New species of *Ligophorus* (Monogenea, Ancyrocephalidae), parasite of *Liza* spp. (Teleostei, Mugilidae) off the Northwestern African coast

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El Hafidi F., Diamanka A., Berrada Rkhami O. & Pariselle A. 2013. — New species of *Ligophorus* (Monogenea, Ancyrocephalidae), parasite of *Liza* spp. (Teleostei, Mugilidae) off the Northwestern African coast. *Zoosystema* 35 (2): 215-225. http://dx.doi.org/10.5252/z2013n2a6

ABSTRACT
This study of monogenean species of *Ligophorus* Euzet & Suriano, 1977 from *Liza* spp. (Mugilidae) from the Northwestern African coast identifies the

occurrence of four new species. *Ligophorus gabrioni* n. sp. on *Liza falcipinnis* (Valenciennes, 1836) is characterized by a small antero-median protuberance and two lateral and symmetrical expansions on the ventral transverse bar; a tubular accessory piece distally expanded; and a vagina that is not sclerotised (not visible). *Ligophorus benhoussai* n. sp. on *Liza grandisquamis* (Valenciennes, 1836) is characterized by a very long sickle-shaped accessory piece, which is wide at the base and tapering at the end, and a α-shaped vagina. Also found on Liza *grandisquamis* were *Ligophorus bazairii* n. sp. and *Ligophorus hamzati* n. sp. The former is characterized by a tubular bottle-opener shaped accessory piece; whereas the latter is characterized by a tubular accessory piece with a bifurcated distal extremity whose branches are also bifurcated. No Monogenea were found on the endemic *Liza bandialensis* Diouf, 1991. In our opinion, the differences in monogenean species richness that exist among the various hosts may be due to fluctuations of host populations as the result of bottleneck or vicariant events.

KEY WORDS
Monogenea,
Mugilidae,
Africa,
new species.

RÉSUMÉ

Nouvelles espèces de Ligophorus *(Monogenea, Ancyrocephalidae) parasites de* Liza *spp. (Teleostei, Mugilidae) au large des côtes Nord-Ouest de l'Afrique.*

Cette première étude des espèces de *Ligophorus* Euzet & Suriano, 1977 récoltées sur des *Liza* spp. (Mugilidae) des côtes Nord-Ouest de l'Afrique, montre la présence de quatre espèces nouvelles. Sur *Liza falcipinnis* (Valenciennes, 1836) : *Ligophorus gabrioni* n. sp. caractérisée par une petite protubérance antéro-médiane et deux expansions symétriques de la barre transversale ventrale ; une pièce accessoire tubulaire avec une expansion distale au niveau de l'appareil copulateur mâle et un vagin non sclérifié (non visible). Sur *Liza grandisquamis* (Valenciennes, 1836) : *Ligophorus benhoussai* n. sp. caractérisée au niveau de l'appareil copulateur mâle par une très longue pièce accessoire en forme de faucille, large à la base et s'effilant vers l'extrémité distale; et un vagin en forme d'α ; *Ligophorus bazairii* n. sp. caractérisée au niveau de l'appareil copulateur mâle par une pièce accessoire tubulaire, en forme de décapsuleur ; et *Ligophorus hamzati* n. sp. caractérisée au niveau de l'appareil copulateur mâle par une pièce accessoire fourchue à son extrémité distale, chaque branche étant à son tour également fourchue. *Liza bandialensis* Diouf, 1991 : nous n'avons pas trouvé de Monogènes sur cette espèce endémique. À notre avis, les différences de richesse spécifique des Monogènes décrits sur les différents hôtes étudiés, pourraient être dues à des fluctuations de la taille des populations hôtes lors d'événements de « bottleneck » ou d'isolement par vicariance.

MOTS CLÉS
Monogenea,
Mugilidae,
Afrique,
espèces nouvelles.

INTRODUCTION

Ligophorus Euzet & Suriano, 1977, with type species *Ligophorus vanbenedenii* (Parona & Perugia, 1890) Euzet & Suriano, 1977 (syn. *Tetraonchus vanbenedenii* Parona & Perrugia, 1890; *Ancyrocephalus vanbenedenii* (Parona & Perrugia, 1890) Johnston & Tiegs, 1922; *Haplocleidus vanbenedenii* (Parona & Perrugia, 1890) Palombi, 1949; *Haliotrema vanbenedenii* (Parona & Perrugia, 1890) Young, 1968), belongs

to the Ancyrocephalidae Bychowsky, 1937. This genus is restricted to monogeneans that infect the gills of mullets (Teleostean, Mugilidae Bonaparte, 1831). Species identification relies on differences in the morphology and size of sclerotised elements of both the haptor and genital structures (see Dmitrieva *et al*. 2012). To date, 51 *Ligophorus* species have been described from Mugilid species belonging to five genera from all over the world: *Mugil* Linnaeus, 1758 (18 species), *Liza* Jordan & Swain, 1884 (28 species), *Chelon* Artedi, 1793 (one species), *Valamugil* Bleeker, 1854 (two species) and *Crenimugil* Schultz, 1946 (two species).

The Northwestern coast of Africa is a very diverse area with particular environmental features (rivers, lakes, lagoons) that allow a high diversity of mullet species to co-exist. For example, in Senegal, Albaret (2003) reported six species: *Mugil bananensis* (Pellegrin, 1927), *Mugil cephalus* Linneaus, 1758, *Mugil curema* Valenciennes, 1836, *Liza dumerili* (Steindachner, 1870), *Liza falcipinnis* (Valenciennes, 1836), and *Liza grandisquamis* (Valenciennes, 1836). A seventh species, *Liza bandialensis* Diouf, 1991, is endemic from the Sine Saloum estuary (Senegal) and is listed by Trape *et al*. (2012). The two host species (*Liza grandisquamis* and *Liza falcipannis*) studied herein for their monogenean fauna are very abundant in lagoons and along the coast from Senegal to Congo (DRC) over a wide range of salinities (Albaret & Legendre 1985), whereas *Liza bandialensis* is rare and limited to the Sine Saloum estuary in Senegal. These three mullet species have never been studied for their parasitic fauna except during a preliminary investigation in the Ivory Coast (Berrada Rkhami *et al.* 1993).

MATERIALS AND METHODS

Host specimens (*Liza falcipinnis* and *Liza grandisquamis*) were collected from the Hann fish market, Dakar, Senegal from fishermen who used mainly purse seines, from Grand Lahou Lagoon, Ivory Coast (from a fishermen who used a cast net) and from Lake Cayo, Congo (from a fisherman who used a beach seine). Gills from three specimens of *Liza bandialensis* originating from Foundiougne village, Saloum channel, Sine Saloum estuary (Senegal) (14°7'N, 16°28'W) were provided by J.-D. Durand (see Trape *et al*. 2012). Fish were identified according to Albaret (2003) and Trape *et al*. (2012). Fish were dissected immediately or were frozen until examination. Gill arches were removed and placed in separate Petri dishes containing clear tap water. Monogeneans were detached from the gills by powerfully flushing water over the filaments and were then transferred and mounted directly onto a slide in a drop of ammonium picrate-glycerol fluid (Malmberg 1957). Each preparation was then covered with a round coverslip and sealed with Glyceel (Bates 1997).

Monogeneans were studied under incident light using a Leica compound microscope. Drawings were made using a drawing tube. Measurements (Fig. 1) were made using a Jandel digitizer and SigmaScan software and are given in micrometers as the mean more or less standard deviation (when $n \geq 30$) followed in parentheses by the range and the number [n] of observations.

ABBREVIATIONS

Institutions

BNHM	British Natural History Museum, London;
MNHN	Muséum national d'Histoire naturelle, Paris.

Morphology

AP	accessory piece;
DA	dorsal anchor;
DB	dorsal bar;
H	hook;
MCO	male copulatory organ;
Pe	penis;
VA	ventral anchor;
VB	ventral bar;
Vg	vagina.

SYSTEMATICS

No monogenean species were found on *Liza bandialensis*, only one species occurred on the gills of *Liza falcipinnis* and three species were found on the gills of *Liza grandisquamis*. All specimens belong to *Ligophorus* as defined by Euzet and Suriano (1977) and emended by Soo & Lim (2012).

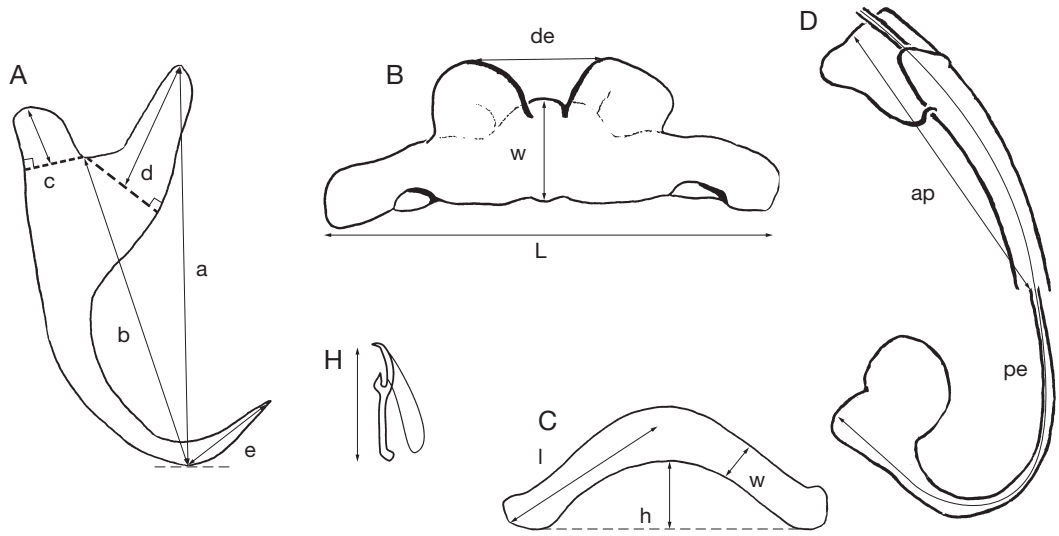

Fig. 1. – Measurements used: **A**, anchor; **B**, ventral transverse bar; **C**, dorsal transverse bar; **D**, MCO; **H**, hook length. Abbreviations for measurments: **a**, total length (distance between the extremity of guard and the inflection point of the blade); **ap**, accessory piece length; **b**, blade length (distance between the border guard/shaft and the inflection point of the blade); **c**, shaft length (distance between the extremity of the shaft and the orthogonal projection line of the border guard/shaft); **d**; guard length (distance between the extremity of the guard and the orthogonal projection line of the border guard/shaft); **de**; distance between expansions; **e**, point length (distance between the extremity of blade and its inflection point); **h**, high; **l**, length of one branch; **L**, total length; **pe**, penis total length; **w**, width at the middle.

Ancyrocephalidae Bychowsky, 1937

Ligophorus Euzet & Suriano, 1977

Type species (by original designation). — *Lig. vanbenedenii* (Parona & Perugia, 1890) Euzet & Suriano, 1977 syn. *Tetraonchus vanbenedenii* Parona & Perrugia, 1890; *Ancyrocephalus vanbenedenii* (Parona & Perrugia, 1890) Johnston & Tiegs, 1922; *Haplocleidus vanbenedenii* (Parona & Perrugia, 1890) Palombi, 1949; *Haliotrema vanbenedenii* (Parona & Perrugia, 1890) Young, 1968.

Ligophorus gabrioni n. sp.
(Fig. 2)

Type material. — Holotype: MNHN HEL313; paratypes: MNHN (10) HEL314, BMNH (10) 2012.12.17.1.

Material examined. — 26 specimens mounted in ammonium picrate-glycerol and five living specimens.

Type host. — *Liza falcipinnis* (Valenciennes, 1836) (Mugilidae).

Site of infection. — Gills, between secondary gill lamellae.

Type locality. — Off Dakar, Senegal (14°43'09"N, 17°25'48"W).

Other localities. — Grand Lahou Lagoon, Ivory Coast (5°08'11"N, 5°01'33"E) and Lake Cayo, Congo (4°43'09"S, 12°00'46"E).

Etymology. — The name *gabrioni* is given in honor of Pr Claude Gabrion, who supervised the early work on mugilid parasites from Western and Northern African coasts.

Description

Flattened adult, 542 (453-645) [26] in length and 123 (92-188) [26] in width at gonad level. Mouth sub-terminal followed by a muscular ovoid pharynx: 45 (40-53) [20] in larger diameter. Haptor, 117

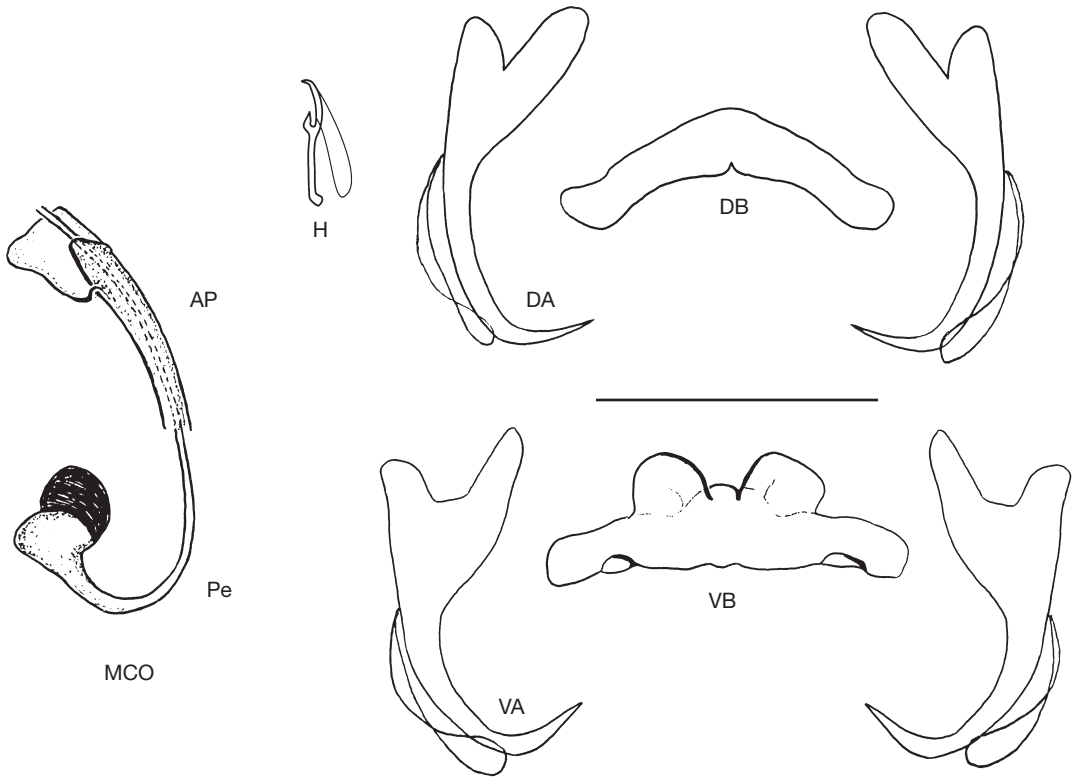

Fig. 2. — *Ligophorus gabrioni* n. sp.: morphological structures as in Fig. 1. Abbreviations: see Material & Methods. Scale bar: 30 µm.

(93-153) [26] maximum width. Dorsal bar invert V-shaped, sometime U-shaped or nearly straight: 22 (20-27) [20] long, 7 (6-10) [20] wide and 8 (1-13) [20] high (variable following the shape of the bar: V, U or straight). Dorsal anchor, with curved blade, bent at right angle near the point; the point one quarter of the blade: a = 38 ± 1 (36-40) [52]; b = 29 ± 1 (27-30) [52]; c = 9 ± 0.6 (7-11) [52]; d = 14 ± 0.6 (12-15) [52]; e = 9 ± 0.6 (8-11) [52]. Ventral bar broad inverted V-shaped with small antero-median protuberance and two lateral and symmetrical expansions: 9 (7-10) [26] apart; ventral bar, 43 (40-44) [26] long and 10 (9-11) [26] wide at the middle. Ventral anchor similar in shape with dorsal, somewhat more robust: a = 37 ± 1 (35-39) [52]; b = 28 ± 1 (27-30) [52]; c = 8 ± 0.6 (7-10) [52]; d = 11 ± 0.5 (10-12) [52]; e = 9 ± 0.6 (7-11) [52]. 14 hooks, 13 ± 0.4 (11-14) [61] long, similar in shape and size (straight shaft, a short guard and a curved blade). MCO consists of small median cirrus and an accessory piece. Curved tubular cirrus, 54 (52-55) [26] long, with an expanded base bipartite, passes through a tubular accessory piece distally expanded: 27 (26-29) [26] total length. No vagina observed, probably not sclerotised. Eggs not seen.

Remarks

The comparison of *Ligophorus gabrioni* n. sp. with the 28 species of *Ligophorus* that were already described from *Liza* spp. [*Liza aurata* (Risso, 1810), *Liza saliens* (Risso, 1810), *Liza ramada* (Risso, 1827), *Liza carinata* (Valenciennes, 1836), *Liza subviridis* (Valenciennes, 1836), *Liza*

vaigiensis (Quoy & Gaimard, 1825), *Liza abu* (Heckel, 1843), and *Liza haematocheila* (Temminck & Schlegel, 1845) (see Bychowsky 1949; Gussev 1955; Euzet & Suriano 1977; Euzet & Sanfilippo 1983; Dmitrieva & Gerasev 1996; Pan 1999; Miroshnichenko & Maltsev 2004; Sarabeev & Balbuena 2004; Balbuena *et al*. 2006; Dmitrieva *et al*. 2007; Dmitrieva *et al*. 2012; Soo & Lim 2012], shows that only *Ligophorus navjotsodhii* Soo & Lim, 2012 and *Ligophorus parvicopulatrix* Soo & Lim 2012 (both from *Liza subviridis)* have no sclerotized vagina. *Lig. parvicopulatrix* differs from *Lig. gabrioni* n. sp. in the shape of the antero-median protuberance (raised median piece vs no raised) and the lack of the accessory piece of the penis (vs presence). *Ligophorus navjotsodhii* differs from *Lig. gabrioni* n. sp. in the shape of the accessory piece associated with the penis: ending in a sharp hook vs ending in a square expansion.

Significantly *Lig. gabrioni* n. sp. resembles *Ligophorus parvicirrus* Euzet & Sanfilippo, 1983 from *Liza ramada* in the shape of the accessory piece and the length of the penis (51 vs 52). These two species could be distinguished by the shape of the ventral transverse bar and, in particular, by the antero-median protuberance, which is massive in *Lig. parvicirrus*. In addition, the vagina in *Lig. parvicirrus* is sclerotized. Comparisons of *Lig. gabrioni* n. sp. with the 23 other species of *Ligophorus* found on the gills of *Mugil, Chelon, Valamugil* and *Crenimugil* spp. show that only *Ligophorus kedahensis* Soo & Lim, 2012 and *Ligophorus fenestrum* Soo & Lim, 2012 have no sclerotised vaginas. *Lig. fenestrum* is unique in possessing anchors with fenestrations and *Lig. kedahensis* differs in the shape of its copulatory organ (no expansion at the extremity of the accessory piece) and the size of its anchors (blade very short in *Lig. kedahensis*).

Ligophorus benhoussai n. sp.
(Fig. 3)

TYPE MATERIAL. — Holotype MNHN HEL311; paratypes MNHN (1) HEL312, BMNH (5) 2012.12.17.2 (it should be noticed that on this BMNH slide there are also five specimens of *Ligophorus hamzati* n. sp. which are registered under no. BMNH 2012.12.17.7).

MATERIAL EXAMINED. — 22 specimens mounted in ammonium picrate-glycerol and five living specimens.

TYPE HOST. — *Liza grandisquamis* (Valenciennes, 1836) (Mugilidae).

SITE OF INFECTION. — Gills, between secondary gill lamellae.

TYPE LOCALITY. — Grand Lahou Lagoon, Ivory Coast (5°08'11"N, 5°01'33"E).

OTHER LOCALITIES. — Off Dakar, Senegal (14°43'09"N, 17°25'48"W) and Lake Cayo, Congo (4°43'09"S, 12°00'46"E).

ETYMOLOGY. — The name *benhoussai* is given for our colleague A. Benhoussa, professor at the faculty of science Mohamed V, Rabat (Morocco), who participated in the fish collection.

DESCRIPTION
Flattened adult, 551 (447-724) [22] long, 116 (84-165) [22] wide at gonad level, pharynx 32 (23-39) [22] larger diameter. Haptor well demarcated with 14 marginal hooks: 12 ± 1.5 (7-17) [282] long; two pairs of large anchors, dorsal with shaft three time longer than guard: a = 46 ± 2 (41-49) [44]; b = 35 ± 2 (31-39) [44]; c = 5 ± 0.6 (4-7) [44]; d = 14 ± 1.2 (12-17) [44]; e = 7 ± 0.7 (5-8) [44]; ventral with guard and shaft of comparable size: a = 48 ± 2 (43-51) [44]; b = 43 ± 2 (39-46) [44]; c = 7 ± 0.8 (5-9) [44]; d = 9 ± 1.1 (6-11) [44]; e = 8 ± 0.7 (7-9) [44] and two connective bars, ventral, 45 (34-65) [22] long and 10 (7-13) [22] wide at the middle, with antero-median protuberance and two lateral expansions: 9 (5-13) [22] apart. Dorsal bar invert V-shaped 22 (17-27) [22] long, 5 (3-6) [22] wide and 8 (5-12) [22] high. MCO as a thin and long copulatory tube: 124 (105-138) [22] long, a very long accessory piece sickle-shaped wide at the base and tapering at the end: 92 (76-107) [22] long. Sclerotized vagina, thin and long, a-shaped: 50 (41-76) [22] long.

REMARKS
The comparison of biometric and morphological parameters of the newly described species with the 51 others species known to date, and in particular with those described from *Liza* spp. shows clear differences: the male copulatory organ of *Ligophorus benhoussai* n. sp. differs from all known species of *Ligophorus* in the shape and size of its accessory

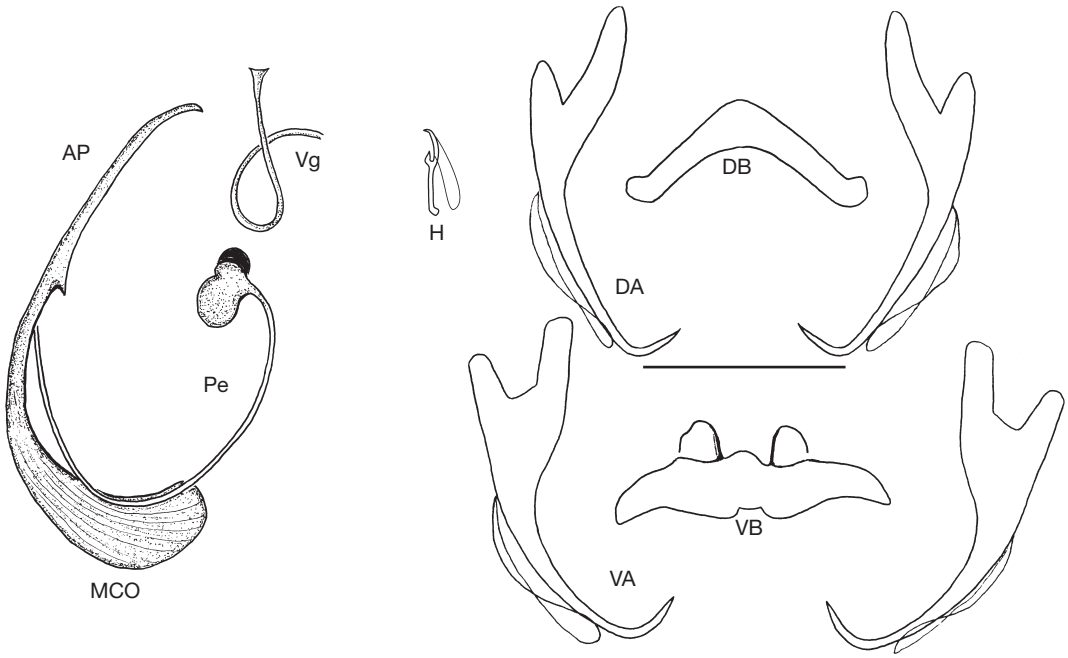

FIG. 3. – *Ligophorus benhoussai* n. sp.: morphological structures as in Fig. 1. Abbreviations: see Material & Methods. Scale bar: 30 µm.

piece (very long and sickle-shaped), as well as that of its vagina (α-shaped).

Ligophorus bazairii n. sp.
(Fig. 4)

TYPE MATERIAL. — Holotype MNHN HEL309; paratypes MNHN (1) HEL310, BMNH (2) 2012.12.17.3 (it should be noticed that on this BMNH slide there are also six specimens of *Lig. hamzati* n. sp. and two *Lig. benhoussai* n. sp. which are registered under the nos BMNH 2012.12.17.5 and BMNH 2012.12.17.6, respectively).

MATERIAL EXAMINED. — Eight specimens mounted in ammonium picrate-glycerol.

TYPE HOST. — *Liza grandisquamis* (Mugilidae).

SITE OF INFECTION. — Gills, between secondary gill lamellae.

TYPE LOCALITY. — Grand Lahou Lagoon, Ivory Coast (5°08'11"N, 5°01'33"E).

ETYMOLOGY. — The name *bazairii* is given for our colleague H. Bazairi, Associate professor at the faculty of science Mohamed V - Agdal, Rabat (Morocco) who participated to the fish collection.

DESCRIPTION

Flattened adult, 436 (365-511) [8] long, 91 (75-106) [8] wide at gonad level, pharynx 27 (21-37) [8] in diameter. Haptor well demarcated with 14 marginal hooks: 14 ± 2 (9-19) [96] long. Dorsal anchor, with guard three time longer than shaft: a = 36 (35-40) [16]; b = 28 (26-34) [16]; c = 4 (4-5) [16]; d = 12 (10-14) [16]; e = 6 (4-7) [16]. Dorsal bar V-shaped: 17 (15-20) [8] long, 3 (2-4) [8] wide and 9 (7-13) [8] high. Ventral anchor with guard two time longer than shaft and long blade: a = 40 (34-44) [16]; b = 34 (27-37) [16]; c = 6 (4-8) [14]; d = 11 (8-12) [14]; e = 7 (4-8) [14]. Ventral bar: 34 (29-37) [8] long and 8 (7-12) [8] wide, slightly straight with small antero-median protuberance and two lateral

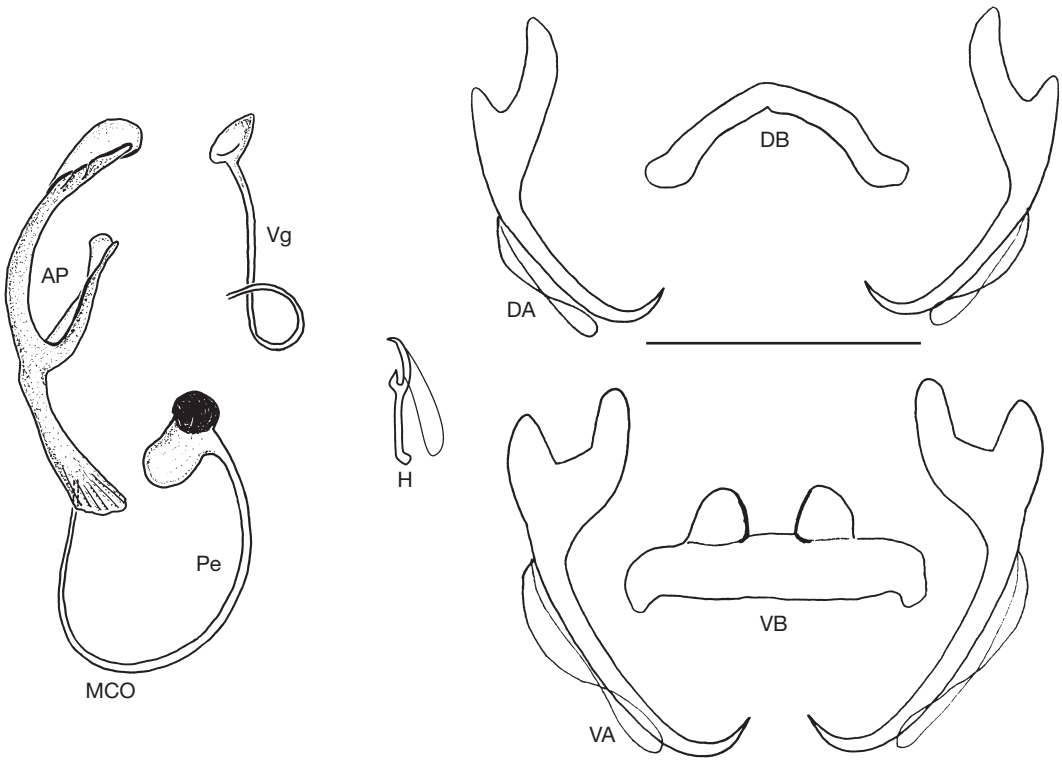

Fig. 4. – *Ligophorus bazairii* n. sp.: morphological structures as in Fig. 1. Abbreviations: see Materials & Methods. Scale bar: 30 µm.

and symmetrical expansions: 10 (6-14) [8] apart. MCO as a long and thin copulatory tube, 124 (109-137) [8] long, passing through a tubular accessory piece, 45 (37-50) [8] long, bifurcated at the distal extremity giving a bottle-opener shape to this piece. Vagina: 46 (42-53) [8] long.

Remarks

This species is distinguished from all the other members of the genus by the shape of the accessory piece (bottle-opener shaped). Only *Ligophorus szidati* Euzet et Suriano, 1977, from Liza *ramada* resembles *Ligophorus bazairii* n. sp., but these two species differ in the shape of the ventral transverse bar and of the expansions, which are adjoining in *Lig. szidati* and 10 µm apart in *Lig. bazairii* n. sp.

Ligophorus hamzati n. sp.
(Fig. 5)

Type material. — Holotype MNHN HEL315; paratypes MNHN (9) HEL316, BMNH (10) 2012.12.17.4.

Material examined. — 30 specimens mounted in ammonium picrate-glycerol.

Type host. — *Liza grandisquamis* (Mugilidae).

Site of infection. — Gills, between secondary gill lamellae.

Type locality. — Grand Lahou Lagoon, Ivory Coast (5°08'11"N, 5°01'33"E).

Etymology. — *Hamzati* is given for Hamzat, name of the son of the first author of this article.

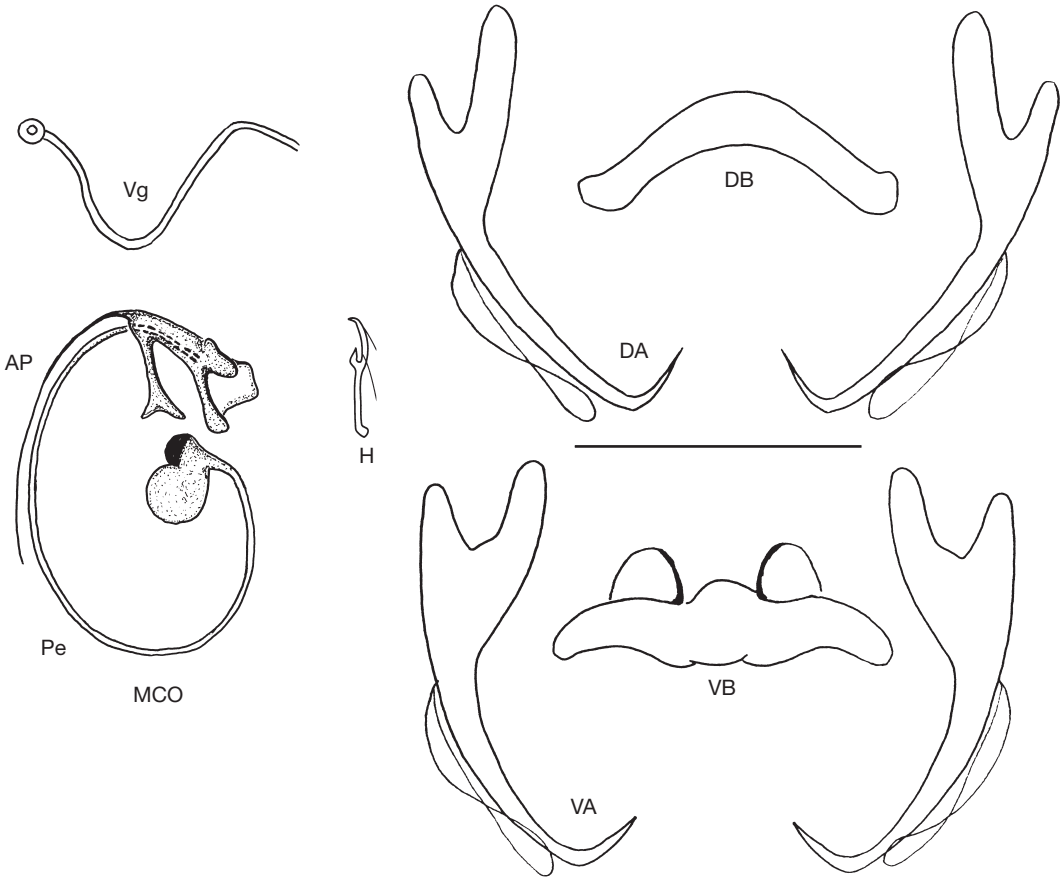

Fig. 5. — *Ligophorus hamzati* n. sp.: morphological structures as in Fig. 1. Abbreviations: see Material & Methods. Scale bar: 30 µm.

Description

Flattened adult, 580 ± 33 (410-537) [30] long and 80 ± 10 (65-116) [30] wide at gonad level, pharynx: 26 (20-33) [28] larger diameter. Haptor well demarcated with 14 marginal hooks: 13 ± 0.9 (8-17) [360] long. Dorsal anchor with guard two time longer than shaft: a = 43 ± 4 (34-50) [60]; b = 34 ± 3 (28-39) [60]; c = 6 ± 0.7 (4-7) [60]; d = 13 ± 1.5 (9-16) [60]; e = 7 ± 0.8 (6-9) [60]. Dorsal bar V-shaped: 20 ± 2 (17-24) [30] long, 4 ± 0.7 (3-6) [30] wide and 7 ± 1.1 (5-10) [30] high. Ventral anchor: a = 42 ± 2 (36-45) [60]; b = 34 ± 2 (31-37) [60]; c = 7 ± 0.8 (5-10) [60]; d = 11 ± 1.3 (8-14) [60]; e = 7 ± 0.6 (6-9) [60]. Ventral bar, 39 ± 3 (32-47) [30] long and 9 ± 2 (6-13) [30] wide, with small antero-median protuberance and two lateral and symmetrical expansions: 10 ± 3 (4-18) [30] apart. MCO as copulatory tube: 92 ± 6 (81-100) [30] long, passes through a tubular accessory piece, 48 ± 7 (38-59) [30] long, with bifurcated distal extremity, each branches bifurcated also. Vagina: 51 ± 10 (21-67) [30] long.

Remarks

This species is distinguished from all *Ligophorus* species by the shape of the accessory piece of the

copulatory organ, which is bifurcated two times at its distal extremities.

DISCUSSION

The co-existence of fish hosts with a great difference in *Ligophorus* species richness is not exceptional. Euzet & Suriano (1977) observed only one species (*Lig. angustus* Euzet & Suriano, 1977) from *Chelon labrosus* (Risso, 1827) in the Mediterranean Sea, whereas the other mullet species may be parasitized by at least two species. Six species were reported from *Liza carinata* by Dmitrieva *et al.* (2012) and from *Liza subviridis* by Soo and Lim (2012), and at least 14 species were reported from *M. cephalus* by Dmitrieva et al. (2012).

Similar differences in monogenean species richness were reported from cichlid hosts in West Africa by Pariselle *et al*. (2003). These authors drew a parallel between parasite species richness and host genetic diversity, which were both shaped by fluctuations of host populations through bottleneck or vicariant events. Therefore, in the case of *Ligophorus* from studied African mugilids, only the population of *Liza bandialensis*, which is endemic to a very limited area in Senegal, may have suffered numerous bottleneck events, leading to reductions in its size, and in turn to the loss of all its monogenean parasites. Among the three other widely distributed *Liza* species in Africa, *Liza falcipinnis,* which was infected by only one *Ligophorus* species, may have had a more stable history (and thus, a lower genetic and parasitic diversity) when compared to *Liza grandisquamis,* which was infected by three *Ligophorus* species and *Liza dumerili*, which according to Berrada Rkhami *et al*. (1993) was infected by over ten *Ligophorus* species.

Acknowledgements

The authors are grateful to the French embassy in Dakar for U3E project grants, to the Khaled Bin Sultan Living Oceans Foundation for financial support (A. Diamanka) and to Professor V. A. Connors (University of South Carolina Upstate, SC, USA) and Associate professor I. de Buron (College of Charleston, SC, USA) for their assistance in text translation. We also want to thank the two referees and the Editor for valuable comments on the manuscript, Professor Emeritus L. Euzet (University Montpellier 2, France) for insightful discussions about mugilid monogeneans and Professor C. Gabrion for the drawings.

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Submitted on 19 July 2012;
accepted on 20 March 2013;
published on 28 June 2013.