pavements, ‘trottoirs’ of L. byssoides represent a combination of habitats that typically characterize the intertidal zone of the protected area of Scandola Nature Reserve. They mainly consist of a pristine combination of habitats considered to be microrefugia for a dense and diversified community of marine, semi-aquatic and semi-terrestrial species, including members of several closely integrated dipteran families (Chironomidae, Ceratopogonidae and Dolichopodidae). The newly described species is encountered in the marine mid-littoral zone of Punta Palazzu (Fig. 6), where larval stages occur exclusively within the large bio-constructions of the ‘long-living’ red calcified alga L. byssoides, which clearly delimit alternate cycles of both submerged and terrestrial habitats. In addition, the bio-concretions of Punta Palazzu are currently considered as the largest Lithophyllum beds in Europe, where valuable knowledge on the biology (growth rate) and ecology of the algal communities are documented by Verlaque (2010).
Figure 5. Pupal exuviae of *Clunio* spp. Distribution pattern, chaetotaxy and details of armament of abdominal segments II-VII of: a) *C. boudouresquei* sp. n.; b) *C. mediterraneus*. Tergite II (dorsal) of: c) *C. boudouresquei* sp. n.; d) *C. mediterraneus*. Tergite VI-VII (dorsal and ventral) of: e-f) *C. boudouresquei* sp. n.; g-h) *C. mediterraneus*. 
While the biological and ecological quality of *L. byssoides* rims are still well-preserved at Punta Palazzu and Port-Cros Island (Figs 6-7), other similar marine sites located along the coastal Mediterranean ecosystem of continental France are becoming extinct, or have been deeply damaged and degraded (Figs 8-9) during the last four decades by human activities, including ecotourism and release of toxic chemical pollutants (e.g., HAP, PCB, abundance of macro- and microplastics). In addition, the *L. byssoides* beds delimited by the latter endangered sites, are heavily threatened by a massive proliferation of an invasive Mytilidae species (*Mytilus galloprovincialis* Lamarck, 1819). This sea mussel significantly predominates when changes in water quality and level of pollution become increasingly high (seashores at Banyuls, SW-France, Figs 8-9), where populations are intensely enlarging and reinforcing their potential expansion in occupying up to 70-80% of the living *L. byssoides* original cover. Such situations are also highlighted in southern France by Blanfuné et al. (2019) for the ‘Canopy-forming Seaweeds’ of *Cystoseira mediterranea* Sauvageau, 1810, where an important decline of local populations with risk of extinction are reported; Linares et al. (2010) and Garragou et al. (2017) report a similar scenario for the Mediterranean Red Coral, suggesting that constructive plans and management measures for conservation and preservation of autochthonous Tyrrhenian elements must be implemented. Consequently, in some of the Tyrrhenian mid-littoral coastlines (Punta Palazzu, Port-Cros, Banyuls), some relevant and vulnerable *Clunio* species are closely confined to the *Lithophyllum* beds, and therefore their loss would be clearly indicative of a combination of anthropogenic impacts and global warming in this geographical region. Such relict Tyrrhenian species are considered as potentially biogeographic representatives and biological indicators of local climate change (in particular, the rise of sea level), which strongly affect both sustainability and viability of the *Clunio* populations.

Geographical distribution

Geographical distribution of known *Clunio* species from European seacoasts (Ashe & O’Connor 2012) and the Tyrrhenian sub-region is given in Figure 10. *Clunio boudouresquei* sp. n. ‘○’ is abundant at the type-locality of Punta Palazzu (Scandola Nature Reserve, West Corsica); weakly represented in southern France (Port-Cros and Porquerolles Islands, Cassis, Banyuls). Occurrences of *C. boudouresquei* sp. n. in southern France indicate that it may be more widespread in other geographical areas of the Tyrrhenian sub-region (insular and continental Provinces), and therefore can be expected from the seacoasts of some neighbouring countries like Italy and Spain. *Clunio marinus* ‘★’ is found along all Atlantic seacoasts in Europe including France, Germany, England, Iceland, Ireland, Italy, Madeira, Netherland, Norway,
Figure 7. Bio-constructions of the red calcified alga *Lithophyllum byssoides* at Port-Cros Island (SE-France). Photo S. Ruitton.

Figure 8. Threatened bio-constructions of *Lithophyllum byssoides* by the massive proliferation of Sea Mussels at Banyuls Seashores (SW-France): level-1. Photo J. Moubayed-Breil.
Spain and Sweden. *Clunio mediterraneus* ‘✶’ is widespread in the Mediterranean Basin: Southern France (Cerbère, Banyuls, Sète, Carry, Marseille, Cassis, Port-Miou, Hyère, Porquerolles, Port-Cros, Nice), northern and western Corsica, the Balearic Islands, Italy, Spain, Turkey, Croatia (the Adriatic Sea). *Clunio ponticus* Michailova, 1980 ‘✪’ is only recorded from the Black Sea (Varna, Bulgaria).

**Thalassosmittia ballestai** Moubayed-Breil, sp. n.

*Thalassosmittia* sp. 1, in Moubayed-Breil & Ashe (2012), Moubayed Breil et al. (2013).

http://zoobank.org/0C9795ED-02C6-47BB-A8A1-190480BE9EEA

**Material examined**

Holotype. France, West Corsica, Scandola Nature Reserve, Focolara Bay (Fig. 14), 42° 21’ 25” N, 8° 34’ 0” E; 1 male pharate adult, leg. J. Moubayed-Breil, 03.VI.2015. Locality No. 31 in Moubayed-Breil & Ashe (2012), locality No. 30 in Moubayed-Breil et al. (2013). Marine water temperature: 10-12°C (min.), 22-24°C (max.).

Paratypes (all leg J.M-B.): 3 pupal exuviae (2 males and 1 female), same locality as for holotype, 03.VI.2015.

Holotype (mounted on 1 slide) and 2 pupal exuviae (1 male and 1 female) are deposited in the collections of the Zoologische Staatssammlung München (ZSM), Munich, Germany. Additional paratypes are deposited in the senior author’s collection.

**Diagnostic characters**

Though the pupal exuviae of *T. ballestai* sp. n. apparently shows a close morphological resemblance with that of *T. thalassophila* (distribution pattern of armament on tergites and shape of anal lobe), some relevant specific characters found in the male adult (shape of tergite IX, anal point and inferior volsella) will sufficiently separate the species described here from other related members of genus *Thalassosmittia* by the below listed characters.

**Male adult**: Temporals with 3 inner and 3 verticals; last flagellomere of antenna distinctly clubbed, abruptly narrowing distally and bearing a brush of curved sensilla chaetica; antennal groove reaching segments 2, AR 0.72; lobes of antepronotum widely opened; antepronotals absent. Brachiolium with 1 seta, veins and squama bare. Tarsomere ta₆ of PI-PII wider and rounded apically; spurs present on tarsomeres ta₋ta₋; sensilla chaetica present on tibia and tarsomeres ta₋ta₋ of PI-PIII. Tergite anal band absent on tergite IX; anal point drop-like shaped and bearing a rounded setiferous lobe at
base; virga with 2 closely grouped spines; inferior volsella rounded lobe-like shaped with bifid basal margin; gonostylus distinctly swollen at base and thinner distally when viewed laterally.

**Pupal exuviae:** Frontal apotome with sub-cylindrical tubercles; dorsocentral Dc distances between dorsocentral Dc; vestigial about 5-7 µm long; Dc and Dc separated by 25 µm, Dc and Dc by 70 µm; transverse row of hooks and orally directed pins present on conjunctives of sternites IV/V-VII/VIII is occasionally absent on IV/V; anal lobe sub-trapezoidal, genital sac distinctly swollen distally and bearing an apical finger-like tubercle. Pedes spurii A and Pedes spurii B absent. Anal lobe sub-trapezoidal to sub-triangular, bearing 2 subequal macrosetae on dorsal side; genital sac swollen distally, bearing a projecting outwards tubercle.

**Etymology:** The new species is named ‘ballestai’ in honour of our colleague Laurent Ballesta (Andromède Océanologie, Carnon, South France) who is still an active marine biologist studying and preserving the Mediterranean marine fauna and flora including the protected area of Scandola Nature Reserve, which represents a precious and valuable inheritance area.

**Male adult**

(n = 2, 1 pharate; Figs 11a, 11c-h, 12a)

Total length 1.55-1.60 mm. Wing length 1.05-1.10 mm. Colouration variable in general, contrasting from light brown to brown even to greenish; Head, antenna, halters and legs light brown; thorax with mesonotal stripes contrasting light brown to brown; anal segment and inferior volsella distinctly contrasting brown to hyaline; wing translucent. Head. Eyes bare between ommatidia, nearly circular with dorso-median extension; inner lateral margin bare. Vertex and coronal area (Fig. 11a) distinctly triangular and orally projecting, basal and median margins of coronal triangle much thicker than distal part, coronal setae absent. Temporals uniserial including 3 inner and 2 outer verticals. Clypeus semicircular to sub-rectangular, with about 16-18 setae in 3-4 rows. Palp-5 segmented, segments I-2 fused, length (µm) of palpomeres I-5: 15, 25, 47, 63, 80; third palpomere with 2 sensilla clavata and 3 sensilla coeloconica located distally. Antenna 550 µm long; last flagellomere 230 µm long, distinctly clubbed distally, distal half abruptly narrowing and bearing a brush of curved sensilla chaetica; antennal groove reaching segments 2; AR 0.72. Thorax. Lobes of antepronotum (Fig. 11c) widely opened; anteprosternal absent; acrochicles 26 in 1-2 rows; dorsocentrae 9 in 1 row; prealars 3; supraalars absent. Humeral pit indistinct. Scutellum semicircular, with 4 uniserial setae. Wing. Brachiolium with 1 seta. Veins and squamae bare. Legs. Tarsomere ta of PI-II wider in its distal part and rounded apically; tibial spurs of PI-II spiniform; spurs present on tarsomeres ta-ta. Sensilla chaetica present in low number on tibia and tarsomeres ta-ta of PI-II: on ta-ta (proximally and distally); only distally on tibiae. Length (µm) and proportions of prothoracic (P1), mesothoracic (P11) and metathoracic (P11) legs as in Table 3.

Abdomen. Hypopygium in dorsal, ventral and lateral view as in Figs 11e-f, 12a (Fig. 11e, dorsal; Fig. 11f, ventral with tergite and anal point removed; Fig. 12a, lateral). Tergite IX semicircular, posterior area with a dark circular setiferous band located close to the base of anal point, which is
clearly visible in lateral view (Fig. 11d). Anal point (Figs 11d, 11e, 12a) about 40-45 µm long, 70-75 µm maximum width at base; broadly triangular at base and drop-like shaped in its remaining part; lateral and apical margins densely covered with setae. Laterosternite IX with 6 setae (3 on each side). Sternapodeme, transverse sternapodeme and phallapodeme as in Fig. 11f, basal part orally projecting, basal part of coxapodeme semicircular and projecting inwards. Virga (Figs 11e, 11g) about 40 µm long, consists of 2 long curved spines.

Gonocoxite about 265 µm long, 75 µm maximum width, much wider at base, narrowing distally to a rounded apex, inner margin with 10-11 stout setae. Inferior volsella large lobe-like shaped, rounded apically with posterior margin distinctly bi-lobed, apical and caudal parts contrasting and hyaline. Gonostylus in dorsal (Fig. 11e) and lateral view (Fig. 11h) 105 µm long, 30 µm maximum width; swollen medially and less wide distally when viewed laterally; posterior margin sinuous and swollen medially; crista dorsalis low and widely extended...
Table 3. Male adult of *Thalassosmittia ballestai* sp. n. Length (µm) and proportions of prothoracic (PI), mesothoracic (PII) and metathoracic (PIII) legs.

|   | fe | ti | ta₁ | ta₂ | ta₃ | ta₄ | ta₅ | LR | BV | SV | BR |
|---|----|----|-----|-----|-----|-----|-----|----|----|----|----|
| PI | 350| 445| 205 | 110 | 85  | 50  | 60  | 0.46| 3.28| 3.89| 2.10|
| PII| 460| 420| 245 | 135 | 80  | 60  | 50  | 0.58| 3.46| 3.59| 2.80|
| PIII| 495| 430| 215 | 115 | 75  | 60  | 55  | 0.50| 3.74| 4.30| 2.60|

is clearly visible only in dorsal view; megaseta present and well-developed.

**Pupal exuviae**

(*n* = 5, 2 males and 3 females; Figs 12c, 12e-k, 13a, 13e)

Total length 1.65-1.70 mm. General colouration contrasting brown to dark brown; frontal apotome with anterior half covered with fine wrinkles; antero-median area of cephalothorax and suture of thorax markedly rugulose and wrinkled; abdomen yellowish to pale, anal lobe and genital sac brown to dark brown. Cephalothorax as in Figs 12c and 13a; frontal apotome (Fig. 13a) triangular with pointed lateral expansions; frontal tubercles about 40-45 µm high, sub-cylindrical and well-developed, frontal setae about 70 µm long, separated by 25-30 µm. Thorax as in Fig. 12c. Median antepronotal nearly subequal (90 and 80-85 µm long), lateral antepronotal and prealars absent; precorneals 85, 80 and 90 µm long. Dorsocentrals consist of 3 unequal setae, length (in µm) of *Dc₁*, *Dc₂*, *Dc₃*: *Dc₁*, vestigial about 5-7; *Dc₂*, 55; *Dc₃*, 70; distance (in µm) between: *Dc₁* to *Dc₂* 25, *Dc₂* to *Dc₃* 70.

Abdomen. Armament, chaetotaxy and distribution pattern of shagreen with details of armament on tergites and sternites: III-VIII (Fig. 12e); V-VII (Figs 12f-k). Tergite I and sternites I-IV bare. Anterior transverse rows of spines present on tergites II-VIII, those on tergites VII-VIII are smaller and less extensive; posterior transverse rows of spines present on tergites III-VIII, becoming gradually more extensive on VI-VIII. Conjunctives of tergites III/IV-VIII/VIII and sternites IV/V-VII/VIII with rows of hooks and orally directed pin-shaped setae (Figs 12e, 12h-k), those on sternite IV/V are occasionally absent (Fig. 12g). Caudal-lateral area of tergites and sternites II-VII with a group of short spines (Figs 12e-k). Pedes spurii A and PSB absent. Number and distribution pattern of lateral setae on segments I-VII, 2, postero-lateral seta on segments V-VI forked; segment VIII with 3 setae located distally. Anal segment in dorsal and ventral view as in Fig. 13e; anal lobe sub-trapezoidal to sub-triangular, 130-135 µm long, 135-140 µm minimum width at base, 185-190 µm maximum width at apex, a rounded patch of short spine present medially, apex bearing a finger-like tubercle which is projecting outwards; genital sac 220 µm long, distinctly swollen distally and overreaching apical margin of anal lobe by 70-75 µm; macrosetae consist of 2 subequal setae, about 90-95 µm long, separated by about 35-40 µm.

**Larva**

Unknown.

**Differential diagnosis**

Only the pupal exuviae of *T. ballestai* sp. n. directly key close to those of *T. thalassophila*, while the male adult is quite different and likely belongs to a local 'Tyrrenian element'. On the basis of some relevant specific characters found in the male adult and pupal exuviae, *T. ballestai* sp. n. is compared, as male adult, to that of *T. thalassophila* and, as pupal exuviae, to other undescribed morphotypes collected in Corsica, continental France, Italy and Spain. However, *T. ballestai* sp. n. is easily distinguished from other related species or taxa/species of *Thalassosmittia* by the following combination of characters.

Male adult: Head with 3 inner verticals (Fig. 11a), is bearing 4 in *T. thalassophila* (Fig. 11b); tergite anal band absent on tergite IX (Figs 11d-e), is conspicuously present in *T. thalassophila* (Figs 11i, 11k); anal point drop-like shaped and much wider at base (Fig. 11e), is parallel-sided with semicircular basal part in *T. thalassophila* (Fig. 11k); virga with 2 closely grouped spines (Figs 11e, 11g), consist of 2 inwardly curved spines and horseshoe-shaped in *T. thalassophila* (Fig. 11j); inferior volsella rounded lobe-like shaped with bifid basal margin (Figs 11e, 12a), is divided in 2 separate parts in *T. thalassophila* (Fig. 11b); gonostylus in lateral view (Fig. 11h), is differently figured in *T. thalassophila* (lateral, Fig. 11l).

Male pupal exuviae: Frontal apotome with sub-cylindrical tubercles (Fig. 13a), are smaller and fused apically in *T. thalassophila* (Fig. 13b), weakly domed in *T. marinus* (Fig. 13c) and conical in *T. sp.* 1 (Fig. 13d); distances between dorso-central *Dc₁* to *Dc₂* and *Dc₂* to *Dc₃* are respectively...
Figure 12 a-k). Male adult and pupal exuviae of Thalassosmittia spp. Anal point and inferior volsella in lateral view of: a) T. ballestai sp. n.; b) T. thalassophila. Cephalothorax of: c) T. ballestai sp. n.; d) T. thalassophila. T. ballestai sp. n.: e) chaetotaxy and details of armament on abdominal segments III-VIII; f-g) tergite V in dorsal and ventral view; h-i) tergite VI in dorsal and ventral view; j-k) tergite VII in dorsal and ventral view.

25 and 70 (Fig. 12c), while are 15 and 55 in T. thalassophila (Fig. 12d); transverse row of hooks and orally directed pins present on conjunctives of sternites V/VI-VII/VIII (Fig. 12e) or occasionally absent on IV/V (Fig. 12g), is regularly present on conjunctives of sternites IV/V-VII/VIII of T. thalassophila (couplet 196 in Langton 1991); anal lobe (Fig. 13e) sub-triangular to sub-trapezoidal, is distinctly triangular in T. thalassophila (Fig. 13f), semicircular in T. marinus (Fig. 13g), rectangular in T. sp. 1 (Fig. 13h) and sub-circular in T. sp. 2 (Fig. 13i); genital sac (Fig. 13e) distinctly swollen distally with an apical finger-like tubercle apically, is differently figured in T. thalassophila (Fig. 13f).
Figure 13. Pupal exuviae of *Thalassosmittia* spp. Frontal apotome of: a) *T. ballestai* sp. n.; b) *T. thalassophila*; c) *T. marinus*; d) *T. sp. 1*. Caudal armament of segment VIII and anal segment of: e) *T. ballestai* sp. n., dorsal and ventral; f) *T. thalassophila*, dorsal and ventral. Caudal armament of segment VIII and anal segment of: g) *T. marinus*; h) *T. sp. 1*; i) *T. sp. 2*.

**Ecology and remarks**

The examined material of *T. ballestai* sp. n. (male adults, male pharate adults and pupal were collected in the type locality of Focolara Bay (Fig. 14) located in Scandola Natural Reserve, western Corsica. Additional material including associated larval stages is needed to determine and confirm the ecology of the new described species. While the marine intertidal zone at Focolara Bay is better preserved during winter and spring periods, it still heavily degraded, as other seacoasts around the Mediterranean Basin, by the impact of pollution and ecotourism activities, which highly increase each year between June and September.

The increasing abundance of plastics along the coastal ecosystem, estuarine zones and the littoral marine environment of Corsica (Bastia, Ajaccio, Porto, etc.) including those of Scandola Nature Reserve, has been observed since the last three decades. Inorganic matter, composed of pellet tar and plastics, collected in both drift and troubleau nets (as shown and detailed in Figs 15-16), has become more dominant major threat to all types of marine organisms. Small particles of plastics, consisting of several forms of both macro- and micro-particles of 0.5-5 to 10-15 mm size, are systematically found from the surface and water column to the seabed sediment and beach, where marine organisms (especially deposit feeders and detritivores)
ingest them. Therefore, these pollutants may adversely impact species that inhabit intertidal zones that cannot adapt to changing conditions via behavioural plasticity; *T. ballestai* may be among these species. Consequently, a major challenge in marine environmental disciplines (evolutionary biology, ecology, conservation) is to better understand and predict how these sensitive species will respond to the impact of human activities and the rise of sea level, which is directly related to the global warming.

**Geographical distribution**

Geographical distribution of known *Thalassosmittia* species from European seacoasts (Ashe & O’Connor 2012) and the Tyrrhenian sub-region is given in figure 10. *Thalassosmittia atlantica* '✩' is known only from the western Atlantic seacoasts including the Canary Islands (type-locality), Madeira, Spain and Portugal. *Thalassosmittia ballestai* sp. n. '❄' is common and abundant in the seashores of Focolara Bay (West Corsica). The records of *T. ballestai* sp. n. (pupal exuviae) from some seashores in southern France need to be confirmed by the presence of associated material composed of adults and pupae. *Thalassosmittia thalassophila* '✤' is present along the Atlantic and some Mediterranean seacoasts in Europe including: France, England, Germany, Greece, Ireland, Italy, Netherland, Romania and Spain.

**Acknowledgements**

The authors are grateful to Dr. Alyssa Andersen (Southwest Minnesota State University, USA) and Dr. Torbjørn Ekrem (NTNU University Museum, Trondheim, Norway) for their constructive
suggestions, which greatly improved the manuscript. Special thanks are also due to Jade and M-Hélène Breil-Moubayed for their kind assistance in achieving the measurements of the leg ratios for the two new species.

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*Article submitted 23. May 2019, accepted by Alyssa M. Anderson 13. July 2019, published 4. October 2019.*