Scientia Marina 83(1)
March 2019, 79-80, Barcelona (Spain)
ISSN-L: 0214-8358

Erratum: A new *Felimare* (Mollusca: Heterobranchia: Nudibranchia) of the Atlantic blue chromodorid chromatic group from Cape Verde

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Citation/Como citar este artículo: Ortigosa D., Pola M., Cervera J.L. 2019. Erratum: A new *Felimare* (Mollusca: Heterobranchia: Nudibranchia) of the Atlantic blue chromodorid chromatic group from Cape Verde. Sci. Mar. 83(1): 79-80.

Ortigosa et al. (2017) described a new species of dorid nudibranch, *Felimare aurantiomaculata*, from Cape Verde archipelago. In the mentioned contribution, Table 2 refers to the specimens used for molecular analyses, sample codes, vouchers, collection sites, GenBank accession numbers and references. However, the published version of this table included the accession numbers of the sequences retrieved only from GenBank, not those of the sequences obtained by the authors. The present erratum includes a complete version of Table 2 with all the accession numbers from Genbank of the sequences used in Ortigosa et al. (2017).

REFERENCES

Ortigosa D., Pola M., Cervera J.L. 2017. A new *Felimare* (Mollusca: Heterobranchia: Nudibranchia) of the Atlantic blue chromodorid chromatic group from Cape Verde. Sci. Mar. 81(3): 387-394. doi: https://doi.org/10.3989/scimar.04594.16A

Table 2. – Specimens used for molecular analyses, sample codes, vouchers, collection sites, GenBank accession numbers and references.

Species	Voucher	Locality	16s	COI	H3	References
Chromodoris magnifica	MNCN 15.05/76513	Pandaican, Philippines	MK468874	MK474131	MK474157	This study
Felimare bilineata	MNCN 15.05/76507	Taghazut, Morocco	MK468892	MK474129	MK474148	This study
Felimare bilineata	MNCN 15.05/76508	Congreso Island, Chafarinas, Spain	MK468891	MK474128	MK491631	This study
Felimare bilineata	MNCN 15.05/76517	La Caleta, Cadiz, Spain	MK468893	MK474130	MK474150	This study
Felimare bilineata	CASIZ 179406	Pedra da Gale, Principe Island	MK468890	MK474126	MK474151	This study
Felimare bilineata	CASIZ 179408	Pedra da Gale, Principe Island	MK468889	MK474127	MK474152	This study
Felimare francoisae	MNCN 15.05/76511	Ponta de Nho Jom, São Vicente, Cape Verde	MK468875	-	MK474135	This study
Felimare francoisae	MNCN 15.05/76512	The Anchor, Boavista, Cape Verde	MK468876	-	MK474136	This study
Felimare aurantimaculata n. sp.	MB28-004391	Tarrafal, Cape Verde	MK468888	-	MK474149	This study
Felimare aurantimaculata n. sp.	MB28-004390	Tarrafal, Cape Verde	MK468887	MK474125	MK474147	This study
Felimare picta	MNCN 15.05/76510	Del Rey Island, Chafarinas, Spain	MK468884	MK474119	MK474140	This study
Felimare picta	MNCN 15.05/76514	Pico Island, Azores, Portugal	MK468883	MK474120	MK474141	This study
Felimare picta	MNCN 15.05/76567	Naples, Italy	MK468885	MK474121	MK474142	This study
Felimare pinna	MNCN 15.05/76509	Calhau, Saragasa, Cape Verde	MK468879	MK474117	MK474146	This study
Felimare porterae	CPIC 1326	San Pedro, California, United States	MK468877	MK474115	MK474138	This study
Felimare porterae	CPIC 1612	California, United States	MK468878	MK474116	MK474139	This study
Felimare tema	BMNH 20030798	Dakar, Senegal	MK468880	MK474122	MK474143	This study
Felimare tema	MNCN 15.05/76515	Porto de Porto Novo, Santo Anton, Cabo Verde	MK468881	MK474123	MK474144	This study
Felimare tema	MNCN 15.05/76516	Canolo, Angola	MK468882	MK474124	MK474145	This study
Felimare tema	CASIZ 179384	Pedra da Gale, Principe Island	HM162594.1	HM162685.1	HM162500.1	Pola and Gosliner (2010) , this study
Felimare tricolor	BAU 2054	Secche di Tor Paterno, Italy	LN715193.1	LN715211.1	MK474153	Furfaro et al. (2016) , this study
Felimare tricolor	CASIZ 179386	Pedra da Gale, Principe Island	MK468886	MK474118	MK474154	This study
Felimida sphoni	CNMO 4965	Acapulco, Guerrero, Mexico	KJ911266.1	MK474133	KJ911246.1	Ortigosa et al. (2014) , this study
Felimida sphoni	CASIZ 175431	Punta Carbon, Guanacaste, Costa Rica	JQ727736.1	MK474132	MK474155	Johnson and Gosliner (2012) , this study
Hypselodoris obscura	CASIZ 144029	Mooloolaba, Queensland, Australia	EU982797.1	EU982745.1	MK474137	Johnson (2011) , this study
Prodoris clavigera	CASIZ 167553	South Shetland Islands, Elephant Island, Antartica	JX274067.1	JX274106.1	MK474134	Palomar et al. (2014) , this study

Scientia Marina 81(3)
September 2017, 387-394, Barcelona (Spain)
ISSN-L: 0214-8358
doi: http://dx.doi.org/10.3989/scimar.04594.16A

A new *Felimare* (Mollusca: Heterobranchia: Nudibranchia) of the Atlantic blue chromodorid chromatic group from Cape Verde

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Summary: A new species of the chromodorid genus *Felimare* (Gastropoda: Heterobranchia) of the Atlantic blue chromatic group is described using material from Cape Verde (eastern Atlantic). *Felimare aurantimaculata* n. sp. was described based on morphological characters, as well as a molecular phylogeny using two mitochondrial (cytochrome *c* oxidase subunit I and 16S rRNA) and one nuclear (histone-3) markers. *Felimare aurantimaculata* n. sp. is characterized by having a ground of dark blue colour with many orange polka dots over the body, dark blue rhinophores and branchial leaves, and very large and not clustered mantle dermal formations (MDFs) at the edge of the mantle, totally absent in the anterior area facing the rhinophores.

Keywords: Chromodorididae; eastern Atlantic; Gastropoda; morphology; new species.

Un nuevo *Felimare* (Mollusca: Heterobranchia: Nudibranchia) del grupo cromático de cromodorídidos atlánticos azules de Cabo Verde

Resumen: Se describe una nueva especie de cromodorídido del género *Felimare* (Gastropoda: Heterobranchia) del grupo cromático azul atlántico usando material de Cabo Verde (Atlántico oriental). *Felimare aurantimaculata* n. sp. se describió a partir de caracteres morfológicos, así como de una filogenia molecular utilizando dos marcadores mitocondriales (citocromo c oxidasa subunidad I y 16S rRNA) y uno nuclear (histona-3). *Felimare aurantimaculata* n. sp. se caracteriza por tener una coloración general azul oscura con muchos lunares anaranjados sobre el cuerpo, rinóforos y hojas branquiales azul oscuro, y formaciones dérmicas del manto (MDFs) muy grandes y no agrupadas en el borde del manto, aunque totalmente ausentes en la región anterior delante de los rinóforos.

Palabras clave: Chromodorididae; Atlántico oriental; Gastropoda; morfología; nueva especie.

Citation/Como citar este artículo: Ortigosa D., Pola M., Cervera J.L. 2017. A new *Felimare* (Mollusca: Heterobranchia: Nudibranchia) of the Atlantic blue chromodorid chromatic group from Cape Verde. Sci. Mar. 81(3): 387-394. doi: http://dx.doi.org/10.3989/scimar.04594.16A

LSID: urn:lsid:zoobank.org:pub:405B82C1-8718-4B4C-90C2-CCC9F1CE5FDA

Editor: C. Froglia.

Received: December 13, 2016. **Accepted**: April 10, 2017. **Published**: July 3, 2017.

INTRODUCTION

Ortea et al. (1996) defined the Atlantic blue chromodorid chromatic group as species of blue colour (from pale blue to navy) with white, blue or orange spots, blotches, or lines, and with a distribution range in the Atlantic Ocean (Mediterranean and Caribbean included). This group comprised species of five formerly different genera: *Hypselodoris* Stimpson, 1855 and *Mexichromis* Bertsch, 1977, nowadays transferred to *Felimare* Ev. Marcus and Er. Marcus, 1967; *Glossodoris* Ehrenberg, 1831 and *Chromodoris* Alder and Hancock, 1855, both as part of the provisional genus '*Felimida*' Ev. Marcus, 1971; and *Risbecia* Odhner, 1934, synonymized by Johnson and Gosliner (2012) with *Hypselodoris*. Ortea's et al. (1996) review, however, did not include in this group other Atlantic species clearly belonging to the blue chromatic group, such as *Felimare zebra* (Heilprin, 1889) from Bermuda.

The *Felimare* genus was re-erected by Johnson and Gosliner (2012). According to these authors, *Felimare* should include all the eastern Pacific, Atlantic and Mediterranean species previously attributed to *Hypselodoris* as well as two species of *Mexichromis* (one from the eastern Pacific and one from the Caribbean). To date, there are 39 described species within the genus: 36 valid species of the genus *Felimare sensu* WORMS (Bouchet and Caballer 2015), and three species described as *Hypselodoris sensu* WORMS, but that according to the Johnson and Gosliner's (2012) hypothesis should be included in *Felimare*: *Hypselodoris samueli* Caballer and Ortea, 2012, *Hypselodoris alaini* Ortea, Espinosa and Buske, 2013, and *Hypselodoris fregona* Ortea and Caballer, 2013 (Caballer and Ortea 2012, Ortea et al. 2013). Recently, Furfaro et al. (2016) raised a subspecies from the Atlantic blue chromodorid chromatic group, *Felimare picta verdensis* (Ortea, Valdés and García-Gómez, 1996), to species rank. However, a contemporary study (Almada et al. 2016) stated that both subspecies *Felimare picta verdensis* and *Felimare picta tema* (Ortea, Valdés and García-Gómez, 1996) are synonyms of *Felimare tema* (Edmunds, 1981).

To date, in the Atlantic coast of Africa, there is evidence of nine species of *Felimare* that fit into the blue chromodorid chromatic group (Table 1). In this paper, we describe a new species of *Felimare* from specimens collected from Cape Verde using morphological characters as well as molecular analyses based on two mitochondrial genes, cytochrome c oxidase subunit I (COI) and 16S rRNA (16S), and one nuclear gene, histone-3 (H3). Thus, the number of the blue chromatic chromodorids from the western coast of Africa has risen to ten.

Table 1. – Species of *Felimare* of the blue Atlantic chromatic group distributed along the western African coast.

Species	Status	Type locality	Distribution
Felimare bilineata (Pruvot-Fol, 1953)	Valid (Johnson and Gosliner, 2012)	Temara, Morocco	From the Gulf of Biscay to Ghana, including the Iberian Peninsula; Madeira and Selvagens Islands (Portugal), Canary Islands (Spain), Morocco, Senegal (Bouchet 1975, Edmunds 1981, Ortea et al. 1996, Cervera et al. 2004)
Felimare ciminoi (Ortea and Valdés, 1996)	Hypothesized by Johnson and Gosliner (2012)	Bonfin, Angola	Angola (Ortea et al. 1996)
Felimare francoisae (Bouchet, 1980)	Hypothesized by Johnson and Gosliner (2012); as *Felimare* by Ortigosa and Valdés (2012)	Cape Verde, Senegal	Senegal, Cape Verde (Ortea et al. 1996)
Felimare garciagomezi (Ortea and Valdés, 1996)	As *Felimare* by Ortigosa and Valdés (2012)	Ghana	Ghana (Ortea et al. 1996)
Felimare gofasi (Ortea and Valdés, 1996)	Hypothesized by Johnson and Gosliner (2012)	Santa Maria, Angola	Luanda and Lobito, Angola (Ortea et al. 1996)
Felimare muniani (Ortea and Valdés, 1996)	Hypothesized by Johnson and Gosliner (2012)	Santo Antonio, Principe Island	Santo Antonio, Principe Island (Ortea et al. 1996)
Felimare pinna (Ortea, 1988)	Hypothesized by Johnson and Gosliner (2012)	Caleoa, Cape Verde	Maio, São Vicente, Boavista, Sal Islands (Cape Verde) (Ortea et al. 1996; Rolán 2005)
Felimare tema (Edmunds, 1981)	Hypothesized by Johnson and Gosliner (2012); valid by Almada et al. (2016)	Tema, Ghana	Cape Verde, Ghana, São Tomé, southern Angola (Ortea et al. 1996)
Felimare tricolor (Cantraine, 1835)	Hypothesized by Johnson and Gosliner (2012)	Bonifacio Strait, Tyrrenian Sea	Arcachon (France), Cantabric Sea, Iberian Peninsula, Azores Islands, Madeira, and Selvagens Islands (Portugal), Canary Island (Spain), Mediterranean Sea (Ortea et al. 1996, Furfaro et al. 2016)
Felimare xicoi (Ortea and Valdés, 1996)	Hypothesized by Johnson and Gosliner (2012)	Praia das Conchas, São Tomé	São Tomé (Ortea et al. 1996)

MATERIALS AND METHODS

Samples for molecular studies

Samples were obtained from targeted collecting trips and specimens deposited at different museums or collections: the Museum of the "Charles Darwin" Department of Biology and Biotechnologies, La Sapienza University, Rome, Italy (BAU); the British Museum of Natural History, London, United Kingdom (BMNH); the Invertebrate Zoology collection at the California Academy of Sciences, San Francisco, United States (CASIZ); the Colección Nacional de Moluscos, Universidad Nacional Autónoma de México, Mexico City, México (CNMO); the California State Polytechnic University Invertebrate Collection, Pomona, United States (CPIC); the Museo Nacional de

Table 2. – Specimens used for molecular analyses, sample codes, vouchers, collection sites, GenBank accession numbers and references.

Species	Voucher	Locality	16s	COI	H3	References
Chromodoris magnifica	MNCN 15.05/76513	Pandaican, Philippines	*	*	*	This study
Felimare bilineata	MNCN 15.05/76507	Taghazut, Morocco	*	*	*	This study
Felimare bilineata	MNCN 15.05/76508	Congreso Island, Chafarinas, Spain	*	*	*	This study
Felimare bilineata	MNCN 15.05/76517	La Caleta, Cadiz, Spain	*	*	*	This study
Felimare bilineata	CASIZ 179406	Pedra da Gale, Principe Island	*	*	*	This study
Felimare bilineata	CASIZ 179408	Pedra da Gale, Principe Island	*	*	*	This study
Felimare francoisae	MNCN 15.05/76511	Ponta de Nho Jom, São Vicente, Cape Verde	*	-	*	This study
Felimare francoisae	MNCN 15.05/76512	The Anchor, Boavista, Cape Verde	*	-	*	This study
Felimare aurantimaculata n. sp.	MB28-004391	Tarrafal, Cape Verde	*	-	*	This study
Felimare aurantimaculata n. sp.	MB28-004390	Tarrafal, Cape Verde	*	*	*	This study
Felimare picta	MNCN 15.05/76510	Del Rey Island, Chafarinas, Spain	*	*	*	This study
Felimare picta	MNCN 15.05/76514	Pico Island, Azores, Portugal	*	*	*	This study
Felimare picta	MNCN 15.05/76567	Naples, Italy	*	*	*	This study
Felimare pinna	MNCN 15.05/76509	Calhau, Saragasa, Cape Verde	*	*	*	This study
Felimare porterae	CPIC 1326	San Pedro, California, United States	*	*	*	This study
Felimare porterae	CPIC 1612	California, United States	*	*	*	This study
Felimare tema	BMNH 20030798	Dakar, Senegal	*	*	*	This study
Felimare tema	MNCN 15.05/76515	Porto de Porto Novo, Santo Anton, Cabo Verde	*	*	*	This study
Felimare tema	MNCN 15.05/76516	Canolo, Angola	*	*	*	This study
Felimare tema	CASIZ 179384	Pedra da Gale, Principe Island	HM162594.1	HM162685.1	HM162500.1	Pola and Gosliner (2010)
Felimare tricolor	BAU 2054	Secche di Tor Paterno, Italy	LN715193.1	LN715211.1	*	Furfaro et al. (2016)
Felimare tricolor	CASIZ 179386	Pedra da Gale, Principe Island	*	*	*	This study
Felimida sphoni	CNMO 4965	Acapulco, Guerrero, Mexico	KJ911266.1	*	KJ911246.1	Ortigosa et al. (2014)
Felimida sphoni	CASIZ 175431	Punta Carbon, Guanacaste, Costa Rica	JQ727736.1	*	*	Johnson and Gosliner (2012)
Hypselodoris obscura	CASIZ 144029	Mooloolaba, Queensland, Australia	EU982797.1	EU982745.1	*	Johnson (2011)
Prodoris clavigera	CASIZ 167553	South Shetland Islands, Elephant Island, Antartica	JX274067.1	JX274106.1	*	Palomar et al. (2014)

Ciencias Naturales, Madrid, Spain (MNCN); and the Museu Nacional de História Natural e da Ciência, Lisbon, Portugal (MUHNAC, formerly Museu Bocage MB).

DNA extraction, amplification and sequencing

DNA extractions were performed using the Qiagen DNeasy Blood and Tissue Kit following the manufacturer's instructions, with some minor changes (100 µL final extraction instead of 200 µL). Partial sequences of COI, 16S and H3 were amplified by PCR using LCO1490 and HCO2198 universal primers for COI (Folmer et al. 1994), 16S ar-L and 16S br-H for 16S (Palumbi et al. 1991), and H3AD5'3' and H3BD5'3' for H3 (Colgan et al. 1998). The master mix for the PCR was carried out in 25 µL volume reactions. PCR contained 2.5 µL of Qiagen buffer, 2 µL of DNA, 2.5 µL of dNTP (2 mM), 5 µL of Q-solution (Qiagen), 1.5-3.5 µM magnesium chloride, 1 µL of each forward and reverse primer (10 µM), 0.25 µL of DNA polymerase (250 units μ^{-1}), 2-3 µL of DNA template, and nuclease-free water. Successful PCR products were purified and sequenced by Macrogen, Inc. All new sequences obtained were deposited in GenBank. COI amplification was performed with an initial denaturation for 3 min at 94-95°C, followed by 39-40 cycles of 30-45 s at 94°C, 30-45 s at 46°C (annealing temperature) and 1-2 min at 72°C, with a final extension of 5 min at 72°C. 16S amplification was performed with an initial denaturation for 3 min at 94-95°C, followed by 39 cycles of 39-45 s at 94°C, 30-50 s at 45-51.5°C (annealing temperature) and 2 min at 72°C, with a final extension of 5-10 min at 72°C. H3 amplification was performed with an initial denaturation for 3 min at 95°C, followed by 40 cycles of 45-60 s at 94-95°C, 45 s at 50°C (annealing temperature) and 2 min at 72°C, with a final extension of 10 min at 72°C.

Phylogenetic analyses

Molecular analysis included a total of 21 specimens including eight species of *Felimare*, four specimens of three other genera of Chromodorididae Bergh, 1891 and one specimen of *Prodoris clavigera* (Thiele, 1912), originally ascribed to *Bathydoris* Bergh, 1884, as an outgroup (Table 2).

DNA sequences were assembled, edited and aligned using Geneious 8.1.2 (Kearse et al. 2012). The alignments were checked by eye. All the sequences were checked for contamination with BLAST (Altschul et al. 1990) implemented in the GenBank database. Protein-coding sequences were translated into amino acids for confirmation of alignment. Pairwise uncorrected *p*-distance values between each taxon, uncorrected *p*-distances between all taxa, and level of saturation for first, second, and third codon positions (*p*-distances against transitions plus transversions) were calculated in MEGA 5.0 (Tamura et al. 2011) for the COI and H3

genes. The most variable regions from the 16S rRNA alignment were removed in the first analyses, using both the default settings and the standard options for stringent and less stringent selection in Gblocks (Talavera and Castresana 2007). When these regions were excluded from the analyses, the combined phylogenetic tree was poorly resolved and with low node support. Therefore, final analyses were performed including all bases. The best-fit models of evolution for each gene were determined using the Akaike information criterion (Akaike 1974) implemented in MrModeltest v. 2.3 (Nylander 2004), resulting in the GTR+I+G model for COI, 16S and H3. Maximum likelihood (ML) analyses were performed using the RA×ML software v7.0.4 (Stamatakis 2006) and node support was assessed with non-parametric bootstrap (BS) with 5000 replicates, random starting trees, and parameters estimated from each dataset under the model selected for the original dataset. Bayesian Inference (BI) analyses were conducted using MrBayes version 3.1.2b (Ronquist and Huelsenbeck 2003) for five million generations with two independent runs and a sampling frequency of 1000. The models implemented were those estimated with MrModeltest v. 2.3. Convergence was diagnosed graphically by plotting for each run the likelihood against the number of generations using the software Tracer version 1.4.1 (Drummond and Rambaut 2007). For each analysis, the first 1250 trees were discarded ('burn-in' period). Node support was assessed with posterior probability (PP). BI and RA×ML phylogenetic analyses were performed on the 280-core "PhyloCluster" hosted at the Center for Comparative Genomics, California Academy of Sciences. Only nodes supported by PP≥0.95 and BS≥75 were considered as resolved. The combined tree provided better resolution than COI (658 pb), H3 (328 pb) or 16S (up to 476 pb) separately. The combined dataset yielded a sequence alignment of 1462 positions. The ABGD method (Puillandre et al. 2012) was performed for the COI alignment using the online version of the software (available at http://wwwabi.snv.jussieu.fr/public/abgd/) (18 Nov 2016). ABGD was run by selecting Jukes-Cantor and Kimura parameters distance, Pmin=0.001, Pmax=0.1, Steps=10, and relative gap width=1.

Samples for morphological studies

Two specimens of *Felimare* were obtained in two different surveys in May 2009 and July 2011 through scuba diving at Tarrafal, Cape Verde, and preserved in 96% ethanol. One specimen was dissected by dorsal incision. The internal features were examined using a dissecting microscope and drawn with a camera lucida. The buccal mass was removed and dissolved in 10% sodium hydroxide until the radula and the labial cuticle were isolated from the surrounding tissue. Both were then rinsed in water, dried and mounted for examination under a Quanta 200 scanning electron microscope.

Morphological and anatomical comparison between the new species and congeners from the eastern Atlantic blue chromodorid chromatic group was based on published information and personal observations.

RESULTS AND DISCUSSION

Molecular analyses

We successfully obtained 64 new sequences; 12 additional sequences were obtained from GenBank (Table 2). The combined tree of COI, 16S and H3 provided better resolution than individual genes trees (Fig. 1). The individual genes trees can be seen in the supplementary material Figure S1. Figure 1 shows the phylogenetic hypothesis based on the combined dataset constructed by BI. The topology of the ML tree was almost identical (not shown).

The genus *Felimare sensu* Johnson and Gosliner (2012) was recovered by the BI (ML=not recovered), and their species were arranged into two major clades: one clade including *Felimare porterae* (Cockerell, 1901) (PP=1, BS=100) and one containing the remaining species of *Felimare* included in this study (PP=0.99). This last clade is subdivided into two subclades: one (PP=1, BS=79) comprised by *Felimare bilineata* (Pruvot-Fol, 1953), *Felimare* n. sp., *Felimare pinna* (Ortea, 1988), and *Felimare tricolor* (Cantraine, 1835); and one (PP=1, BS=99) comprised by *Felimare picta* (Schuitz in Philippi, 1836) and *Felimare tema*.

The maximum intraspecific pairwise uncorrected *p*-distance for COI between specimens of *F. bilineata* was 4.23%. The minimum interspecific *p*-distance within *Felimare* was between *Felimare* n. sp. and *F. bilineata* and was 8.63% (Table 3). Both ABGD species delimitation method analyses recovered eight partitions with prior maximal distance P=0.001 for 1 group and P=0.035 for 8 groups. (Fig. 1).

Taxonomy

Family CHROMODORIDIDAE
Genus *Felimare* Ev. Marcus and Er. Marcus, 1967

Felimare aurantimaculata n. sp.
(Figs 2, 3 and 4)

Hypselodoris sp., Wirtz, 2009: 54, Fig. 2.

Holotype: MB28-004390, 30 mm in length alive, Peter Wirtz, Tarrafal, Santiago Island, Cape Verde, 2009. *Paratype*: MB28-004391, dissected, 50 mm in length alive, Emanuel de Oliveira, Tarrafal, Santiago Island, Cape Verde, 23 m deep, 08 June 2011.

External morphology. Body high and elongate, with dark blue colour and smooth surface. Small round orange spots all over the body, including the foot (Fig. 2). Mantle edge narrow. Dorsum with a series of large and unclustered MDFs on the edge of the mantle, totally absent in the anterior area facing the rhinophores, 15 on the 50 mm specimen (MB28-004391), and 9 on the 30 mm specimen (MB28-004390). MDFs easily seen through the mantle. Posterior end of the foot not covered by the notum (Fig. 2). Rhinophores and branchial leaves dark blue, slightly lighter in colour. Rhinophores of two specimens with 22 lamellae, arranged nearly horizontal. Ten unipinnate branchial leaves in the 50 mm specimen (MB28-004391).

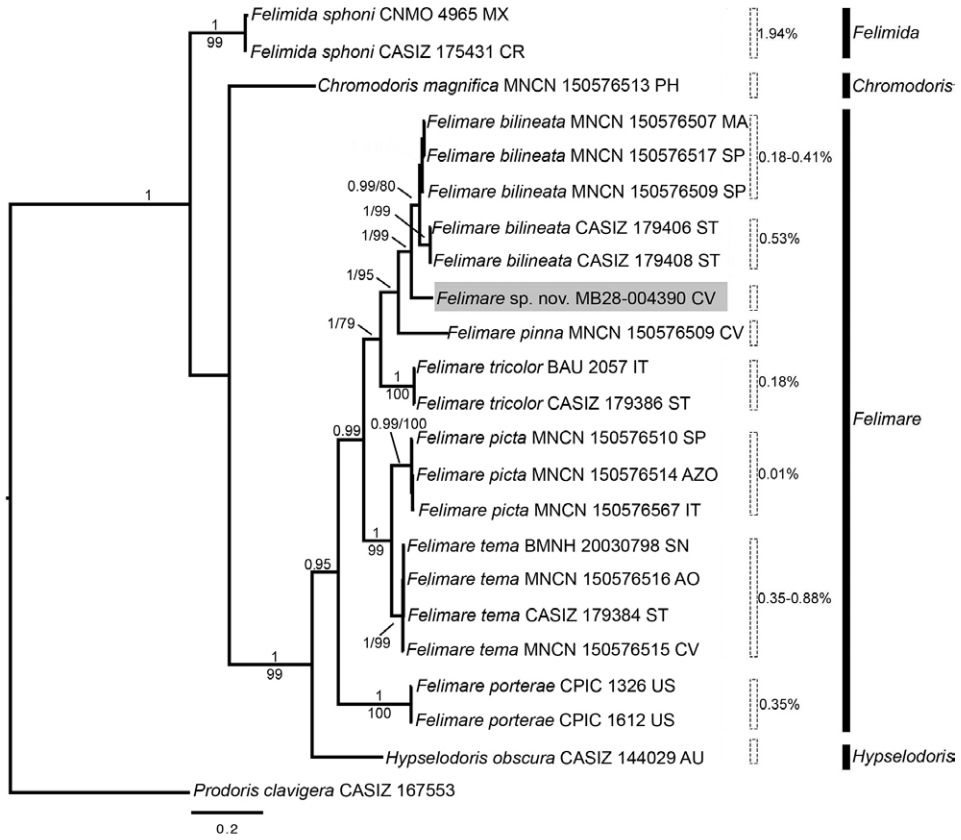

Fig. 1. – Phylogenetic hypothesis based on BI of the combined dataset (H3+COI+16S). Numbers above branches represent PP. Numbers below branches represent BS. Unsupported branches not labelled. Dashed rectangles are ABGD groups (Jukes-Cantor parameter). *p*-uncorrected distances for COI data set for each species. The new species is within the grey rectangle.

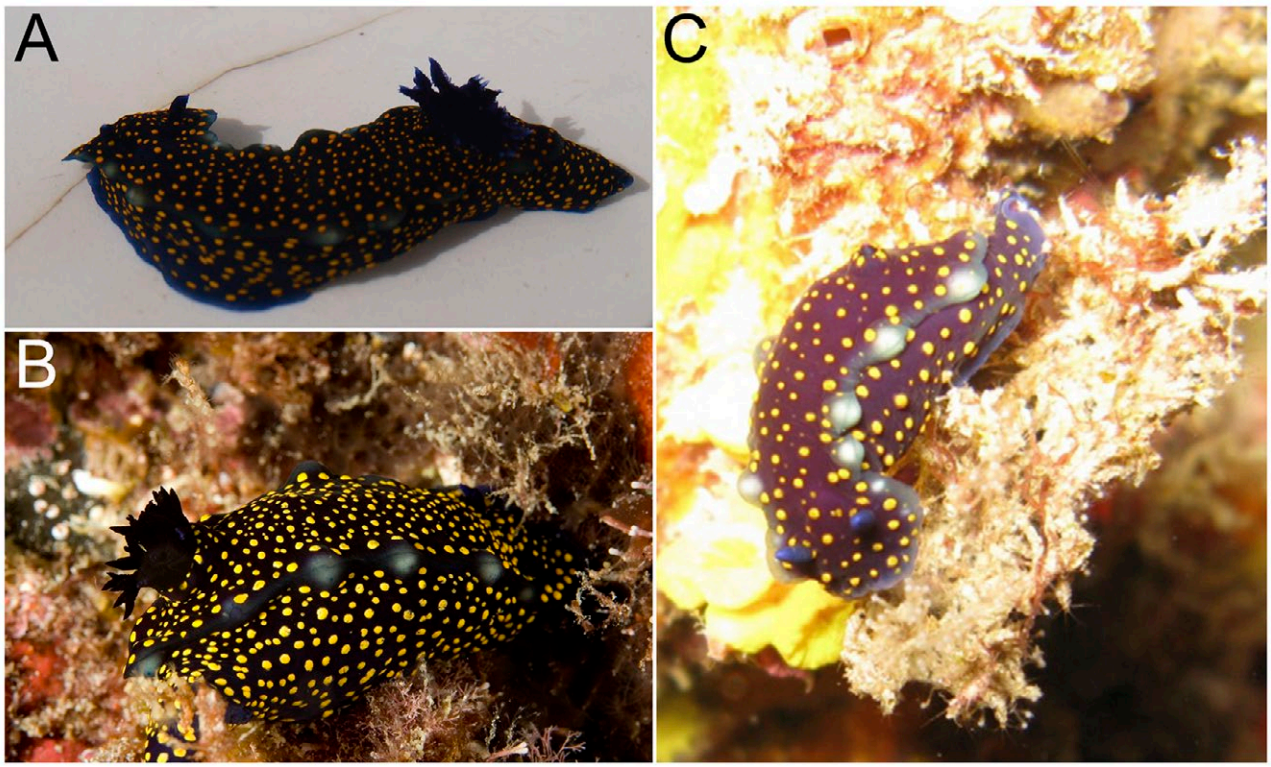

Fig. 2. – Living specimens of *Felimare aurantimaculata* n. sp. A, B, paratype (MB28-004391); C, holotype (MB28-004390) (photos: A, B, P. Wirtz; C, J. Fernandes).

Table 3. – Minimum and maximum and COI gene pairwise uncorrected *p*-distances between *F. aurantimaculatata* n. sp. and the remaining species of the genus *Felimare*.

Species	%
F. bilineata	8.63-9.68
F. pinna	15.67
F. tema	15.14-15.67
F. tricolor	14.26-14.44
F. porterae	15.49
F. picta	16.02-16.37

Anatomy (Figs 3, 4). Jaw composed of two pieces covered by unicuspid rodlets (Fig. 3A, B). The radular formula of the 50-mm specimen (MB28-004391) is 69×114.0.114. (Fig. 3C). Without rachidian radular tooth. Innermost lateral teeth sharp bifid, inner lateral teeth with two small denticles on their outer edge (Fig. 3D). Middle lateral teeth curved and bicuspid (Fig. 3E). Outermost teeth slightly bifid, broad tips, with up to four denticles on outer edge (Fig. 3F).

Reproductive system (Fig. 4A, B) with vestibular gland elongated. Vagina very wide and muscular. Pyriform seminal receptacle with a short and thin conduct that joins along the middle length of the vagina. Bursa copulatrix spherical. Uterine duct short and narrow, entering the female gland near the entrance of the oviduct. Ampulla elongated and wide. Penis unarmed. Prostate elongated, located anteriorly to female gland, narrowing slightly to a convoluted deferent duct, all over the reproductive system. Female gland half the size of the entire reproductive system.

Distribution. To date only known from Tarrafal, Santiago Island, Cape Verde.

Etymology. The name refers to the Latin words *aurantiacus*, meaning orange, and *maculatus*, meaning spot, which refers to the chromatic pattern of the body, scattered with orange polka dots.

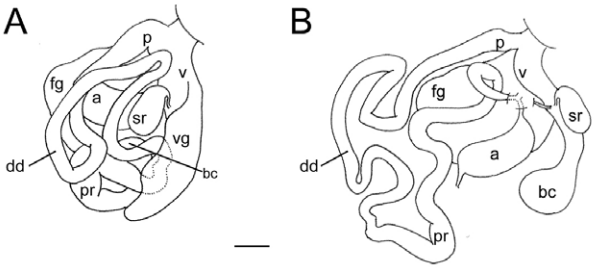

Fig. 4. – Complete reproductive system of *Felimare aurantimaculata* n. sp. (MB28-004391). A, original view. B, view with all the organs separated. Abbreviations: a, ampulla; bc, bursa copulatrix; dd, deferent duct; fg, female gland; p, penis; pr, prostate; sr, seminal receptacle; v, vagina; vg, vestibular gland. Scale bar=0.5 mm.

Comparative diagnosis. Though all the *Felimare* species distributed along the Atlantic coast of Africa and belonging to the blue Atlantic chromatic group have some chromatic yellow pattern over light to dark blue, *Felimare aurantimaculata* n. sp. is the only one having small orange dots instead of a white middle line with a distinct and unique pattern as in *Felimare pinna*; parallel white line or yellow stripes as in *Felimare bilineata*, *Felimare ciminoi* (Ortea, Valdés and García-Gómez, 1996), *Felimare francoisae* (Bouchet in Bouchet and Ortea, 1980), *Felimare garciagomezi* (Ortea and Valdés, 1996), *Felimare tema*, *Felimare tricolor* and *Felimare xicoi* (Ortea and Valdés, 1996); or irregular patterns as in *Felimare gofasi* (Ortea, Valdés and García-Gómez, 1996). The morphotype of *Felimare picta* from the Azores Islands has small yellow spots in a lower density all over the body that make it resemble *Felimare aurantimaculata* n. sp., but our results show that they are different species nested in different subclades (Fig. 1). The size of the

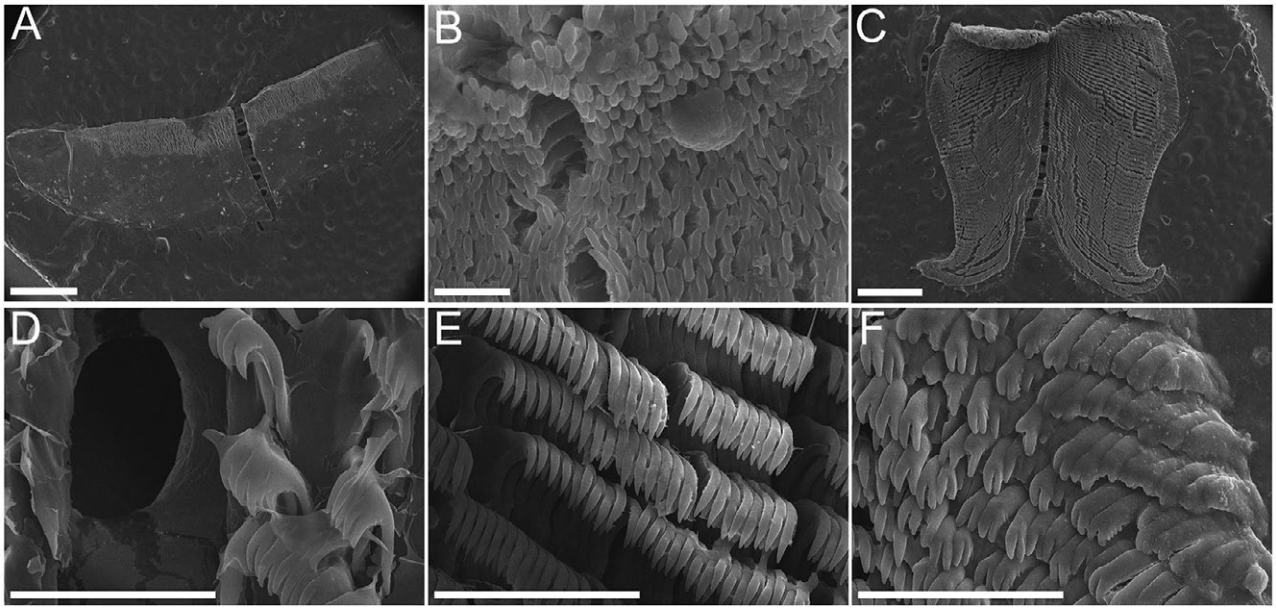

Fig. 3. – Scanning electron micrographs of the radula of *Felimare aurantimaculata* n. sp. (MB28-004391). A, labial cuticle, scale bar=1 mm; B, detail of the labial cuticular rodlets, scale bar=100 μm; C, radula, scale bar=1 mm; D, innermost lateral teeth, scale bar=100 μm; E, middle lateral teeth (right), scale bar=200 μm; F, outermost teeth [right], scale bar=200 μm).

Table 4. – Comparative table of the main features for *Felimare* species belonging to the blue Atlantic chromatic group distributed along the western African coast.

Species	MDFs arrangement	Jaw rodlets (number of cuspids)	Radular formula (size of the specimen in mm)	Branchial leaves	References
F. bilineata	On the posterior end	1-2	66×152.0.152 (40)	Up to 10	Ortea et al. (1996), García-Gómez (2002)
F. ciminoi	Not present	1	34×31.0.31 (?)	7	Ortea et al. (1996)
F. francoisae	On anterior and posterior ends	3-4	45×30.0.30 (?)	12	Bouchet and Ortea (1980), Ortea (1988), Ortea et al. (1996)
F. garciagomezi	On each side of rhinophores and on the posterior end	3-4	23×12.0.12 (4)	Up to 6	Edmunds (1981)
F. gofasi	Not present	1	59×65.0.65 (12)	Up to 8	Ortea et al. (1996)
F. muniani	Three on the posterior end	1	42×51.0.51 (15)	5	Ortea et al. (1996)
F. pinna	At the posterior end	2-3	47×54.0.54 (12)	Up to 9	Ortea et al. (1996), Rolán (2005)
F. tema	Around the mantle margin, absent only in the middle region (as *H. verdensis*)	1	82×190.0.190 (76) 76×139.0.139 (?) 70×154.0.154 (?)	9	Edmunds (1981), Ortea et al. (1996)
F. tricolor	On the posterior end	1-2	53×49.0.49 (10) 62×56.0.56 (20)	8-10	Ortea et al. (1996)
F. xicoi	7, behind the branchial leaves	1-3	63×61.0.61 (18)	6	Ortea et al. (1996)
F. aurantimaculata n. sp.	Around the mantle margin, absent only in the anterior region before the rhinophores	1	69×114.0.114 (50)	10	Present study

MDFs of *Felimare aurantimaculata* sp. nov. is larger than that of the remaining known species of the genus. Moreover, the arrangement of the MDFs in *Felimare aurantimaculata* n. sp. is also unique among the above blue chromatic group, since the remaining species lack MDFs in the middle region of their mantle edge or they are limited to the posterior end (Table 4). The species *F. francoisae* and *F. garciagomezi* (previously named as *Mexichromis*) differ from *Felimare aurantimaculata* n. sp., besides the chromatic pattern, in having jaw rodlets with 3-4 cuspids, instead of unicuspid rodlets as in *F. ciminoi* and *F. gofasi* (Table 4). The reproductive system is like that of other species of *Felimare*, formerly ascribed to *Hypselodoris*, such as the size and shape of the vestibular gland; the muscularized wide vagina; the spherical shape of the bursa copulatrix; and the pyriform seminal receptacle, generally attached in some part of the vagina, with the exception of *Felimare molloi*, that joins just at the entrance of the bursa copulatrix (Ortea et al. 1996, Gosliner and Johnson 1999).

Recently, using molecular techniques, Almada et al. (2016) and Furfaro et al. (2016) ended the controversy related to the *Felimare picta* complex. They both stated that *Felimare tema* (Edmunds, 1981) is a valid species distributed from Cape Verde and Senegal to Angola, in the southern hemisphere, while *Felimare picta* is restricted to the northern hemisphere, but with a broader distribution, from the type locality in the Mediterranean sea up to the Gulf of Mexico. Although there is now no doubt that *F. picta* is not distributed in the southeastern Atlantic, we decided to include *F. picta* in our phylogenetic analyses to discard the possibility that *Felimare aurantimaculata* n. sp. could be a chromatic morphotype of this species. IB, ML, *p*-distance and ABGD strongly support the hypothesis that *Felimare aurantimaculata* n. sp. is a new valid species.

ACKNOWLEDGEMENTS

We are indebted to all the people who provided us with the material and photographs of the study material: Emannuel d´Oliveira, Jose Fernandez, Justin Hart, David Piras, Gonçalo Rosa, Naoufel Tamsouri, Manuel Jiménez Tenorio and Peter Wirtz. We also thank the staff at the Center for Comparative Genomics at the California Academy of Sciences, especially Anna Sellas and Brian Simison. Joaquim Reis provided valuable comments that improved the quality of this paper. This contribution was supported by the research project CGL2010-17187/BOS, funded by the Spanish Ministry of Economy and Competitiveness.

REFERENCES

Akaike H. 1974. A new look at the statistical model identification. IEEE Trans Automatic Control. 19: 716-723. https://doi.org/10.1109/TAC.1974.1100705

Almada F., Levy A., Robalo J.I. 2016. Not so sluggish: the success of *Felimare picta* complex (Gastropoda, Nudibranchia) crossing Atlantic biogeographic barriers. PeerJ 4: e1561. https://doi.org/10.7717/peerj.1561

Altschul S.F, Gish W., Miller W., et al. 1990. Basic local alignment search tool. J. Mol. Biol. 215: 403-410. https://doi.org/10.1016/S0022-2836(05)80360-2

Bouchet P. 1975. Nudibranches nouveaux des côtes du Senegal. Vie Milieu 25: 119-132.

Bouchet P., Caballer M. 2015. *Felimare* Ev. Marcus and Er. Marcus, 1967. In: World Register of Marine Species, accessed on 01 March 2016 at http://www.marinespecies.org/aphia.php?p=taxdetails&id=558624

Bouchet P., Ortea J. 1980. Quelques Chromodorididae bleus (Mollusca, Gastropoda, Nudibranchiata) de l'Atlantique oriental. Ann. Inst. Oceanogr. 56: 117-125.

Caballer M., Ortea J. 2012. Description of a new species of *Hypselodoris* (Gastropoda: Nudibranchia: Chromodorididae) from Venezuela. Rev. Acad. Can. Cienc. 23: 93-106.

Cervera J.L., Calado G., Gavaia C., et al. 2004. An annotated and updated checklist of the opisthobranchs (Mollusca: Gastropoda) from Spain and Portugal (including islands and archipelagos).

Bol. Inst. Esp. Oceanogr. 20: 1-122.
Colgan D.J, Mclauchlan A., Wilson G.D.F, et al. 1998. Molecular phylogenetics of the Arthropoda: relationships based on histone H3 and U2 snRNA DNA sequences. Aust. J. Zool. 46: 419-437. https://doi.org/10.1071/ZO98048
Drummond A.J., Rambaut A. 2007. BEAST: Bayesian evolutionary analysis by sampling trees. BMC Evol. Biol. 7: 214. https://doi.org/10.1186/1471-2148-7-214
Edmunds M. 1981. Opisthobranchiate Mollusca from Ghana: Chromodorididae. Zool. J. Linn. Soc. 72: 175-201. https://doi.org/10.1111/j.1096-3642.1981.tb01657.x
Folmer O., Black M., Hoeh W., et al. 1994. DNA primers for amplification of mitochondrial cytochrome *c* oxidase subunit I from diverse metazoan invertebrates. J. Mol. Biol. Biotechnol. 3: 294-299.
Furfaro G., Modica M.V., Oliverio M. et al. 2016. A DNA-barcoding approach to the phenotypic diversity of Mediterranean species of *Felimare* Ev. Marcus and Er. Marcus, 1967 (Mollusca: Gastropoda), with a preliminary phylogenetic analysis. Ital. J. Zool. 83: 195-207. https://doi.org/10.1080/11250003.2016.1150525
García-Gómez J.C. 2002. Paradigmas de una fauna insólita. Los moluscos opistobranquios del estrecho de Gibraltar. Serie Ciencias, 20. Inst. Est. Gibraltareños, Algeciras, Spain.
Gosliner T.M., Johnson R.F. 1999. Phylogeny of *Hypselodoris* (Nudibranchia: Chromodorididae) with a review of the monophyletic clade of Indo-Pacific species, including descriptions of twelve new species. Zool. J. Linn. Soc. 125: 1-114. https://doi.org/10.1111/j.1096-3642.1999.tb00586.x
Johnson R.F. 2011. Breaking family ties: taxon sampling and molecular phylogeny of chromodorid nudibranchs (Mollusca, Gastropoda). Zool. Scripta 40: 137-157.
Johnson R., Gosliner T.M. 2012. Traditional taxonomic groupings mask evolutionary history: A molecular phylogeny and new classification of the chromodorid nudibranchs. PloS One 7: e33479. https://doi.org/10.1371/journal.pone.0033479
Kearse M., Moir R., Wilson A., et al. 2012. Geneious Basic: an integrated and extendable desktop software platform for the organization and analysis of sequence data. Bioinformatics 28: 1647-1649. https://doi.org/10.1093/bioinformatics/bts199
Nylander J.A.A. 2004. MrModeltest v2.3. Program distributed by the author. Evolutionary Biology Centre, Uppsala University.
Ortea J. 1988. Moluscos opistobranquios del Archipiélago de Cabo Verde: Chromodorididae. Pub. Ocas. Soc. Port. Malacol. 11: 1-16.
Ortea J., Valdés Á., García-Gómez J.C. 1996. Revisión de las especies atlánticas de la familia Chromodorididae (Mollusca: Nudibranchia) del grupo cromático azul. Avicenia Suppl. 1: 1-165.
Ortea J., Espinosa J., Buske Y., et al. 2013. Additions to the inventory of the sea slugs (Opisthobranchia and Sacoglossa) from Guadeloupe (Lesser Antilles, Caribbean Sea). Rev. Acad. Can. Cienc. 25: 163-194.
Ortigosa D., Valdés Á. 2012. A new species of *Felimare* (formerly Mexichromis) (Gastropoda: Opisthobranchia: Chromodorididae) from the Yucatan Peninsula, Mexico. Nautilus 126: 98-104.
Ortigosa D., Pola M., Carmona L., et al. 2014. Redescription of *Felimida elegantula* (Philippi, 1844) and a preliminary phylogeny of the European species of *Felimida* (Chromodorididae). J. Mollusc. Stud. 80: 541-550. https://doi.org/10.1093/mollus/eyu041
Palomar G., Pola M., García-Vázquez E. 2014. First molecular phylogeny of the subfamily Polycerinae (Mollusca, Nudibranchia, Polyceridae). Helgol. Mar. Res. 68: 143-153. https://doi.org/10.1007/s10152-013-0374-z
Palumbi S.R., Martin A., Romano S., et al. 1991. The Simple Fool's Guide to PCR.: Department of Zoology, University of Hawaii. Honolulu, 45 pp.
Pola M., Gosliner T.M. 2010. The first molecular phylogeny of cladobranchian opisthobranchs (Mollusca, Gastropoda, Nudibranchia). Mol. Phylogenet. Evol. 56: 931-941. https://doi.org/10.1016/j.ympev.2010.05.003
Puillandre N., Lambert A., Brouillet S., et al. 2012. ABGD, Automatic Barcode Gap Discovery for primary species delimitation. Mol. Ecol. 21: 1864-1877. https://doi.org/10.1111/j.1365-294X.2011.05239.x
Rolán E. 2005. Malacological Fauna from the Cape Verde Archipelago: Part 1 (Vol. 1). ConchBooks. 455 pp.
Ronquist F., Huelsenbeck J.P. 2003. MrBayes 3: Bayesian phylogenetic inference under mixed models. Bioinformatics 19: 1572-1574. https://doi.org/10.1093/bioinformatics/btg180
Stamatakis A. 2006. RAxML-VI-HPC: maximum likelihood-based phylogenetic analyses with thousands of taxa and mixed models. Bioinformatics 22: 2688-2690. https://doi.org/10.1093/bioinformatics/btl446
Talavera G., Castresana J. 2007. Improvement of phylogenies after removing divergent and ambiguously aligned blocks from protein sequence alignments. Syst. Biol. 56: 564-577. https://doi.org/10.1080/10635150701472164
Tamura K., Peterson D., Peterson N., et al. 2011. MEGA5: Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. Mol. Phyl. Evol. 28: 2731-2739. https://doi.org/10.1093/molbev/msr121
Wirtz P. 2009. Thirteen new records of marine invertebrates and two of fishes from Cape Verde Islands. Arquipélago Life Mar. Sci. 26: 51-56.

SUPPLEMENTARY MATERIAL

The following supplementary material is available through the online version of this article and at the following link: http://scimar.icm.csic.es/scimar/supplm/sm04594esm.pdf

Fig. S1. – Phylogenetic hypothesis based on BI for each gene (16S, COI, H3). Numbers above branches represent PP. Numbers below branches represent BS. Unsupported branches not labelled. The new species is within the grey rectangle.

Scientia Marina 81(3)
September 2017, S1-S2, Barcelona (Spain)
ISSN-L: 0214-8358

A new *Felimare* (Mollusca: Heterobranchia: Nudibranchia) of the Atlantic blue chromodorid chromatic group from Cape Verde

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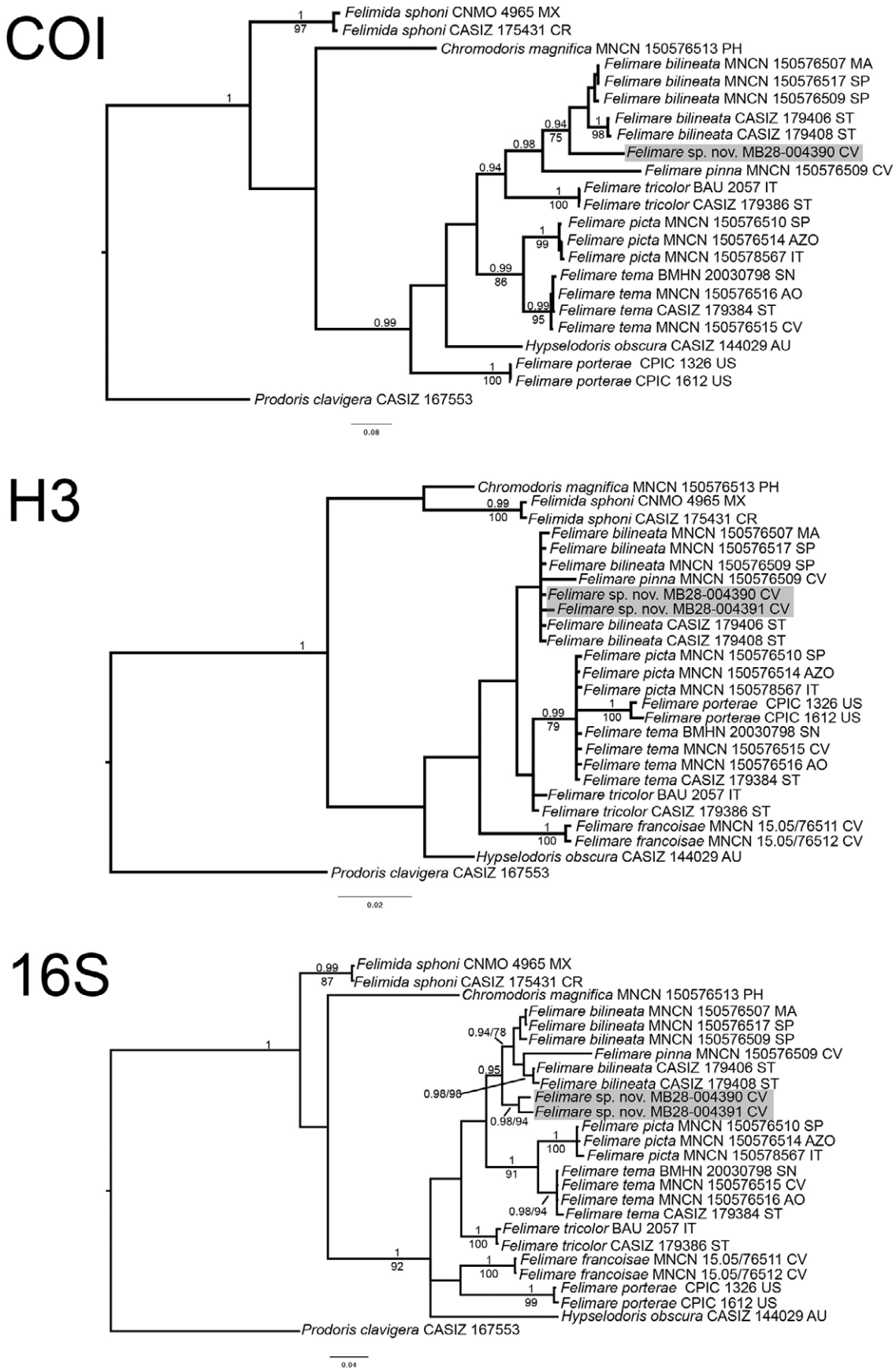
Supplementary material



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