

Leptostraca (Crustacea: Phyllocarida: Nebaliidae) from French coastal waters: new records and new data on their ecology and distribution

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Abstract: The European leptostracans (Nebaliidae) have recently been subjected to a number of reviews for British and Iberian Peninsula waters. This study reassesses leptostracan species within French coastal waters in order to 1) correct potential past misidentifications and 2) to confirm the geographical distribution of species currently described on a European scale. Following the re-examination of 132 specimens initially identified as *Nebalia* sp. or *Nebalia bipes*, six species have been identified. Among them, four species (*Sarsinebalia urgorrii*, *Nebalia troncosoi*, *Nebalia reboredae* and *Nebalia kocatasi*) are newly recorded for French coasts. The distribution of *N. troncosoi*, with a previous northern limit at the Iberian Peninsula, now extends from the English Channel to the French Mediterranean Sea. Including the shallow species *Nebalia herbstii* and *Nebalia strausi*, which were already recorded in France, and the deep-water species *Nebalia abyssicola*, *Sarsinebalia typhlops* and *Sarsinebalia biscayensis*, nine species of leptostracans are now listed in the French marine fauna.

Résumé : *Leptostracés (Crustacea : Phyllocarida : Nebaliidae) des eaux côtières françaises : nouveaux signalements et nouvelles données sur leur écologie et distribution.* Les leptostracés (Nebaliidae) européens ont fait récemment l'objet de révisions pour les eaux britanniques et ibériques. Cette étude suit cette démarche pour les côtes françaises afin de lever de fortes suspicions d'erreurs d'identification et de valider la répartition géographique des espèces actuellement décrites à l'échelle européenne. Parmi les 132 individus réexaminés, initialement identifiés en tant que *Nebalia* sp. ou *Nebalia bipes*, quatre espèces (*Sarsinebalia urgorrii*, *Nebalia troncosoi*, *Nebalia reboredae* et *Nebalia kocatasi*) sont nouvellement recensées pour les côtes françaises. L'aire de répartition de *N. troncosoi*, auparavant limitée au nord de la péninsule ibérique, s'étend de la Manche à la Mer Méditerranée. En incluant les espèces de l'intertidal déjà inventoriées en France, *Nebalia herbstii* et *Nebalia strausi*, et des eaux profondes, *Nebalia abyssicola*, *Sarsinebalia typhlops* et *Sarsinebalia biscayensis*, neuf espèces de leptostracés sont maintenant répertoriées dans la faune marine française.

Keywords: Diversity • Distribution • Misidentification • Leptostraca • New records • Reassessment

Introduction

Leptostracans are marine crustaceans, generally benthic and which live on the surface of the sediment (Haney & Martin, 2004). They are characterised by a hinged rostrum and an anterior bivalved carapace, eight leaf-like pairs of thoracopods on the thorax and six pairs of pleopods on the abdomen. The order Leptostraca comprises four families, eleven genera, including one fossil genus (Song & Min, 2017), and an increasing number of species. For example, in 2004, 33 species of leptostracans were referenced around the world (Haney & Martin, 2004), whereas in 2019, 60 species had been already described (Mees & Walker-Smith, 2019).

In western Europe, twelve leptostracan species, belonging to the family Nebaliidae and the genera *Nebalia* Leach, 1814 and *Sarsinebalia* Dahl, 1985, have been reported from the British Isles (McCormack et al., 2016) to the Iberian Peninsula coasts (Moreira et al., 2009b) although their distributions have been poorly studied.

Over the past few decades, seven species of Nebaliidae have been recorded within French waters: *Nebalia bipes* Fabricius, 1780, *Nebalia herbstii* Leach, 1814, *Nebalia strausi* Risso, 1826, *Nebalia abyssicola* Ledoyer, 1997, *Nebalia biarticulata* Ledoyer, 1997, *Sarsinebalia typhlops* Sars G.O., 1870 and *Sarsinebalia biscayensis* Ledoyer, 1998 (Mauchline, 1984; Dahl, 1985; Ledoyer, 1997 & 1998; Walker-Smith & Poore, 2001; Koçak et al., 2011). Among this list the presence of *N. bipes*, known as “a purely Arctic-north boreal species” according to Dahl’s revision (1985), should be regarded as erroneous until confirmed. Despite suspicions about the presence of this species along the European coasts (Moreira et al., 2009a; McCormack et al., 2016), misidentification of this species was frequent until recently and *N. bipes* was regularly recorded on French coasts (e. g. Fournier et al., 2014; Latry & Fournier, 2014; Truhaus et al., 2016; RESOMAR – French marine stations and observatories network – database <http://resomar.cnrs.fr/bases/index.php>). In this publication, we revised the list of Nebaliidae present in the French coastal waters by examining material collected along the French coasts.

Materials and Methods

All specimens were collected along French coasts with the collaboration of six academic marine laboratories (Institut Universitaire Européen de la Mer (IUEM),

Laboratoire d’Ecogéochimie des Environnements Benthiques (LECOB), Laboratoire Littoral Environnement et Sociétés (LIENSs), Station Marine de Dinard, Station Biologique de Roscoff, Station Marine d’Arcachon) and seven consulting companies (Association du Grand Littoral Atlantique - Comité Régional des Pêches Maritimes et des Elevages Marins de Bretagne (AGLIA-CRPMEM), BIO-LITTORAL, Cellule de Suivi du Littoral Normand (CSLN), Groupe d’Etude des Milieux Estuariens et Littoraux de Normandie (GEMEL-Normandie), Laboratoire Environnement Ressources Finistère Bretagne Nord (LERBN), Station de Recherches Sous-marines et Océanographiques (STARESO), TBM Environnement). Most of the samples were collected on subtidal habitats using 0.1 m² grab samplers (Van Veen or Smith-McIntyre) or dredges. Few specimens were directly gathered from the shore at low tide. Samples were sieved aboard through a 1 mm mesh and fixed in a 4% formol-saline solution. Once sorted, organisms were stored in 70% ethanol in the laboratories. Additional samples were collected at most of the stations for sedimentary analysis (grain size and total organic matter content-TOM). Sediments were ordered following the Folk approach (Folk, 1954).

Species were identified following the keys published by Moreira et al. (2009b) and McCormack et al. (2016). Sex was determined by examining the antennae: adult males possess antennae almost as long as the body whereas female antennae are shorter than the carapace (Fig. 1A & C). For juvenile males, antennae are approximately the same length as females, but have a flagellum bearing more articles (Fig. 1B). Measurements of specimens’ total length (TL) were performed from the articulation of the rostrum to the posterior end of the caudal rami, excluding setation.

Some specimens examined as part of this study were deposited in the collection of the Muséum National d’Histoire Naturelle, Paris (MNHN).

Results

A total of 132 Nebaliidae specimens (initially identified as *Nebalia bipes* or *Nebalia* sp.) were examined. They were collected from 42 different locations along the Atlantic, English Channel and Mediterranean French coasts, between 1998 and 2017 (Table 1 & Fig. 2). In all, six species were identified (Table 1 & Fig. 2): *N. herbstii* and *N. strausi* which were already known along French coasts and *N. troncosoi*, *N. reboredae*, *N. kocatasi* and *S. urgorrii* which had never been recorded in France before.

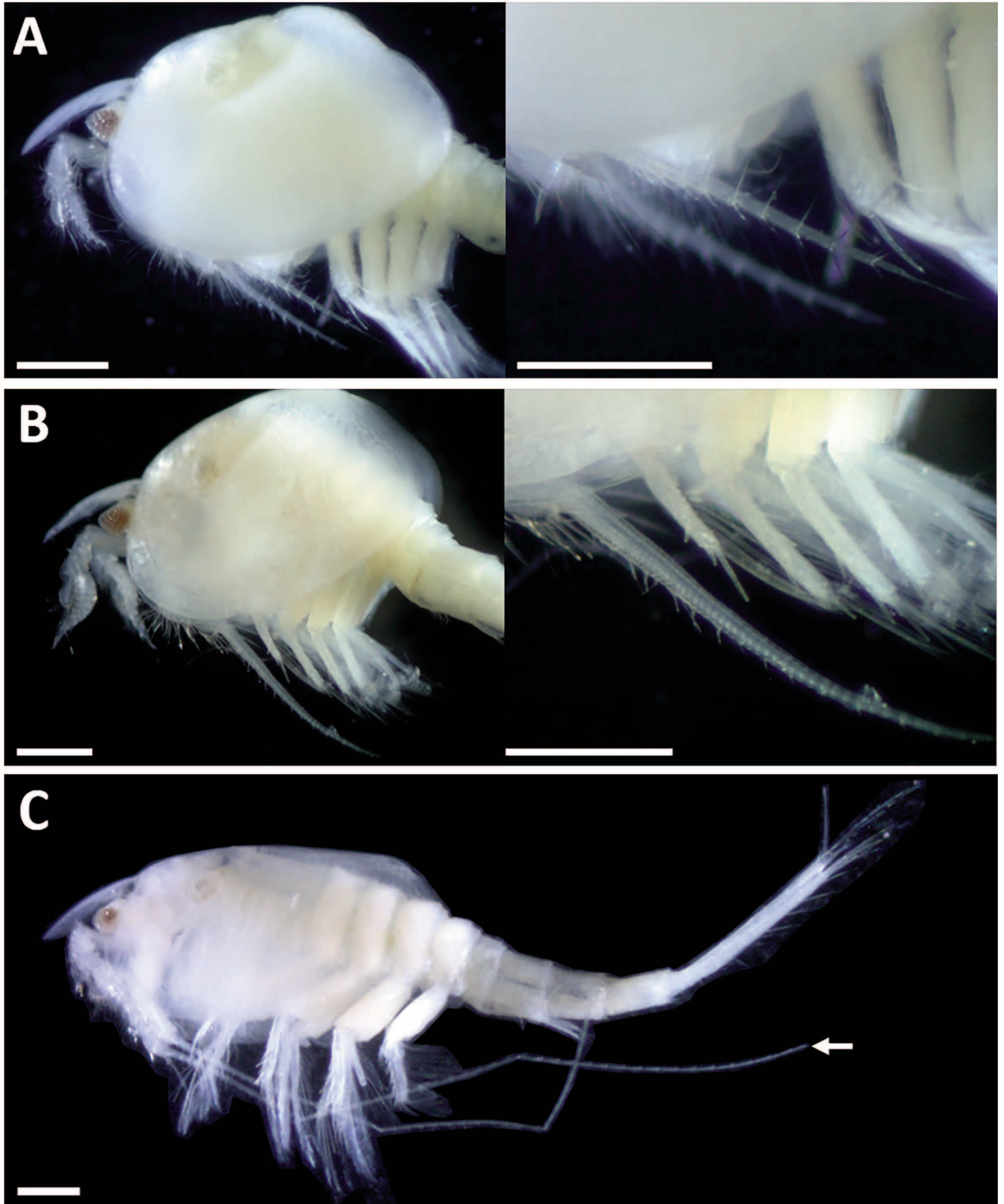


Figure 1. *Nebalia troncosoi*. Antenna. **A.** Female, Faraman, Site 41, 2012. **B.** Juvenile male, Faraman, Site 41, 2012. **C.** Adult male (the white arrow shows the distal part of the antennae), Armanville, Site 11, 2016. Scale bar: 500 μm .

Table 1. Coordinates and characteristics of the sampling sites. Species names refer to the revised *Nebalia bipes* or *Nebalia* sp. specimens.

Site	Location	Species	Latitude-Longitude	Depth (m)	% Gravel	% Sand	% Mud	Sedimentary type	% TOM
1	Heuqueville	<i>N. troncosoi</i>	49°37'00"N-0°07'02"E	19	20.8	61.0	18.2	muddy sandy gravel to gravelly muddy sand	1.6
2	Bay of Seine	<i>N. reboredae</i>	49°18'26"N-0°12'26"W	24	19.5	75.9	0.4	gravelly sand	-
3	Bay of Seine	<i>N. strausi</i>	49°18'53"N-0°11'26"W	24	44.1	54.2	1.1	gravelly sand	-
4	Saint Marcouf	<i>N. troncosoi</i>	49°29'36"N-1°12'11"W	15	1.0	98.5	0.5	slightly gravelly sand	1.3
5	Cap Lévy	<i>N. troncosoi</i>	49°40'44"N-1°30'18"W	18	0.4	90	9.6	very fine sand	2.2
6	Cherbourg	<i>N. troncosoi</i>	49°40'12"N-1°36'33"W	9	0	72.1	27.8	very fine muddy sand	3.4
7	Pirou	<i>N. reboredae</i>	49°09'52"N-1°39'01"W	11	1.2	98.8	0.1	medium sand	0.8
8	Chausey archipelago	<i>N. reboredae</i>	48°55'33"N-1°48'14"W	15	51.4	45.4	3.3	maërl	2.1
9	Chausey archipelago	<i>N. reboredae</i> , <i>N. troncosoi</i> , <i>S. urgortii</i>	48°54'26"N-1°46'48"W	10	4.9	94.6	0.5	fine sand	1.3
10	Chausey archipelago	<i>N. kocatasi</i>	48°52'40"N-1°46'13"W	-	-	-	-	-	-
11	Armanville	<i>N. reboredae</i> , <i>N. troncosoi</i> , <i>S. urgortii</i>	48°52'31"N-1°36'38"W	10	1.3	98.3	0.4	medium sand	2.7
12	Ilot Saint-Michel	<i>N. reboredae</i> , <i>N. troncosoi</i> , <i>S. urgortii</i>	48°40'10"N-2°26'27"W	15	25.1	73.9	1.0	sandy fine gravel	2.2
13	Ilot Saint-Michel	<i>S. urgortii</i>	48°40'12"N-2°25'44"W	16.5	10.3	89	0.7	very fine gravelly medium sand	1.6
14	Ilot Saint-Michel	<i>S. urgortii</i>	48°40'10"N-2°26'27"W	15.5	30.1	69.2	0.7	sandy very fine gravel	1.7
15	La Horaine	<i>N. reboredae</i>	48°47'21"N-2°48'20"W	41	55.5	44	0.5	sandy very fine gravel	1.6
16	Lannion	<i>N. kocatasi</i>	48°45'44"N-3°41'49"W	38	0.2	95.1	4.7	muddy sand	-
17	Pierre Noire	<i>N. troncosoi</i>	48°42'30"N-3°51'58"W	18	1	91.3	7.7	very fine to fine sand	1.8
18	East Duons	<i>N. reboredae</i>	48°43'1"N-3°52'52"W	25	0.8	95.8	3.4	very fine to fine sand	1.4
19	East Duons	<i>S. urgortii</i>	48°43'26"N-3°53'34"W	20	2.6	94.7	2.7	medium to fine sand	-
20	Perharidy	<i>N. herbstii</i>	48°43'38"N-4°0'22"W	fore-shore	-	-	-	under rock with decaying algae	-
21	Aber Wrac'h	<i>N. kocatasi</i>	48°36'23"N-4°34'39"W	10	-	-	-	mixed muddy sand	-
22	Aber Wrac'h	<i>N. reboredae</i>	48°36'53"N-4°35'35"W	15	-	-	-	mixed sand	~1.5
23	Lilia-Plouguerneau	<i>N. troncosoi</i>	48°36'28"N-4°35'42"W	fore-shore	0.1	98.5	1.5	sand	1.3
24	Molène	<i>N. troncosoi</i>	48°23'50"N-4°56'53"W	fore-shore	0.7	97.6	1.4	sand with <i>Zostera</i>	1.0
25	Molène	<i>N. kocatasi</i>	48°23'14"N-4°51'15"W	5	49.6	49.2	1.2	maërl	3.5
26	Grand Dellec	<i>N. herbstii</i>	48°21'1"N- 4°34'15"W	fore-shore	-	-	-	under algae on rocky shore	-
27	Bay of Brest	<i>N. troncosoi</i>	48°19'18"N-4°24'11"W	10	57.3	42.7	-	maërl	6.2
28	Bay of Brest	<i>N. kocatasi</i>	48°19'10"N-4°23'06"W	10	43.1	56.9	-	maërl	3.8
29	Bay of Brest	<i>N. kocatasi</i>	48°18'39"N-4°21'22"W	10	22.2	77.8	-	maërl	4.2
30	Glénans	<i>S. urgortii</i>	47°43'45"N-4°0'42"W	12	-	-	-	maërl	-

Site	Location	Species	Latitude-Longitude	Depth (m)	% Gravel	% Sand	% Mud	Sedimentary type	% TOM
31	Pointe des Corbeaux	<i>N. troncosoi</i>	46°41'00"N-2°13'12"W	24	0	97	3	fine sand	1.4
32	Bretignolles	<i>N. troncosoi</i>	46°36'09"N-1°57'23"W	21	0	79.5	20.5	fine muddy sand to fine sand	2.3
33	Fiers d'Ars	<i>N. kocatasi</i>	46°13'29"N-1°29'10"W	1	0.48	44.7	54.8	sandy mud	2-4
34	Off Gironde estuary	<i>N. troncosoi</i>	45°45'42"N-1°26'36"W	28	1.5	97.1	1.4	fine sand	-
35	Off Gironde estuary	<i>N. troncosoi</i>	45°28'58"N-1°17'58"W	29	0.3	64.4	35.3	muddy sand	-
36	Off Gironde estuary	<i>N. troncosoi</i>	45°27'17"N-1°25'44"W	38	0.6	52.9	46.5	muddy sand	-
37	Lake Hossegor	<i>N. strausi</i>	43°40'46"N -1°25'45"W	2.6	1.8	58.5	39.8	fine gravelly fine sand	7.6
38	Canet-en-Rousillon	<i>N. troncosoi</i>	42°43'57"N-3°04'56"E	30	0	64	36	muddy sand	2
39	Palavas	<i>N. troncosoi</i>	43°28'00"N-3°59'00"E	20	-	-	-	-	-
40	Espiguette	<i>N. troncosoi</i>	43°26'07"N-4°12'21"E	19	0	97.9	2.1	fine sand	1.5
41	Faraman	<i>N. troncosoi</i>	43°20'00"N-4°43'13"E	12	0	95.5	4.5	fine sand	1.3
42	Porquerolles	<i>S. urgorii</i>	43°01'08"N-6°16'28"E	48	16.0	83.7	0.3	close to maërl	2.2

The highest diversity is observed along the coasts of North Brittany where *N. troncosoi*, *N. reboredae*, *N. kocatasi*, *N. herbstii* and *S. urgorii* were collected. *N. troncosoi* is widely distributed along the French coastal zone, from the Bay of Seine (English Channel) to the Gulf of Lion (Mediterranean Sea) (Fig. 2, Site 1 to Site 41). *Sarsinebalia urgorii* was found around the Brittany (English Channel and Bay of Biscay) and along the Mediterranean coast (Fig. 2). The four other species, *N. reboredae*, *N. kocatasi*, *N. herbstii* and *N. strausi* were not found within the Mediterranean Sea (Fig. 2). *N. reboredae* and *N. herbstii* were only collected within the English Channel and the Mer d'Iroise (Fig. 2).

Systematic

Order LEPTOSTRACA Claus, 1880
Family NEBALIIDAE Samouelle, 1819
Genus *Nebalia* Leach, 1814

Nebalia troncosoi Moreira, Cacabelos & Domínguez, 2003
(Figs 1 & 3)

Material examined

Haute Normandie: 2 females, Site 1, 30 May 2012. Female, Site 1, April 2015. **Cotentin peninsula:** MNHN-IU-2019-2298, Adult male, Site 11, 10 May 2016. MNHN-IU-2019-2297, Female, Site 5, 14 June

2017. Female, Site 9, 11 May 2016. Subadult male, Site 5, 9 May 2016. Subadult male, Site 4, 12 May 2016. Female, Site 5, 14 June 2017. Female, Site 6, 24 April 2007. 3 females, Site 5, 24 April 2007. 5 specimens (4 females, subadult male), Site 5, 21 May 2008. 5 spec. (3 females, 2 subadult males), Site 5, 14 May 2009. Female, Site 6, 20 April 2010. 5 females, Site 5, 20 April 2010. Female, Site 11, 12 May 2010. 2 females, Site 6, 12 April 2011. 12 spec. (11 females, subadult male), Site 5, 12 April 2011. Subadult male, Site 6, 29 May 2012. 3 subadult males, Site 5, 29 May 2012. 2 females (ovigerous female, previgerous female), Site 6, 13 May 2013. 2 females, Site 5, 13 May 2013. 2 females, Site 5, 16 April 2015. **Brittany:** Ovigerous female, Site 17, 24 Sept 2014. Female, Site 23, April 2016. Female, Site 24, March 2011. Female, Site 27, January 2016. Adult male, Site 12, 7 September 2017. **Bay of Biscay:** Female, Site 35, 4 March 2011. Female, Site 36, 3 March 2011. Adult male, Site 34, 3 March 2011. Subadult male, Site 31, 24 April 2016. Subadult male, Site 32, 24 April 2016. Subadult male, Site 32, 24 April 2015. **Mediterranean Sea:** Ovigerous female, Site 39, October 1998. Subadult male, Site 38, August 2010. Female, Site 40, 2012. 4 spec. (3 females, subadult male), Site 41, 2012.

Diagnosis

As described by Moreira et al. (2003a), *N. troncosoi* is mainly characterized by a short antennular flagellum composed of seven articles (Fig. 3A) and acute

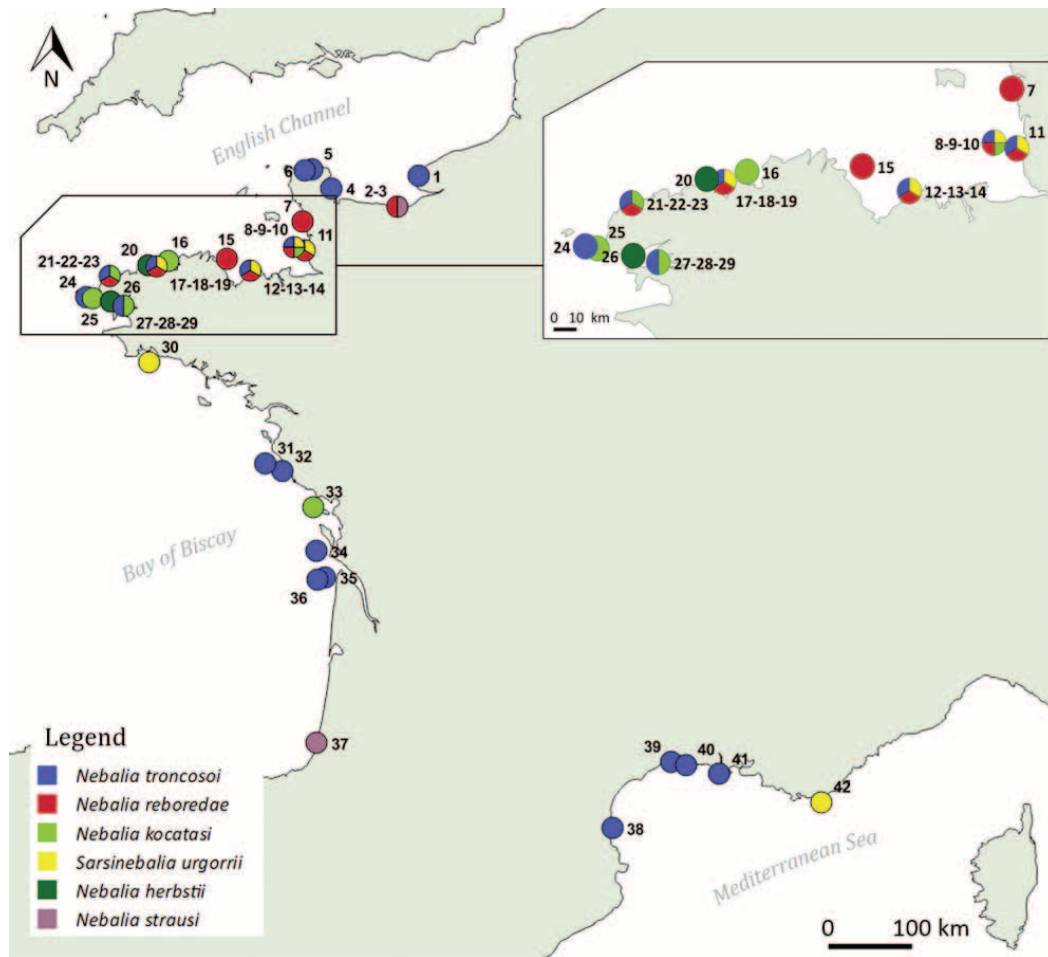


Figure 2. Distribution of newly recorded species of Nebaliidae along French coasts. Numbers refer to the “Site” column in the Table 1.

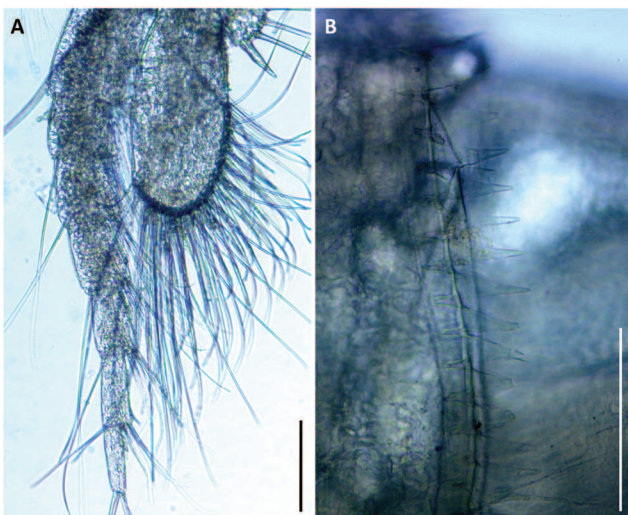


Figure 3. *Nebalia troncosoi*. **A.** Antennular flagellum and scale, Cap Lévy, Site 5, April 2015. **B.** Pleonite 6 distal border, Armanville, Site 11, May 2016. Scale bars: 100 μ m.

denticles along the postero-dorsal border of pleonites 6-7 (Fig. 3B).

Taxonomic remarks

In comparison to the original description of *N. troncosoi* (Moreira et al., 2003a), some morphological variations were noticed in material examined. Small lobes at the distal border of the eyes were not discernable on the examined specimens. The antennular flagellum of females has five to eight articles depending on specimen's size, which refines the original *N. troncosoi* description where seven articles are stated (Moreira et al., 2003a). Similarly, for both females and males, the fifth and sixth pleopods bore three to five stout spines, depending on the specimen's size, along disto-lateral and terminal border vs four stout spines in the original description (Moreira et al., 2003a). One mature female sampled off the Gironde estuary in 2011 and confirmed as *N.*

truncosoi by J. Moreira showed both the antennular flagellum with eight articles and the fifth pleopod with five stout spines (Fig. 2, Site 31).

Adult males were much larger than adult females (Fig. 1A & C) (e.g. TL of the three adult males collected = 6,0 mm; 5,4 mm; 6,3 mm vs TL of three adult females = 3,7 mm (ovigerous); 4,2 mm; 4,3 mm). Immature males showed some morphological differences compared to the adult males. The antennular flagellum of juveniles was strongly fusiform (Fig. 1B) in comparison to adult males. Some juvenile specimens exhibited antennular flagellae with more than the nine articles as described by Moreira et al. (2003a) (one immature male with 11 articles found in the Cherbourg Harbour). Mature males had pleopods 1-4 with numerous dense long plumose setae. The peduncle of their first pleopod had the terminal dorsal spine reaching one quarter of the length of the spine row of the exopod (the centre for juveniles).

Distribution in French waters

Seine-Maritime coast, Cotentin peninsula coasts, Chausey archipelago, North and Western Brittany coasts (English Channel, France), Ile d'Yeu, Vendée coast, off Gironde estuary (Bay of Biscay), Gulf of Lion (Western Mediterranean Sea) (Fig. 2).

Distribution in western European waters

Galician coast (North-West Spain) (Moreira et al., 2003a; Moreira & Troncoso, 2007; Lourido et al., 2008), Guipúzcoa (North Spain) (Martínez et al., 2007), Figueira da Foz (Portugal) (Sampaio et al., 2016).

Ecology

Present study: very fine muddy sand, fine sand, medium sand, gravelly sand, maërl bed, sand with *Zostera marina*. From mediolittoral to 38 m in depth. Galician coast: muddy sand, at depths of 7 m (Moreira et al., 2003a). Portuguese coasts: fine sand to medium sand, at depths of between 41 and 65 m (Sampaio et al., 2016). Guipúzcoa coast: mud to coarse sand, at depths of between 3 and 23 m (Martínez et al., 2007).

Nebalia reboredae Moreira & Urgorri, 2009
(Fig. 4)

Material examined

Haute Normandie: Female, Site 2, 10 April 2015.
Cotentin peninsula: MNHN-IU-2019-2295, Female, Site 8, 7 May 2013. MNHN-IU-2019-2294, Adult male,

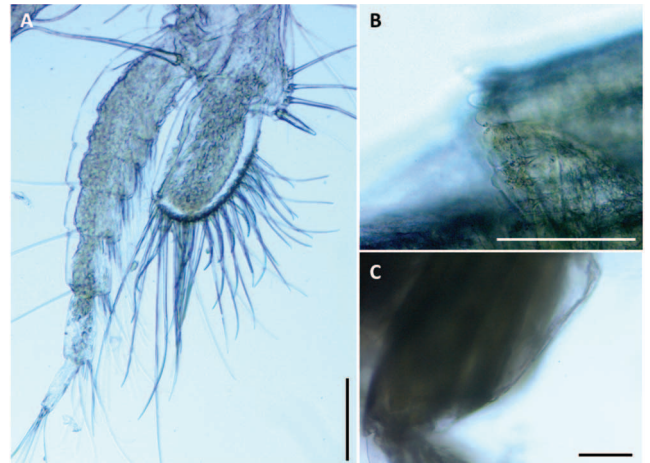


Figure 4. *Nebalia reboredae*. **A.** Antennule. **B.** Pleonite 6 dorso-distal border. **C.** Pleopod 4 protopod. Pirou, Site 7, April 2014 and May 2015. Scale bars: 100 μ m.

Site 7, 30 April 2014. Female, Site 7, 10 May 2015. Female, Site 7, 12 May 2015. Juvenile, Site 9, 12 May 2015. 3 spec. (adult male, 2 juveniles), Site 11, 10 May 2016. **Brittany:** Female, Site 18, 3 October 2015. Ovigerous female, Site 22, June 2009. Female, Site 15, 6 April 2017. Female, Site 12, 7 April 2017.

Diagnosis

The specimens examined were consistent with the description in Moreira et al. (2009b). Adult males were much bigger than adult females (e.g. TL of the two adult males collected = 5,6 mm; 6,3 mm vs TL of three adult females = 3,7 mm; 3,2 mm; 4,2 mm).

Nebalia reboredae differs from the other *Nebalia* species as the fourth article of the antennule has one short thick distal spine and the antennular flagellum comprises 7-8 articles (Fig. 4A), the posterior dorsal borders of pleonites 6-7 possess distally rounded to truncated denticles (Fig. 4B) and the pleopod 4 protopod does not present serrations (Fig. 4C) (Moreira et al., 2009b).

Distribution in French waters

Baie de Seine, Chausey archipelago, Cotentin peninsula coasts, North Brittany coasts (English Channel, France) (Fig. 2).

Distribution in western European waters

Galician coast (North-West Spain) (Moreira et al., 2009b), North Sea, Scotland, England, Ireland and Wales waters (McCormack et al., 2016).

Ecology

Present study: fine sand, medium sand, gravelly sand, heterogeneous clean sand and maërl bed, at depths of between 7 and 25 m. Galician coast: medium sand, at depth of 6.4 m (Moreira et al., 2009b). British Isles: gravelly sand, at depths of between 5.5 and 40 m (McCormack et al., 2016).

Nebalia kocatasi Moreira, Koçak & Katagan, 2007 (Fig. 5)

Material examined

Cotentin peninsula: Female, Site 10, 7 July 2015. **Brittany:** Ovigerous female, Site 21, June 2009. 8 specimens (4 females, 4 juveniles), Site 33, November 2004. Female, Site 28, January 2016. Female, Site 29, January 2016. MNHN-IU-2019-2293, MNHN-IU-2019-2292, 2 females, Site 25, February 2016. Female, Site 16, April 2016.

Diagnosis

As described by Moreira et al. (2007), *Nebalia kocatasi* is mainly characterized by the third article of the antenna, presenting three robust spines on the external lateral face, the length of the proximal one being around half as long as the two others (Fig. 5A). The endopod of the second maxilla is composed of two sub-equal articles (Fig. 5B).

Taxonomic remarks

The specimens examined here are consistent with the

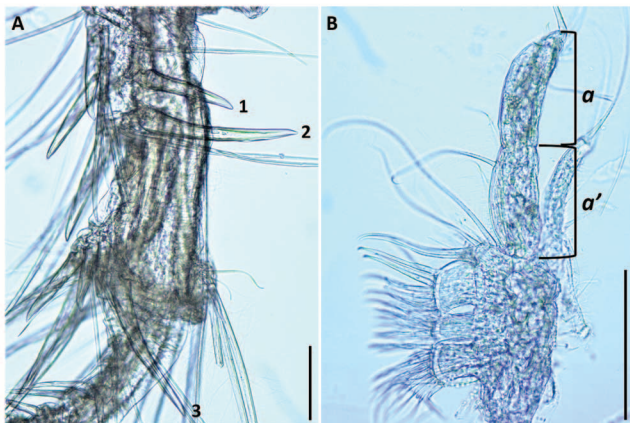


Figure 5. *Nebalia kocatasi*. **A.** Antenna third article, with lateral spine like setae (numbered), 1 being the proximal one, shorter than setae 2 and 3. **B.** Maxilla 2, a and a' respectively represent the distal and proximal articles of the endopod. Chausey archipelago, Site 10, July 2012. Scale bars: 100 µm.

description of Moreira et al. (2007), except for one mature female which showed an antennular flagellum with 13 articles whereas the original description described only 11 articles (Moreira et al., 2007).

Distribution in French waters

Cotentin peninsula coasts, North and West Brittany coasts (English Channel, France), Ile de Ré (Bay of Biscay) (Fig. 2).

Distribution in western European waters

Izmir Bay, Turkey, Cyprus, Aegean Sea to the western Iberian Peninsula and the Canary Islands (Moreira et al., 2007; Koçak et al., 2011), Irish coasts, Scottish coasts, Shetland (McCormack et al., 2016).

Ecology

Present study: sandy mud, muddy sand, heterogeneous sand and maërl bed, at depths of between 1 to 38 m. Galician coast: muddy to sandy sediments, at depths of between 8 and 23 m (Moreira et al., 2007). British Isles: mud to cobbles and gravel sediment, maërl bed, at depths of between 4 and 23.2 m (McCormack et al., 2016).

Nebalia herbstii Leach, 1814

Material examined

Brittany: MNHN-IU-2019-2291, 1 female, Site 26, 28 February 2017. 5 females, Site 20, 19 September 2017.

Diagnosis

Nebalia herbstii is characterized by the combination of following criteria: rounded denticles along the postero-dorsal border of pleonites 6-7; fourth article of the antennule peduncle with three or more distal thick spines; antennular flagellum with more than 10 articles; exopod of second maxilla extends past the proximal article of the endopod; anal scale with the point lying over mid-line of the scale; distal article of the mandible palp with parallel margins (Dahl, 1985).

Distribution in French waters

Present study: Bay of Brest (Mer d'Iroise), North Brittany coast (English Channel). Previous to this study: From Roscoff to Saint-Jean-de-Luz (Dahl, 1985, Houbin, pers. obs.), Bassin d'Arcachon (Auby, 1993) (English Channel to Bay of Biscay), Western France (Walker-Smith & Poore, 2001).

Distribution in western European waters

Shetland, western British Isles (Dahl, 1985). Scotland and England (McCormack et al., 2016). Spanish coasts (Walker-Smith & Poore, 2001). Northern coast of the Iberian Peninsula (Martínez et al., 2007).

Ecology

Present study: under stones and algae on rocky shore. British Isles: Shallow (6.1-15.9 m), near-shore waters over sands, muds, gravels and maërl (McCormack et al., 2016). Under stones that lay on mud amongst hollows of rocks (Leach, 1814).

Nebalia strausi* Risso, 1826Material examined*

Haute Normandie: Adult male, Site 3, 13 April 2015. **Bay of Biscay:** 3 females, 2 subadult males, 4 juveniles (1 female, 1 male and 1 juvenile deposited under the code: MNHN-IU-2019-2296), Site 37, 7 March 2017.

Diagnosis

Nebalia strausi is characterized by the combination of acute denticles along the postero-dorsal border of pleonites 6-7, the antennular flagellum with more than 10 articles, the terminal dorsal spine of the peduncle of the first pleopod reaching at most to centre of the spine row on the exopod and the exopod of second maxilla extends past the proximal article of the endopod (Dahl, 1985).

Distribution in French waters

Present study: Bay of Seine (English Channel, France), Lake Hossegor (Bay of Biscay, France). Previous to this study: Banc d'Arguin (Tu Do et al., 2011), English Channel (Guyonnet & Droual, 2017, pers. obs.), French Mediterranean coasts (Ledoyer, 1997).

Distribution in western European waters

Guernsey (Dahl, 1985), Ireland (McCormack et al., 2016). Gulf of Naples, Italy (type locality), Eastern Atlantic, from the North-West coast of France to St Helena (Dahl, 1985). Western Mediterranean (Dahl, 1985). Eastern Mediterranean (Koçak & Katagan, 2006; Koçak et al., 2007).

Ecology

Present study: gravelly sand, at depths of 2.6 and 24 m. Coarse sediments, from gravel to coarse sand

at depths of between 12.7 to 15.2 m (Moreira et al., 2009b). Maërl, medium sand to mud at depths of between 4 to 23.4 m (McCormack et al., 2016).

Genus *Sarsinebalia* Dahl, 1985

Sarsinebalia urgorrii Moreira, Gestoso & Troncoso, 2003 (Fig. 6)

Material examined

Cotentin peninsula: MNHN-IU-2019-2299, female, Site 11, 12 May 2010. MNHN-IU-2019-2300, subadult male, Site 9, 12 May 2015. Female, Site 9, 12 May 2015. **Brittany:** 3 females, Site 26, 23 September 2016. 5 females (ovigerous female, 4 preovigerous females), Site 19, 11 June 2017. **Bay of Biscay:** Juvenile, Site 12, 3 September 2017. Female, Site 13, 3 September 2017. Subadult male, Site 14, 3 September 2017. **Mediterranean Sea:** Subadult male, Site 42, 2015.

Diagnosis

Sarsinebalia urgorrii can be distinguished from other species of *Sarsinebalia* by the combination of pigmented eyes with ommatidia (Fig. 6C) and a supraorbital scale not surpassing the distal end of the eye (Moreira et al., 2003b; McCormack et al., 2016). The exopod of the second maxilla is longer than the first article of the endopod. The antennal flagellum

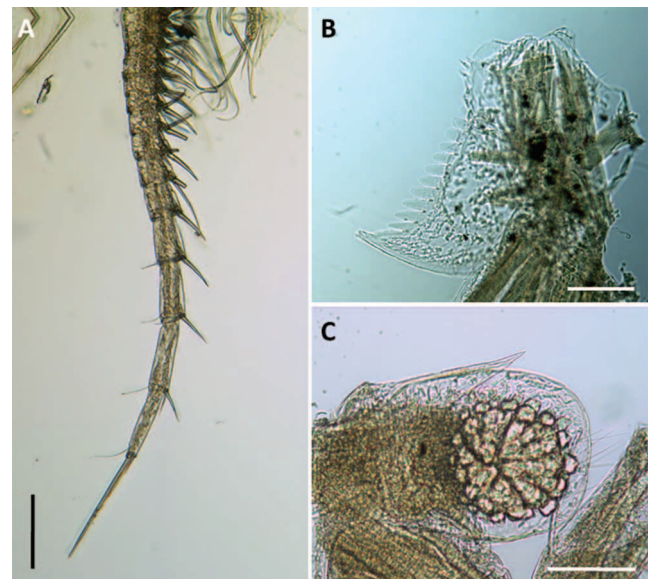


Figure 6. *Sarsinebalia urgorrii*. **A.** Antenna. **B.** Fourth pleopod. **C.** Eye. Glénans archipelago, Site 30, September 2009. Scale bars: 100 μ m.

possesses short spine-like setae (Fig. 6A). Posterolateral border of the fourth pleonite bears rounded teeth ending in a larger tooth (Fig. 6B). The sixth pleopod has four large spines on its distolateral border.

Taxonomic remarks

All specimens concurred with the original description of Moreira et al. (2003b), except that their eyes did not show a red pigmentation even if ommatidia are clearly visible. This has also been observed on several specimens from the British Isles (McCormack et al., 2016) due to the alcohol conservation.

Ecology

Present study: fine sand, medium sand to fine gravel, maërl bed, at depths of between 10 and 48 m. Galician coast: muddy, sandy and medium sand, at depths of between 7 and 10 m (Moreira et al., 2003b). Medium sand to very coarse sand, at depths of between 12.7 and 20 m (Moreira et al., 2009b). Mud to coarse shelly gravel, at depths of between 9.3 and 435 m (McCormack et al., 2016).

Distribution in French waters

Chausey archipelago, Cotentin Peninsula, North Brittany coasts (English Channel), Glénan archipelago (Bay of Biscay), Islands of Porquerolles (Mediterranean Sea) (Fig. 2).

Distribution in western European waters

Galicia (North-West Spain) (Moreira et al., 2003b & 2009b), all around British Isles (McCormack et al., 2016).

In accordance with McCormack et al. (2016), we suggest that all records of *S. typhlops* from shallow waters need reconsideration (e.g. Ledoyer, 1997). *S. typhlops* is a deeper species, which occurs between 210-2900 m (Sars, 1896; Lo Bianco, 1903; Tattersall, 1905; Hessler & Sanders, 1965; Mauchline & Gage, 1983).

Discussion

Our study reveals a total of six species (Table 1) of Nebaliidae mainly misidentified as *N. bipes* and thus confirming the absence of *N. bipes* in the European temperate waters (Dahl, 1985). Among these six species, four had never been recorded in France before: *Sarsinebalia urgorrhii*, *Nebalia troncosoi*, *Nebalia reboredae* and *Nebalia kocatasi*. Along with

the three deep-sea species known in French waters (*Nebalia abyssicola*, *Sarsinebalia typhlops* and *Sarsinebalia biscayensis*) (Dahl, 1985; Ledoyer, 1998; Moreira et al., 2012), the inventory of French leptostracans species now reaches nine species. We follow the assumption of McCormack et al. (2016) about *Nebalia biarticulata* that this species might refer to the male of another species.

Nebalia troncosoi was described in Galicia, North-West Spain (Moreira et al., 2003a) and was reported from Guipúzcoa, North Spain (Martínez et al., 2007) to Figueira da Foz, Portugal (Sampaio et al., 2016). The occurrence of *N. troncosoi* in the French coastal waters extends its geographical range up to the English Channel as well as the French Mediterranean Sea. In 2006, two specimens were identified as *N. troncosoi* in Lough Foyle, northern Ireland (Sampaio et al., 2016; C. Ashelby, pers. comm.). Those specimens were provisionally confirmed as most likely belonging to *N. troncosoi* by J. Moreira, but considering that additional specimens including both sexes would be desirable to confirm the identification (C. Ashelby, pers. comm.). However, McCormack et al. (2016) did not record any additional specimens along British coasts and thus they did not include *N. troncosoi* from their report of British leptostracans (C. Ashelby, pers. comm.). Therefore, the English Channel appears to be the current northern limit of its range and the presence of *N. troncosoi* in the British Isles remains to be confirmed.

Sarsinebalia urgorrhii, *N. reboredae* and *N. kocatasi*, recorded around Iberian Peninsula (Moreira et al., 2009b) and the British Isles (McCormack et al., 2016), were expected to occur along French coasts (McCormack et al., 2016). Our study confirms these statements and fills the distributional range gap for these three species.

Nebalia reboredae has been recorded as the most common leptostracan species in the North Sea and around the British Isles (McCormack et al., 2016). In comparison, *N. troncosoi* was, in this study, the most abundant species in French coastal waters (accounting for more than 65% of specimens). Nevertheless, due to the diversity and the variability of habitats sampled in our study, alongside with the varying sampling effort, the sampling methods (e.g. grabs, as most specimens were sampled during studies focusing on the whole benthos), and the lack of data from intertidal areas, it is difficult to assume with precision which species is the most common along French coasts. The use of other sampling methods such as light-traps, specific for sampling crustaceans able to move in the water column, would

permit a better characterization of the leptostracan diversity, their distributional ranges, and their ecology (Haney & Martin, 2016; McCormack et al., 2016; McLeod & Costello, 2017).

Our results also provide new information about the ecology on some species by confirming, for the first time, the presence of *S. urgorrii*, *N. troncosoi* and *N. reboredae* in maërl bed habitats.

Finally, our study also highlights the importance, when in doubt, to contact taxonomists to identify species and to leave identifications at a higher taxonomical level to avoid misidentifications. For instance, erroneous identification can lead to underestimate biological indices (Haase et al., 2010) and even inappropriate management measures (Casciotta et al., 2012). For example, the substitution of the sensitive species *S. urgorrii* (Biotic index = 0 (Borja, 2017); group I of the AZTI Marine Biotic Index (AMBI) (Borja et al., 2000)) with the opportunistic species *N. bipes* (group V) is responsible for calculation errors in the AMBI value. By cascade effects, the ecological status might be wrong and the associated management decisions inappropriate (Haase et al., 2010).

Conclusion

Our study reports the presence of four leptostracan species that had never been recorded in France before. Three of them (*Sarsinebalia urgorrii*, *Nebalia reboredae* and *Nebalia kocatasi*) had already been identified within the waters of Spain and British Isles, and a fourth, *Nebalia troncosoi*, which had never been recorded north of the Iberian Peninsula. Regarding the reevaluation of 132 specimens, the leptostracan diversity in French waters now includes nine species, with *Nebalia herbstii* and *Nebalia strausi*, also recorded in this study, and *Nebalia abyssicola*, *Sarsinebalia typhlops* and *Sarsinebalia biscayensis*, identified previously in deep-sea samples (Dahl, 1985; Ledoyer, 1998; Moreira et al., 2012). Finally, we expect that the use of specific sampling methods could provide new informations about the ecology and distribution of leptostracans along French waters, and eventually further expand their inventory.

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