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Sea Slugs (Mollusca, Gastropoda, Heterobranchia) from the Medes Islands (Costa Brava, NE Spain): Biodiversity and Ecological Study over a Decade

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Abstract

The Mediterranean Sea faces escalating environmental pressures from the unsustainable exploitation of resources and insufficient management. Marine protected areas (MPAs), such as the Parc Natural del Montgrí, les Illes Medes i el Baix Ter (PNMMBT) on Spain's Costa Brava, serve as critical refuges for biodiversity conservation. Between 2010 and 2019, we conducted systematic visual surveys of sea slugs (Mollusca: Heterobranchia) within the PNMMBT, documenting 8289 individuals representing 98 species: 76 Nudibranchia, 10 Sacoglossa, 5 Aplysiida, 3 Pleurobranchida, 2 Umbraculida, 1 Runcinida, and 1 Cephalaspidea. Temporal, spatial, and bathymetric distribution analyses revealed a steady increase in species richness over time, suggesting the MPA's ecosystems appear to remain in relatively good condition. To further refine our assessment, we incorporated citizen science records from the MINKA platform, expanding the documented diversity to 141 species including 99 Nudibranchia, 12 Sacoglossa, 5 Aplysiida, 6 Pleurobranchida, 2 Umbraculida, 4 Runcinida, 10 Cephalaspidea, 1 Acteonimorpha, 1 Pteropoda, and 1 Ringiculimorpha. This integrated approach highlights the value and complementarity of structured scientific surveys and community-contributed data in biodiversity monitoring. Citizen science fosters public engagement in research and provides scalable, cost-effective data that would otherwise be logistically unfeasible to obtain. By bridging these methodologies, we demonstrate how participatory science enhances the detection of species distributions, tracks ecological shifts, and bolsters conservation strategies in the current era of global biodiversity decline.

Keywords: biodiversity; Heterobranchia sea slugs; natural park; Medes Islands; Spain

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1. Introduction

In recent decades, there has been a marked increase in biodiversity-focused ecological research [1]. Heightened governmental and public awareness, coupled with the critical status of certain habitats, has intensified efforts to conserve and protect biodiversity [2]. In the marine environment, advances in autonomous diving technologies and the widespread availability of high-quality, user-friendly underwater photography equipment have enabled numerous experienced non-professional divers to contribute meaningfully to our knowledge of species inhabiting shallow infralittoral zones. The advent of social media and online platforms has further facilitated the near-real-time sharing of species records, significantly enhancing the dissemination of knowledge.

Sea slugs—a group of gastropod mollusks within the subclass Heterobranchia (formerly classified under the now-obsolete subclass Opisthobranchia)—have long fascinated both researchers and naturalists due to their striking morphology and vivid coloration. Over the past two to three decades, interest in this group has grown considerably. This trend can be attributed to several factors: the emergence of dedicated online platforms, such as M@re Nostrum [3], Sea Slug Forum [4], Medslugs [5], OPK [6], GROC [7], and others; the increasing participation of certified divers in community science initiatives; and significant advances in underwater photography, which have made these techniques broadly accessible.

Systematic, long-term studies on the biodiversity of heterobranch marine sea slugs in specific coastal locations remain scarce globally.

The heterobranch sea slug fauna of Catalonia (north-eastern Spain) has been the subject of extensive research since the 1970s [8–12]. According to the most recently published catalogue [11], 257 sea slug species were recorded in the region up to 2016, and continued research is progressively adding new records to this total. However, relatively few comprehensive studies have targeted the heterobranch sea slug fauna of specific localities along the Catalan coast. Among the notable exceptions are the study by Domènech et al. [13], which examined the spatial and temporal variability of sea slugs over an annual cycle in Port Lligat Bay, and the work of Dacosta et al. [14] in the nearby Es Caials inlet, both situated within the Cap de Creus Natural Park (Costa Brava, NE Spain). More recent contributions include Parera et al. [15], who surveyed sea slug biodiversity along the Barcelona coastline, and Ballesteros & Pontes [16], who reported on sea slug fauna from the coast of Blanes, in the southern part of Costa Brava.

The modern systematic study of marine benthic communities in Catalonia began with the Programa Bentos [17], conducted between 1972 and 1974. This initiative, led by the renowned ecologist Ramón Margalef of the University of Barcelona's Department of Ecology, focused on understanding the ecological dynamics of benthic communities on hard-bottom substrates. As part of this program, benthic communities were surveyed at seven coastal sites in Catalonia, including the Medes Islands. This research laid the groundwork for a series of subsequent initiatives. The first of these, Programa Medes I (1976–1978) [18], also coordinated by Ramón Margalef, investigated both the terrestrial and marine communities of the Medes Islands. It was followed by Programa Medes II (1980–1981) [19], directed by J. D. Ros—one of Spain's pioneers in sea slug research. Results from these programs were compiled in a monographic volume [20] that listed 36 heterobranch sea slug species from the Medes Islands [21,22]. Manuel Ballesteros's doctoral thesis [9] added 11 additional sacoglossan and nudibranch records from sites around the archipelago. Subsequent corrections reduced the number of valid species to 34.

In 2007, the MolusCat project was launched as an online database of Catalan mollusk observations within the general BIOCAT project (Biodiversity Data Bank of Catalonia) [23]. Extracting and reviewing earlier sea slug records for UTM grid square EG15—which contains the Medes Islands, most of the Montgrí coastline, and the southern Bay of Pals—increased the species tally to 46. Subsequent corrections reduced the number of valid species to 42.

The present study began in 2010, with regular visual surveys of sea slugs around the Medes Islands by volunteers from the GROC (Grup de Recerca dels Opistobranquis de Catalunya)—a community science group. Since 2012, these surveys have been continued by the VIMAR group and are still ongoing.

The Parc Natural del Montgrí, les Illes Medes i el Baix Ter (PNMMBT) was established in 2010, following several decades of scientific research, management proposals, and varying degrees of protection applied to the marine–terrestrial zone surrounding the Medes Islands. It is located in the central part of Costa Brava (Catalonia, NE Spain), approximately 140 km north of Barcelona. The town of L'Estartit is the only coastal location in the park, with the Medes Islands lying approximately 900 m away. This area is renowned for its exceptional marine biodiversity, rich benthic communities, and unique ecosystems, attracting tens of thousands of divers from around the world every year. The waters surrounding the Medes Islands benefit from their proximity to the mainland and the input of organic matter from the Ter River, resulting in a highly productive and ecologically diverse system.

The main objective of this study was to understand the biodiversity and abundance of sea slugs in the PNMMBT over time through monthly visual surveys. Additionally, secondary objectives included studying the depth distribution and water temperature ranges of the species, and for informative purposes, we calculated the Shannon diversity index for the different study years. Finally, and taking into account all the information obtained from our data and the species records appearing on various citizen science platforms, a list of all species recorded within the PNMMBT has been compiled. The resulting long-term time series enabled the analysis of species trends and facilitated the exploration of relationships between sea slug distribution patterns and environmental variables such as temperature, depth, light availability, substrate, and food

2. Materials and Methods

2.1. Study Area

The study area encompasses two zones—the Montgrí coast to the north and the Medes Islands to the south (Figure 1)—both characterized by calcareous rocky shorelines. Although the Montgrí coast was subject to intense fishing activity prior to its inclusion in the PNMMBT, it is currently considered to be in good ecological condition according to indicators from the park's management reports. Owing to the inaccessibility of much of its coastline, this area remains largely unaffected by tourism and urban development. The Medes Islands (Figure 1) form a small archipelago that constitutes the marine extension of the Montgrí massif. The archipelago consists of two main islands—Meda Gran and Meda Petita—and several islets, including Carall Bernat, Tascó Gros, Tascó Petit, Medallot, and Ferranelles. These are situated approximately 900 m offshore from Punta de la Guixera, near the port town of L'Estartit.

Figure 1. The Medes Islands lie less than 1 km offshore from L'Estartit, Girona, Spain. Picture by Miquel Pontes.

The surveyed localities within both areas are shown in Figure 2. A complete list of sites, along with their characteristics and the number of surveys conducted at each, is provided in Table 1.

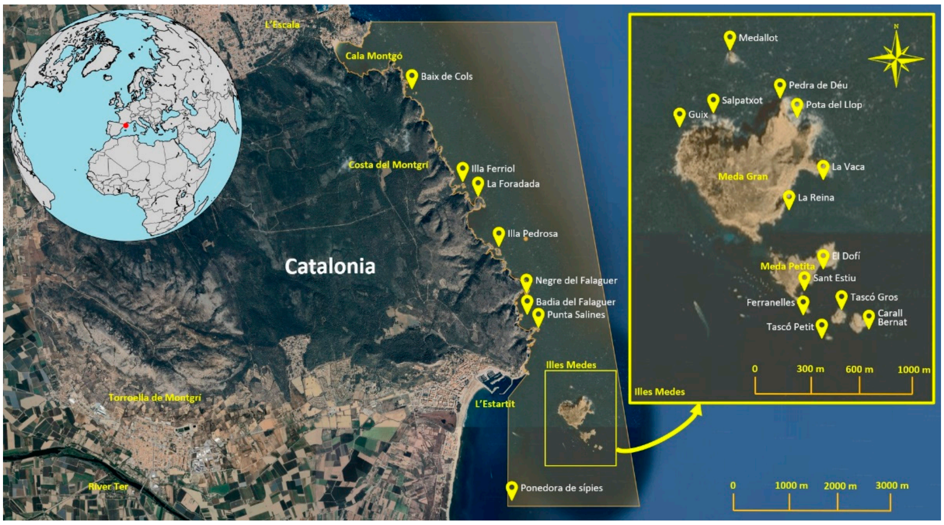

Figure 2. Localities where structured censuses were conducted. On the right, an enlargement of the sampling points on the Medes Islands. Satellite imagery © Google; Natural Park boundaries courtesy of MINKA (ICM-CSIC).

Table 1. The census locations, along with their GPS coordinates, depth ranges, and the total number of surveys conducted at each site during the study period, are detailed below.

Zone	Locality	Coordinates	N°. Surveys	Depth Range
Montgrí	Baix de Cols	42.100353 N, 3.186637 E	1	(2.5–18.5 m)
	Illa Ferriol	42.084415 N, 3.197003 E	2	(7.0–18.0 m)
	La Foradada	42.081541 N, 3.201541 E	1	(5.0–14.0 m)
	Illa Pedrosa	42.073283 N, 3.204867 E	1	(4.0–17.4 m)
	Badia de Falaguer	42.067198 N, 3.210972 E	6	(2.7–26.2 m)
	Punta Salines	42.060978 N, 3.213847 E	3	(3.4–25.6 m)
Illes Medes	Medallot	42.051491 N, 3.221987 E	3	(3.7–36.9 m)
	Guix	42.049182 N, 3.219273 E	4	(5.8–21.6 m)
	Salpatxot	42.049533 N, 3.220824 E	8	(3.0–26.0 m)
	Pedra de Déu	42.050033 N, 3.224174 E	6	(6.0–26.5 m)
	Pota del Llop	42.049331 N, 3.225443 E	2	(4.5–30.8 m)
	La Vaca	42.047388 N, 3.225768 E	7	(3.0–31.0 m)
	La Reina	42.046387 N, 3.224656 E	1	(5.2–25.0 m)
	El Dofí	42.043866 N, 3.226427 E	10	(4.0–32.8 m)
	Sant Estiu	42.043197 N, 3.225954 E	3	(6.0–20.4 m)
	Ferranelles	42.042231 N, 3.225505 E	20	(0.5–27.0 m)
	Tascó Gros	42.042121 N, 3.226816 E	5	(1.8–30.0 m)
	Tascó Petit	42.041124 N, 3.226538 E	17	(3.2–27.2 m)
	Carall Bernat	42.041460 N, 3.228149 E	6	(5.2–39.3 m)
Baix Ter	Ponedora de Sípies	42.042833 N, 3.202150 E	1	(20.0–26.0 m)
		Total Surveys	107	

2.2. Sampling

From 2010 to 2019 (with the exception of 2018 because of logistical problems), monthly visual censuses of heterobranch sea slugs were conducted within the PNMMBT. During the first two years, surveys focused exclusively on the Ferranelles locality and were carried out by members of the Grup de Recerca dels Opistobranquis de Catalunya (GROC) community science group. From 2012 onward, censuses were performed throughout the PNMMBT by members of the VIMAR–Vida Marina community science group. Over the entire study period, a total of 107 surveys were completed across 20 locations within the PNMMBT, comprising 13 in the Medes Islands, 6 along the Montgrí coast, and 1 in the Baix Ter area (Table 1). Since 2012, sampling sites have been selected to represent a range of profiles, depth ranges, and habitats, with the goal of maximizing species diversity detection. All samplings consisted of monthly visual and photographic surveys conducted by SCUBA diving to a maximum depth of 30 m. The vast majority of dives involved between 4 and 6 divers, and sampling effort was standardized by limiting each dive to a strict duration of 60 min, which is the sampling unit in this work. Over the nine years, more than 40 divers have participated in the surveys, most of them having made more than 10 sea slug census dives. The physical and community characteristics of each of the sampled locations are found in the annual reports issued by the VIMAR group [24] to the management of the PNMMBT.

Individuals were identified in situ during the dives, and photographs were taken to confirm the identification of uncertain individuals later in the laboratory. Because of the protected status of the park, substrate sampling was not permitted, limiting the ability to collect small or cryptic species living within the substrate. During each dive, data recorded on PVC slates included the date, observer, species observed, number of individuals, size of each specimen, depth, substrate type, presence of spawning, and water temperature. These data were subsequently compiled in Microsoft Excel for further analysis. Since sampling efforts vary between different locations, in order to compare abundances between them, the ratio of observed individuals/h of sampling has been calculated for each one. To address the depth preferences of the species, subjective criteria have been established to divide the depth at which they were observed into 5 m intervals (0–5 m, 6–10 m, 11–15 m, 16–20 m, 21–25 m, 26–30 m, and >30 m). For the nomenclature of the species and their taxonomy, the indications of the World Register of Marine Species (WoRMS) [25] have generally been followed.

2.3. Photographic Equipment

Various cameras and housings were employed by the samplers to photograph individuals, including a Nikon D300 (Nikon, Tokyo, Japan) with a Nikon 60 mm macro lens housed in a Sea&Sea aluminum housing, fitted with a Subsee 10+ wet lens and two Sea&Sea YS-D1 strobes; a Nikon D610 (Nikon, Tokyo, Japan) with the same lens and housing setup; a Nikon D7500 (Nikon, Tokyo, Japan) with a Nikon 60 mm macro lens in an Isotta aluminium housing, equipped with a Nauticam SMC-1 (Nauticam, Fort Lauderdale, FL, USA) wet lens and two Inon Z240 Type 2 (Inon, Tokyo, Japan) underwater strobes; a Sony Alpha A6000 (Sony, Tokyo, Japan) in a SeaFrogs polycarbonate housing (Seafrogs, Shenzhen, China) paired with a Sea&Sea YS-01 (Sea&Sea, Tokyo, Japan) underwater strobe; a Sony Alpha A6300 (Sony, Tokyo, Japan) in a SeaFrogs aluminium housing (Seafrogs, Shenzhen, China) with an Inon Z240 Type 2 (Inon, Tokyo, Japan) underwater strobe; a Canon EOS 550D (Canon, Tokyo, Japan) in an Ikelite polycarbonate housing (Ikelite, Indianapolis, Indiana, USA) with a Sea&Sea YS-D1 (Sea&Sea, Tokyo, Japan) underwater strobe; and two Olympus TG4 and TG5 (Olympus, Tokyo, Japan) compact cameras in Olympus polycarbonate housings, used without external strobes. All photographs taken during the monthly censuses were reviewed by three of the authors (E.M., M.P., and M.B.) to correctly identify the species.

3. Results

3.1. General Biodiversity

Over the nine-year study period, a total of 8289 sea slug individuals were recorded. Table 2 summarizes the number of individuals and species observed each year, together with the total diving hours and sampling effort. The average annual abundance was approximately 900 individuals, with notable peaks in 2016 and 2017, when more than 1400 individuals were counted. Conversely, 2014 saw the lowest count, with only 461 individuals, which coincided with prolonged adverse weather conditions limiting sampling to just 36 h of diving. The average number of individuals observed per hour of sampling was 16, reaching maximum values of 27 and 23 individuals per hour in 2016 and 2017, respectively, and minimum values of 12 individuals per hour in 2013 and 2015. Species richness (α-diversity) varied between slightly under 50 and slightly over 60 species. The threshold of 60 species was only exceeded in 2011, 2016, and 2017.

Table 2. Total number of individuals, species observed, and sampling effort in each year.

Year	Number of Individuals	Total Species	Diving Hours	Individuals/Hour
2010	725	48	48	15
2011	1160	62	89	13
2012	582	49	40	14
2013	788	52	63	12
2014	461	36	32	14
2015	691	55	54	12
2016	1467	61	53	27
2017	1447	61	62	23
2019	968	45	53	18
Total	8289	98	494	Mean: 16

In total, 98 distinct species were recorded within the PNMMBT boundaries, including 62 species not previously documented in the natural park. It is important to note that, due to the protected status of the park, substrate sampling (e.g., hydrozoan colonies or various algal substrates) was not permitted. As a result, the species list presented in Table 3 primarily comprises larger and more conspicuous taxa readily visible to observers during visual censuses.

Table 3 presents the list of species along with their absolute and relative abundances. Only 6 of the 98 species recorded exceeded 5% relative frequency (Figure 3)—*Cratena peregrina*, *Edmundsella pedata*, *Flabellina affinis*, *Felimare tricolor*, *Peltodoris atromaculata*, and *Diaphorodoris papillata*—together accounting for 54.45% of all individuals observed. Meanwhile, 74 species each represented <1% of the total, and 18 species were recorded as single individuals, highlighting the inherent variability and unpredictability of visual detection for some taxa. In the years 2016 and 2017, which yielded the highest specimen counts, *Cratena peregrina* was particularly abundant, with 369 individuals recorded in 2016 and 204 in 2017. *Flabellina affinis* was abundant in 2016 with 211 individuals recorded, and *Felimare tricolor* reached 169 individuals in 2017. Notably, *Cratena peregrina* also showed high numbers in 2019, with 222 individuals recorded. Taxonomically, the species recorded across the study comprised 76 Nudibranchia, 10 Sacoglossa, 5 Aplysiida, 3 Pleurobranchida, 2 Umbraculida, 1 Runcinida, and 1 Cephalaspidea.

Table 3. Absolute and relative abundances (%) of species recorded in the PNMMBT over the nine-year study period.

ID	Species	Absolute Abundance	% Relative Abundance
1	*Cratena peregrina*	1379	16.98
2	*Edmundsella pedata*	687	8.46
3	*Flabellina affinis*	683	8.41
4	*Felimare tricolor*	606	7.46
5	*Peltodoris atromaculata*	544	6.70
6	*Diaphorodoris papillata*	520	6.40
7	*Calmella cavolini*	329	4.05
8	*Thuridilla hopei*	215	2.65
9	*Paraflabellina ischitana*	209	2.57
10	*Felimare orsinii*	190	2.34
11	*Tenellia caerulea*	185	2.28
12	*Diaphorodoris luteocincta*	184	2.27
13	*Placida dendritica*	175	2.16
14	*Candiella striata*	162	2.00
15	*Nemesignis banyulensis*	149	1.84
16	*Doto koenneckeri*	145	1.79
17	*Felimida krohni*	142	1.75
18	*Facelinopsis marioni*	134	1.65
19	*Felimare fontandraui*	116	1.43
20	*Candiella odhneri*	114	1.40
21	*Diaphorodoris alba*	113	1.39
22	*Elysia viridis*	103	1.27
23	*Elysia timida*	88	1.08
24	*Bosellia mimetica*	82	1.01
25	*Phyllidia flava*	63	0.78
26	*Berghia coerulescens*	61	0.75
27	*Crimora papillata*	57	0.70
28	*Caloria elegans*	51	0.63
29	*Luisella babai*	46	0.57
30	*Tenellia ocellata*	44	0.54
31	*Felimare villafranca*	42	0.52
32	*Limacia clavigera*	26	0.32
33	*Tylodina perversa*	25	0.31
34	*Polycera quadrilineata*	25	0.31
35	*Doto floridicola*	24	0.30
36	*Candiella manicata*	24	0.30
37	*Tenellia genovae*	20	0.25

Table 3. *Cont.*

ID	Species	Absolute Abundance	% Relative Abundance
38	*Platydoris argo*	19	0.23
39	*Marionia blainvillea*	17	0.21
40	*Elysia gordanae*	16	0.20
41	*Aplysia parvula*	16	0.20
42	*Berthellina edwardsii*	15	0.18
43	*Felimare picta*	15	0.18
44	*Eubranchus farrani*	15	0.18
45	*Favorinus branchialis*	15	0.18
46	*Facelina auriculata*	14	0.17
47	*Tenellia morrowae*	14	0.17
48	*Coryphella lineata*	13	0.16
49	*Paraflabellina gabinierei*	12	0.15
50	*Felimida luteorosea*	12	0.15
51	*Facelina rubrovittata*	11	0.14
52	*Trapania maculata*	11	0.14
53	*Felimida binza*	10	0.12
54	*Placida verticilata*	9	0.11
55	*Dendrodoris limbata*	8	0.10
56	*Trapania lineata*	7	0.09
57	*Felimida purpurea*	7	0.09
58	*Aplysia fasciata*	6	0.07
59	*Runcina adriatica*	6	0.07
60	*Tenellia miniostriata*	5	0.06
61	*Aglaja tricolorata*	5	0.06
62	*Aplysia punctata*	5	0.06
63	*Spurilla neapolitana*	5	0.06
64	*Calmella gaditana*	4	0.05
65	*Idaliadoris neapolitana*	4	0.05
66	*Candiella lineata*	4	0.05
67	*Doto* sp.	4	0.05
68	*Dendrodoris grandiflora*	3	0.04
69	*Piseinotecus soussi*	3	0.04
70	*Doto coronata*	3	0.04
71	*Placida cremoniana*	3	0.04
72	*Doto paulinae*	3	0.04
73	*Doto dunnei*	3	0.04
74	*Petalifera petalifera*	2	0.02
75	*Facelina annulicornis*	2	0.02
76	*Aeolidiella alderi*	2	0.02
77	*Umbraculum umbraculum*	2	0.02
78	*Atalodoris pusilla*	2	0.02

Table 3. *Cont.*

ID	Species	Absolute Abundance	% Relative Abundance
79	*Hancockia uncinata*	2	0.02
80	*Atalodoris sparsa*	2	0.02
81	*Geitodoris planata*	1	0.01
82	*Tenellia foliata*	1	0.01
83	*Tenellia albopunctata*	1	0.01
84	*Jorunna tomentosa*	1	0.01
85	*Antiopella cristata*	1	0.01
86	*Facelina vicina*	1	0.01
87	*Hermaea variopicta*	1	0.01
88	*Elysia flava*	1	0.01
89	*Berthella perforata*	1	0.01
90	*Caloria quatrefagesi*	1	0.01
91	*Felimare bilineata*	1	0.01
92	*Tayuva maculosa*	1	0.01
93	*Armina neapolitana*	1	0.01
94	*Berthella ocellata*	1	0.01
95	*Aplysia depilans*	1	0.01
96	*Okenia mediterranea*	1	0.01
97	*Doto eireana*	1	0.01
98	*Doriopsilla rarispinosa*	1	0.01

3.2. Abundance by Sampling Stations and Seasons

Table 4 summarizes the number of individuals recorded over the study period across various sites within the study areas: the Montgrí coast, Medes Islands and Baix Ter. On the Montgrí coast, the sites of Falaguer and Punta Salines stand out, with 522 and 361 individuals recorded, respectively. In the Medes Islands, Ferranelles and Tascó Petit clearly dominate, with 1483 and 1389 individuals observed, respectively—greatly exceeding counts at other locations in the area. Although survey effort varied among sites, the most informative metric is the number of individuals recorded per hour of observation. To account for differences in effort, a ratio was calculated by dividing the total number of individuals observed by the total observation hours at each site. Using this standardized measure, the Montgrí coast site of Foradada stands out with 46 individuals per hour, followed by Baix de Cols with 37 individuals per hour. In contrast, Illa Ferriol and Ponedora de Sípies exhibited the lowest ratios, with four and one individuals per hour, respectively. In the Medes Islands, the ratios were relatively uniform, ranging from 8 individuals per hour at Racó del Sant Estiu to 28 individuals per hour at Tascó Gros. Most sites in this area recorded values between 15 and 20 individuals/hour.

At the site of Tascó Petit in the Medes Islands, an intensive census was conducted in 2011, involving 11 dives carried out with consistent sampling effort—one per month, except in April when adverse sea conditions prevented diving. A total of 904 individuals were recorded. Figure 4 illustrates the monthly variation in the number of individuals observed, although no clear abundance trend was evident. Nevertheless, with the exception of August, higher numbers of sea slug sightings were generally recorded in winter (especially February and December) and spring (notably May and June).

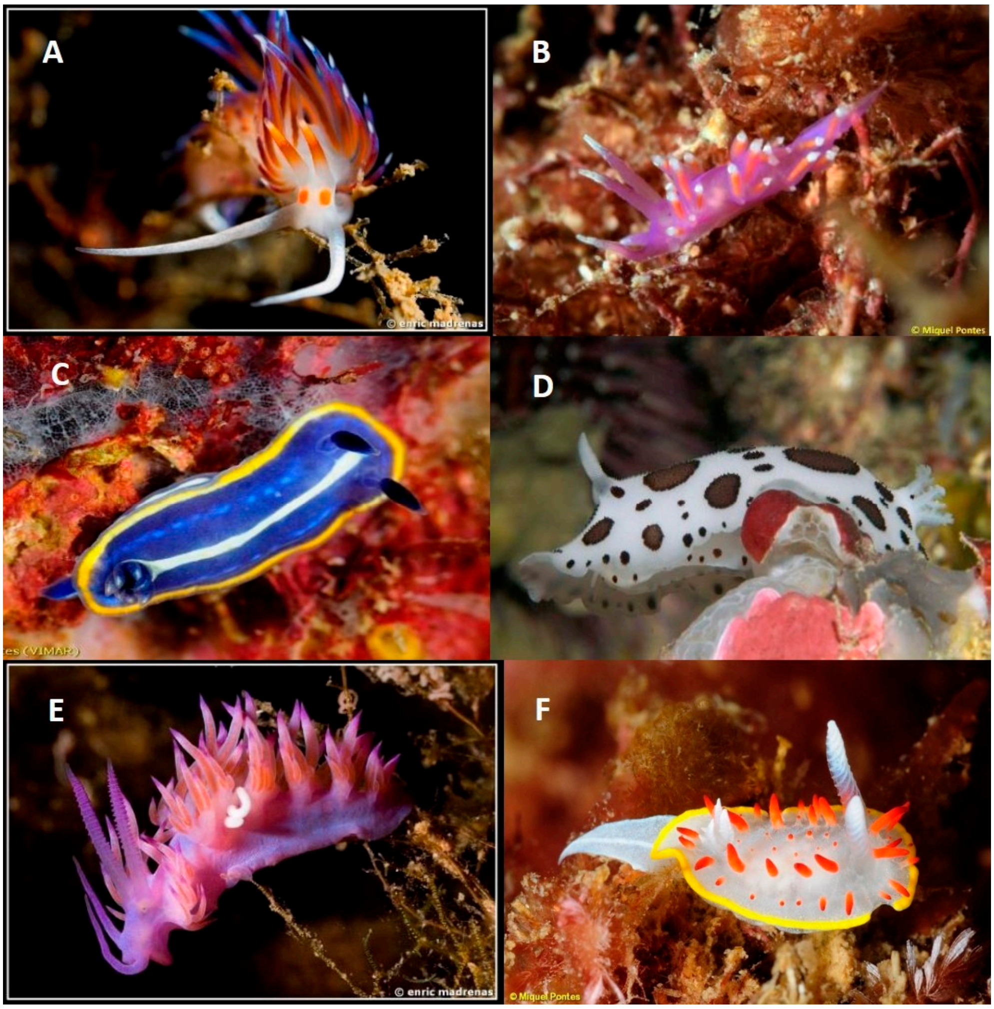

Figure 3. Species with more than 5% relative abundance over the study period. (**A**) *Cratena peregrina*; (**B**) *Edmundsella pedata*; (**C**) *Felimare tricolor*; (**D**) *Peltodoris atromaculata*; (**E**) *Flabellina affinis* with white eggs of a parasitic copepod; (**F**) *Diaphorodoris papillata*. Pictures (**A**,**E**): Enric Madrenas; Pictures (**B**–**D**,**F**): Miquel Pontes.

Table 4. Number of observed individuals throughout the study period across the different sites within the study areas. The overall ratio of individuals per hour does not include the single observation from the Baix Ter zone, as it is not representative of the sampling effort.

Zone and Location	Observed Individuals	Sample Hours	Ratio Individuals/Hour
Montgrí coast	1411	71	Average 20
Baix de Cols	183	5	37
Falaguer	522	27	19
Illa Ferriol	52	12	4
Illa Pedrosa	64	6	11
La Foradada	228	5	46
Punta Salines	361	16	23
Medes Islands	6877	408	Average 16
Carall Bernat	486	22	23
Dofí Nord	289	27	11

Table 4. *Cont.*

Zone and Location	Observed Individuals	Sample Hours	Ratio Individuals/Hour
Dofí Sud	416	26	16
El Guix	281	18	16
El Medallot	239	12	23
Ferranelles	1483	93	16
La Reina	85	6	14
La Vaca	474	37	13
Pedra de Déu	385	17	16
Pota del Llop	133	9	15
Racó del Sant Estiu	137	17	8
Salpatxot	470	34	14
Tascó Gros	610	22	28
Tascó Petit	1389	68	21
Baix Ter	1	1	Average 1
Ponedora de Sípies	1	1	1

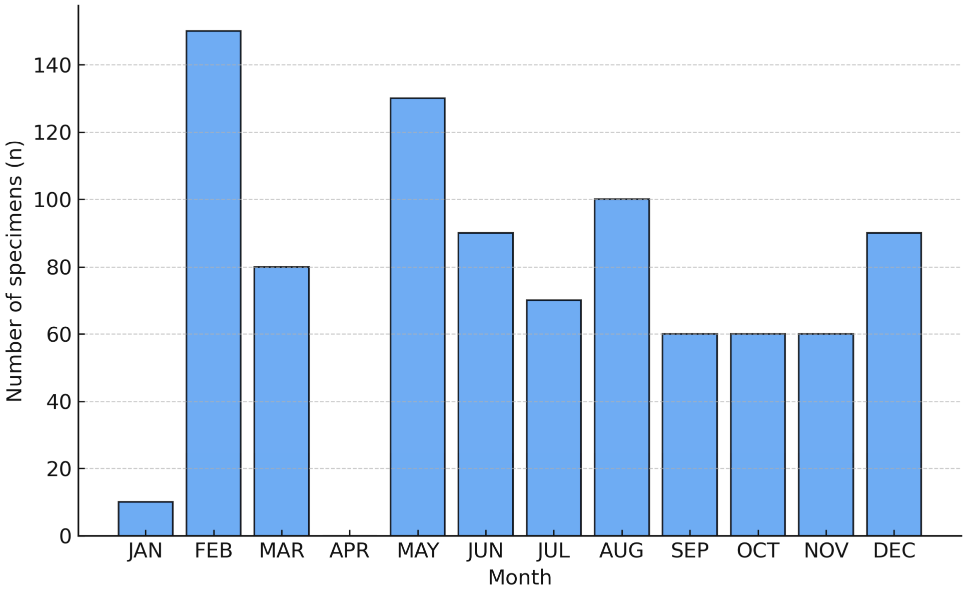

Figure 4. Abundances of individuals in the monthly censuses in the locality of Tascó Petit, Medes Islands, over the year 2011.

Figure 5 shows the abundance of the five most abundant species found in our study in the different seasons of the year. It can be seen how *Cratena peregrina* and *Flabellina affinis*, two species of aeolidaceans, are more abundant in the summer and autumn months, which is when their food species, the hydrozoans of the genus *Eudendrium*, are at peak colony development. Another aeolidacean, *Edmundsella pedata,* has a broader diet with several species of hydrozoans such as the sertularid of the genus *Abietinaria*, the thecate hydrozoan of the genus *Aglaophenia,* or the athecate hydrozoan of the genus *Eudendrium*, so it occurs more homogeneously throughout the seasons of the year. The dorid nudibranchs *Felimare tricolor* and *Peltodoris atromaculata* occur throughout the year with minor differences in abundance during the seasons since the sponges on which they feed have a constant presence on the seabed throughout the year.

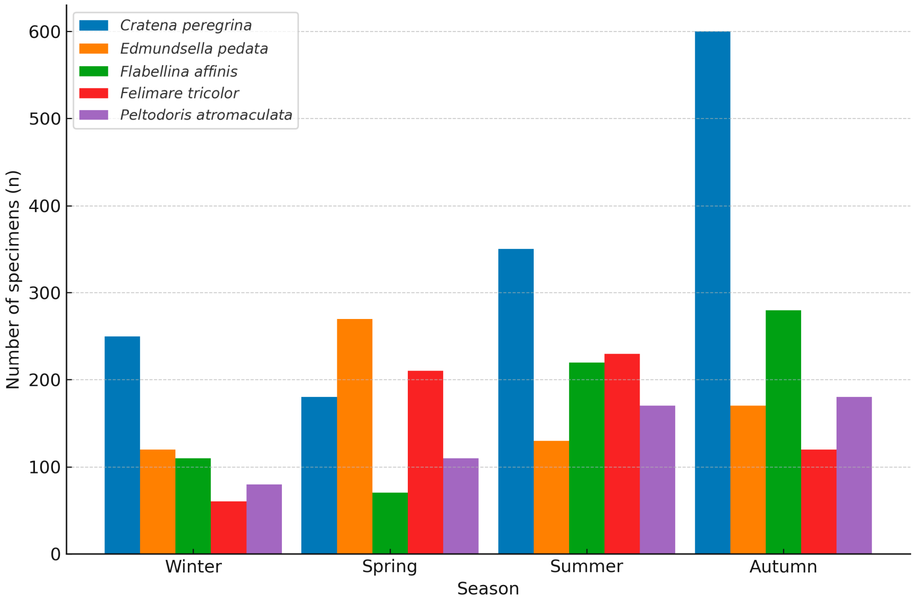

Figure 5. Abundance in the different seasons of the year of the five most abundant species found in our study. The numbers on the y-axis indicate the number of individuals observed.

Considering the three water temperature ranges (T < 15 °C; 15 °C ≤ T < 20 °C; T ≥ 20 °C), there are no significant differences in the percentage of records observed, which are 32%, 32%, and 36% respectively.

Regarding the species, 46% of the observations of *Cratena peregrina* occurred when the temperature is higher than 20 °C and the number of observations decreased as the water temperature decreased (28% of observations with the water between 15 and 20 °C and 26% of observations when the water was less than 15 °C). Another of the most abundant species, *Edmundsella pedata*, was recorded in 43% of observations when the water was between 15 and 20 °C and only 18% of the observations when the water temperature was below 15 °C. The sacoglossan *Elysia timida* was present in 94% of observations when the seawater was above 20 °C and was never observed at temperatures below 15 °C. On the other hand, the doridacean *Diaphorodoris papillata* reached its highest number of observations, 56% of records, when the water temperature was below 15 °C, and 30% of the observations when the temperature was between 15 °C and 20 °C, so it can be considered as a species that has a preference for colder waters and is therefore more abundant in the winter and early spring months. The evolution of the average water temperature in the study area in the different months and years can be seen in Figure 6. Analyzing the Shannon index in the different months sampled over the years, it can be observed how it presents relatively uniform values for the respective temperature intervals (Table 5), so it can be assumed that the temperature factor is not a conditioning factor in terms of biodiversity.

Table 5. Shannon diversity index values according to seawater temperature (°C) in the sampled months.

Seawater Temperature	**T < 15 °C**	**T ≥ 15 °C T < 20 °C**	**T ≥ 20 °C**
Shannon Diversity Index	4.68	4.54	4.04

3.3. Abundance by Depth Intervals

Figure 7 presents the number of sea slug observations by 5 m depth intervals across the different years of the study, excluding 2011 and 2018 due to the absence of depth data. While not all survey sites allow divers to reach the maximum depth of 30 m, the distribution of observations across years generally follows a bell-shaped (Gaussian) pattern, with peak counts typically around 20 m. Notable exceptions include 2014, 2016, and 2019, where peak observations occurred in the 11–15 m, 6–10 m, and 11–15 m intervals, respectively. Notably, 616 individuals were recorded in the 6–10 m range in 2016, and 469 individuals in the 16–20 m range in 2017.

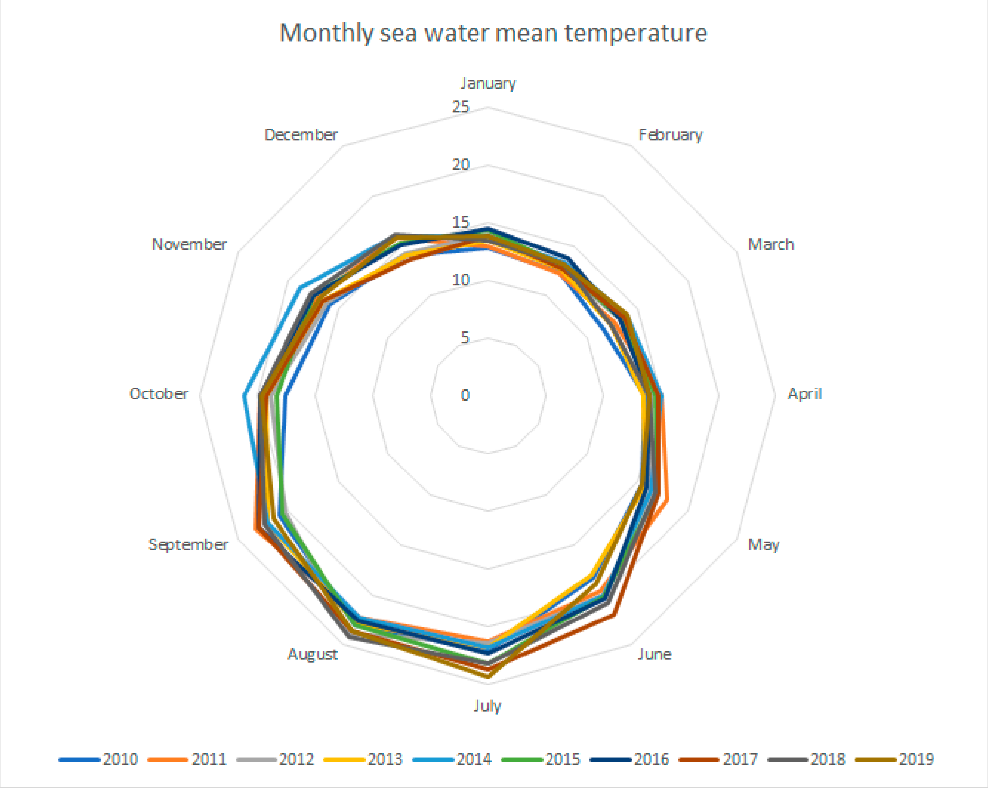

Figure 6. Mean monthly seawater temperatures (°C) recorded in the study area during the study years. Data extracted from temperature reports by Josep Pascual (Servei Meteorològic de Catalunya [26]).

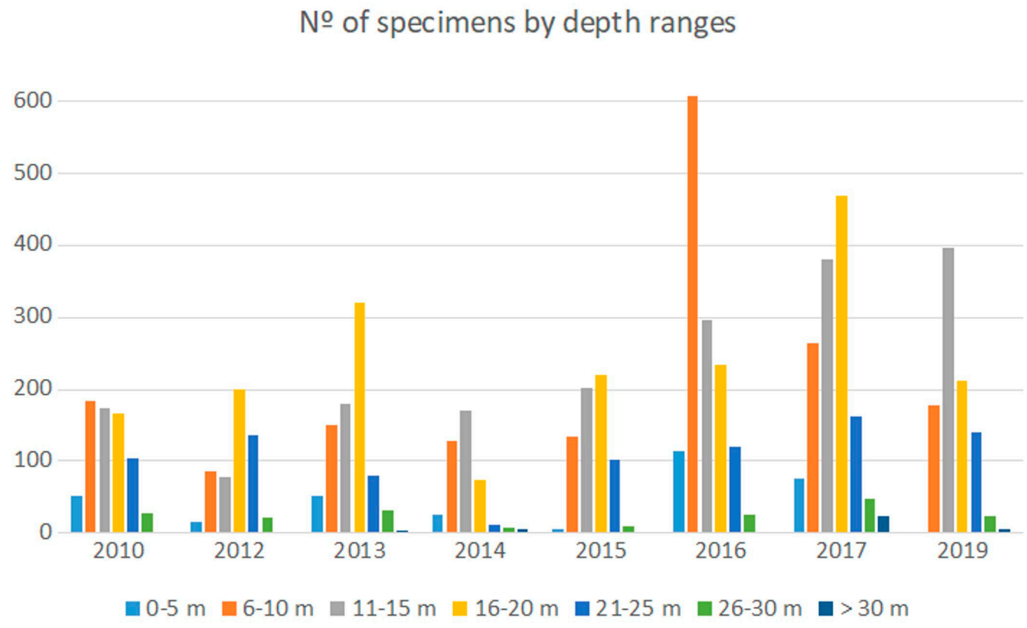

Figure 7. Observations of individuals by depth intervals across the study years.

At higher taxonomic levels, such as family or order, distinct depth-related patterns emerge. Sacoglossan species, owing to their herbivorous diet, are more commonly found in the shallower depth ranges (0–5 m and 6–10 m), where photophilic algal biodiversity is the greatest. In contrast, at depths below 15 m or in low-light habitats, dorid nudibranchs—particularly those that feed on sponges—are more frequently observed. These results indicate that both depth and light availability are key factors influencing the vertical distribution of sea slug assemblages.

3.4. Shannon–Wiener Index

The Shannon–Wiener diversity index (H′) remained relatively stable throughout the study period (Figure 8), with values ranging from 4.09 in 2016 to 4.65 in 2011, and a global average of 4.4 across all years. These consistently high values reflect the presence of rich and diverse sea slug assemblages within the PNMMBT.

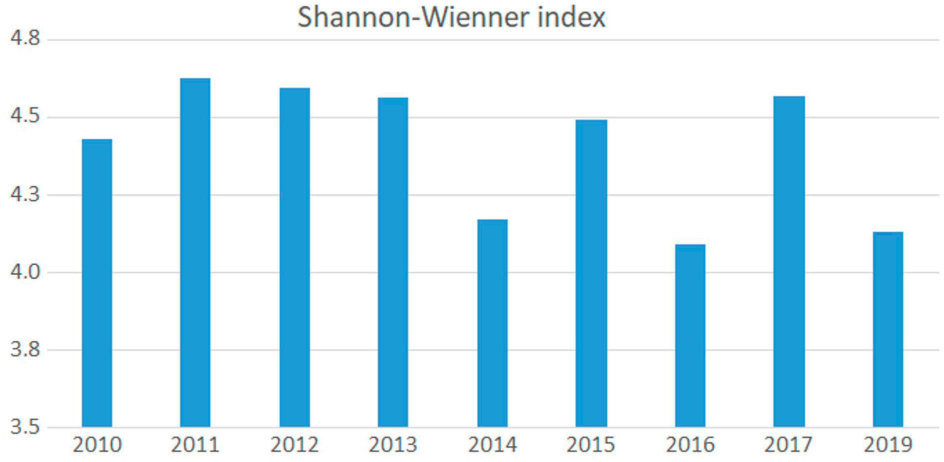

Figure 8. Evolution of the Shannon–Wiener index (H′) throughout the study period.

Figure 9 and Table 6 illustrates the number of species cited in each of the studies indicated on the x-axis (blue line), the species added to the sea slug census in the PNMMBT in each of these studies (brown line), and the cumulative total of total species (gray line).

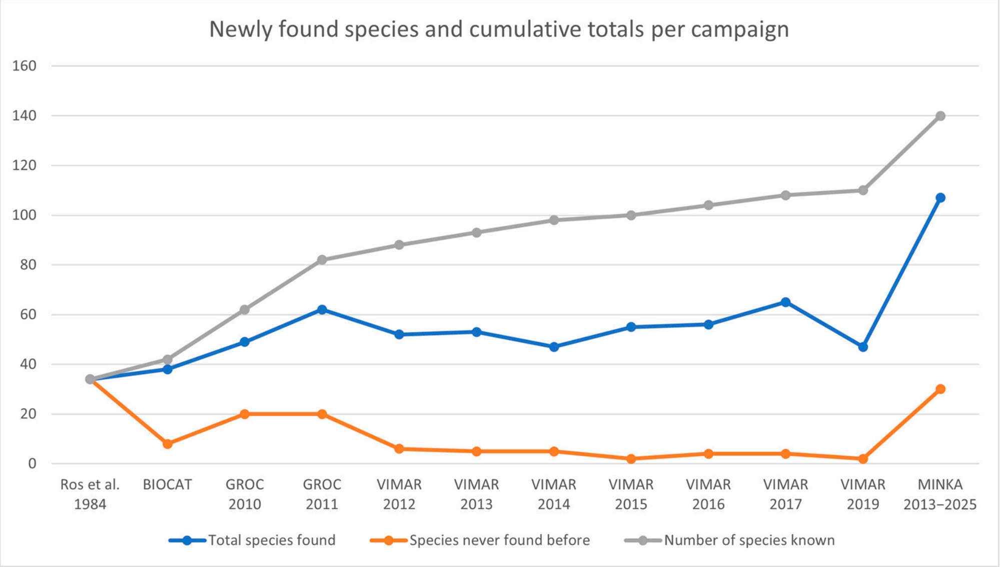

Figure 9. Newly found species and cumulative totals per sampling campaign. Starting point refers to the first study by J.D. Ros et al. [20].

Table 6. Newly found species and cumulative totals per sampling campaign in the PNMMBT.

	Total Species Found	Species Never Found Before	Number of Species Known
Ros et al. [20]	34	34	34
BIOCAT	38	8	42
GROC 2010	49	20	62
GROC 2011	62	20	82
VIMAR 2012	52	6	88
VIMAR 2013	53	5	93
VIMAR 2014	47	5	98
VIMAR 2015	55	2	100
VIMAR 2016	56	4	104
VIMAR 2017	65	4	108
VIMAR 2019	47	2	110
MINKA 2013–2025	108	31	141

3.5. Later Findings

Visual surveys within the PNMMBT continued beyond the end of the formal study in 2019, but were interrupted in March 2020 due to mandatory confinement measures during the SARS-CoV-2 pandemic. Following this hiatus, sampling activities resumed under normal conditions; however, other groups and citizen scientists were engaged. In recent years, citizen science has emerged as a powerful tool for biodiversity research, conservation, and public engagement. Digital platforms dedicated to citizen science now allow naturalists, researchers, and amateurs alike to document and share observations of wildlife in real time, significantly enriching collective knowledge. Among these platforms, MINKA [27] has distinguished itself as a collaborative hub designed to bridge the gap between professional scientists and the broader public in Catalonia and the rest of Spain. MINKA functions as an inclusive observation-sharing platform where users can upload photographs, identify species, and contribute ecological data, particularly in marine and coastal environments. It emphasizes accessibility and scientific rigor, allowing contributions from both experienced researchers and amateur naturalists. Observations submitted to MINKA are publicly available, always validated by experts (this is a differential trait with other platforms like iNaturalist), and can be used to support scientific research, biodiversity monitoring, and environmental education. By fostering a dynamic and supportive community, platforms like MINKA empower citizens to participate in scientific discovery, while also enabling professionals to access large volumes of field data that would be otherwise unattainable. In this way, citizen science not only democratizes knowledge creation but also plays an increasingly critical role in documenting species distributions, detecting range shifts, and responding to global biodiversity challenges.

Figure 10 shows all the sea slug species recorded on the aforementioned MINKA citizen science platform, represented by blue markers. As can be seen, the vast majority of records appear in the northern and southern areas of the park boundaries, where the coast is rocky, and on the Medes Islands. There are no records in the central area of the park because it is a sandy beach area lacking rocky outcrops, which is heavily visited by bathers for most of the year.

To give a more accurate view of the current sea slug diversity in the PNMMBT, we have included the first records (for the studied area) of numerous species uploaded to the MINKA platform, tagged as research-grade by experts, based on contributed photographs, and produced an annotated taxonomical list serving as an updated, annotated, reference checklist for the sea slugs of the Parc Natural del Montgrí, les illes Medes i el Baix Ter.

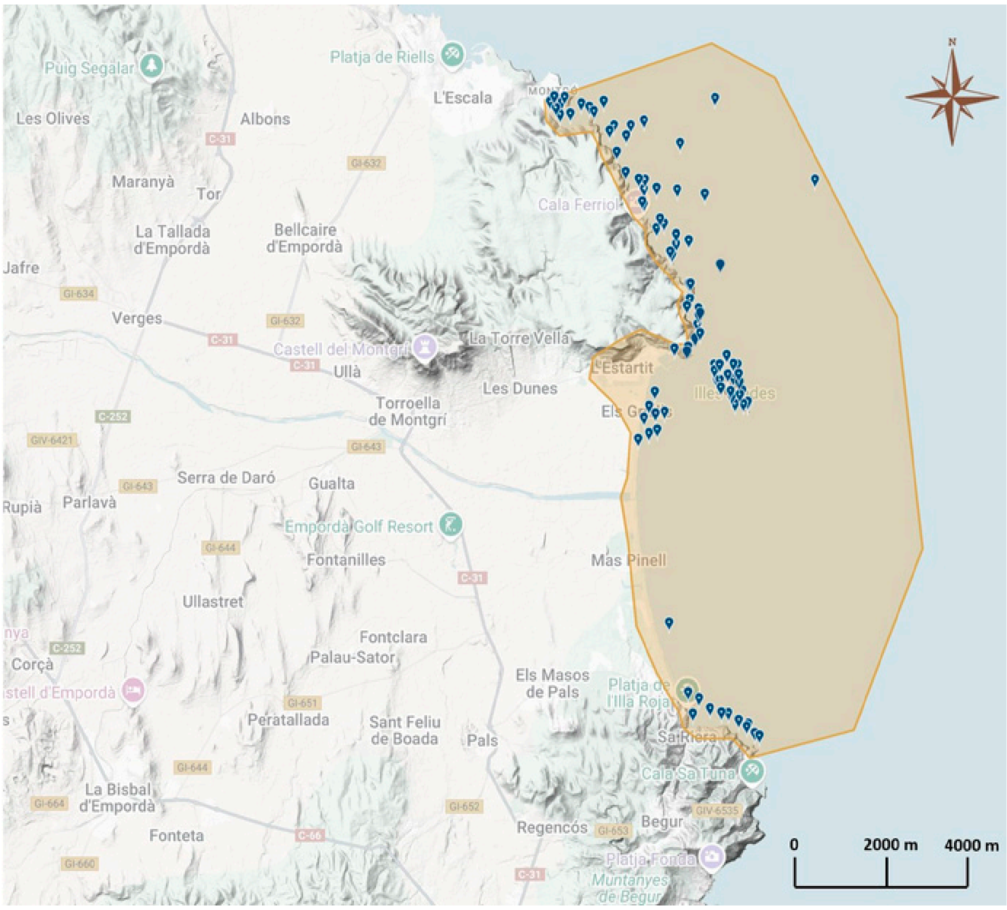

Figure 10. PNMMBT points (in blue) where sea slug species have been reported on the MINKA citizen science platform. The orange-colored area corresponds to the PNMMBT boundaries including its influence zones. Source: MINKA platform [27].

3.6. Annotated Taxonomic Checklist of Sea Slugs in the PNMMBT

This checklist provides an annotated account of all sea slug species recorded to date from the Parc Natural del Montgrí, les Illes Medes i el Baix Ter (PNMMBT) covering the Medes Islands, the Montgrí coastline northward to Cala Montgó, and southward through the Baix Ter region to the mouth of the Ter River. Some species come from the area of influence, southern part of bay of Pals to the north, and Sa Riera inlet to the south. Records are based on verified observations produced on the field. Species marked with an asterisk (*) in the checklist were documented in the area solely by community scientists via the MINKA citizen science platform and fall outside the scope of the initial study. Where relevant, superscript notes offer additional taxonomic or ecological commentary. In each group, the families are arranged alphabetically. Within each family, species are listed alphabetically.

Class GASTROPODA
Subclass Heterobranchia
  Subterclass Acteonimorpha
    Acteonidae
      * *Acteon tornatilis* [1]
  Order Aplysiida
    Aplysiidae

Aplysia depilans
Aplysia fasciata
Aplysia punctata[2]
Petalifera petalifera
Phyllaplysia lafonti
Order Cephalaspidea
Aglajidae
Aglaja tricolorata
* *Camachoaglaja africana*[3]
Philinopsis depicta
Bullidae
* *Bulla striata*[4]
Cylichnidae
* *Cylichna cylindracea*[5]
Haminoeidae
Haminoea hydatis
Haminoea navicula
Philinidae
* *Hermania scabra*[6]
* *Philine catena*[7]
* *Philine quadripartita*[8]
Order Nudibranchia
Aeolidiidae
Aeolidiella alderi
Berghia coerulescens
* *Berghia verrucicornis*[9]
* *Cerberilla bernadettae*[10]
* *Limenandra nodosa*[11]
Spurilla neapolitana
Arminidae
Armina neapolitana
Cadlinidae
Cadlina laevis
Calycidorididae
Diaphorodoris alba
Diaphorodoris luteocincta[12]
Diaphorodoris papillata
Chromodorididae
Felimare bilineata
Felimare fontandraui
Felimare orsinii
Felimare picta
Felimare tricolor
Felimare villafranca
Felimida binza
Felimida krohni
Felimida luteorosea
Felimida purpurea
Coryphellidae
Coryphella lineata[13]

Dendrodorididae
  Dendrodoris grandiflora
  Dendrodoris limbata
  * *Dendrodoris temarana* [14]
  Doriopsilla rarispinosa [15]
Dendronotidae
  Scyllaea pelágica [47]
Discodorididae
  Geitodoris planata
  * *Geitodoris portmanni* [16]
  Jorunna tomentosa
  * *Paradoris indecora* [17]
  Peltodoris atromaculata
  Platydoris argo
  * *Taringa armata* [18]
  Tayuva maculosa [19]
Dorididae
  Doris verrucosa
Dotidae
  * *Doto cervicenigra* [20]
  Doto coronata
  Doto dunnei
  Doto eireana
  Doto floridicola
  Doto koenneckeri
  Doto paulinae
  * *Doto pygmaea* [21]
  Doto rosea
Eubranchidae
  * *Amphorina andra* [22, 24]
  * *Eubranchus exiguus* [23]
  Eubranchus farrani [24]
Facelinidae
  Caloria elegans
  Caloria quatrefagesi
  Cratena peregrina
  Facelina annulicornis
  Facelina auriculata
  * *Facelina dubia* [25]
  Facelina rubrovittata
  Facelina vicina [26]
  Facelinopsis marioni
  Favorinus branchialis
Fionidae
  * *Fiona pinnata* [27]
Flabellinidae
  Calmella cavolini
  Calmella gaditana
  Edmundsella pedata
  Flabellina affinis

  Paraflabellina gabinierei
  Paraflabellina ischitana
Goniodorididae
  * *Goniodoridella picoensis*[28]
  Okenia mediterranea
  Trapania lineata
  Trapania maculata
Hancockiidae
  Hancockia uncinata
Janolidae
  Antiopella cristata
Myrrhinidae
  Nemesignis banyulensis
Onchidorididae
  Atalodoris pusilla[29]
  Atalodoris pictoni[30]
  Atalodoris sparsa
  * *Idaliadoris depressa*[31]
  Idaliadoris neapolitana
Phyllidiidae
  Phyllidia flava
Piseinotecidae
  Piseinotecus soussi
Polyceridae
  Crimora papillata
  Limacia cf. *iberica*[32]
  Limacia inesae[33]
  * *Martadoris mediterranea*[34]
  Polycera quadrilineata
Samlidae
  Luisella babai
Tethydidae
  Tethys fimbria
Trinchesiidae
  Tenellia albopunctata
  Tenellia caerulea
  * *Tenellia cuanensis*[35]
  * *Tenellia foliata*[36]
  Tenellia genovae
  Tenellia miniostriata
  Tenellia morrowae[37]
  Tenellia ocellata
Tritoniidae
  Candiella lineata
  Candiella manicata
  Candiella odhneri[38]
  Candiella striata
  Marionia blainvillea
Order Pleurobranchida
Pleurobranchidae

Berthella aurantiaca [39]
Berthella ocellata
Berthella perforata [40]
Berthellina edwardsii
Pleurobranchaea meckeli
Pleurobranchus testudinarius
Order Pteropoda
Creseidae
* *Creseis acicula* [41]
Superorder Ringiculimorpha
Ringiculidae
* *Ringicula conformis* [42]
Order Runcinida
Runcinidae
Runcina adriatica
Runcina bahiensis
Runcina coronata
* *Runcina* cf. *ornata* [43]
Superorder Sacoglossa
Hermaeidae
Hermaea variopicta
Limapontiidae
Placida cremoniana
Placida dendritica
Placida verticilata
* *Placida viridis* [44]
Oxynoidae
* *Oxynoe olivacea* [45]
Plakobranchidae
Bosellia mimetica
Elysia flava
Elysia gordanae [46]
Elysia timida
Elysia viridis
Thuridilla hopei
Order Umbraculida
Tylodinidae
Tylodina perversa
Umbraculidae
Umbraculum umbraculum

Observation and Taxonomical Notes

(1) First report of *Acteon tornatilis* in the PNMMBT was recorded on 9 January 2021 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/74189—accessed on 7 July 2025).
(2) A recent study by Golestani et al. [28] concluded that all Mediterranean Sea hares previously identified as *Aplysia parvula* actually belong to *Aplysia punctata*. As a result, our records have been synonymized accordingly.
(3) First report of *Camachoaglaja africana* in the PNMMBT was recorded on 4 June 2023 at the Falaguer dive site by Joan Roig (MINKA—https://minka-sdg.org/observations/130896—accessed on 7 July 2025).

(4) First report of *Bulla striata* in the PNMMBT was recorded on 29 June 2024 at Cala Montgó by Xavier Salvador (MINKA—https://minka-sdg.org/observations/289396—accessed on 7 July 2025).

(5) First report of *Cylichna cylindracea* in the PNMMBT was recorded on 9 January 2021 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/74187—accessed on 7 July 2025).

(6) First report of *Hermania scabra* in the PNMMBT was recorded on 20 July 2024 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/306206—accessed on 7 July 2025).

(7) First report of *Philine catena* in the PNMMBT was recorded on 26 December 2017 at Cala Montgó by Xavier Salvador (MINKA—https://minka-sdg.org/observations/34350—accessed on 7 July 2025).

(8) First report of *Philine quadripartita* in the PNMMBT was recorded on 14 July 2024 at Cala Montgó by Xavier Salvador (MINKA—https://minka-sdg.org/observations/299032—accessed on 7 July 2025).

(9) First report of *Berghia verrucicornis* in the PNMMBT was recorded on 14 September 2017 at Cala Montgó by Margot Bosch (MINKA—https://minka-sdg.org/observations/482580—accessed on 7 July 2025).

(10) First report of *Cerberilla bernadettae* in the PNMMBT was recorded on 18 February 2021 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/74254—accessed on 7 July 2025).

(11) First report of *Limenandra nodosa* in the PNMMBT was recorded on 25 July 2016 at Cala Montgó by Guillem Mas (MINKA—https://minka-sdg.org/observations/480229—accessed on 7 July 2025).

(12) Many authors previously considered *Diaphorodoris luteocincta* var. *alba* and var. *reticulata* to be morphological variants of the same species. However, morphological and molecular analyses by Furfaro et al. [29] refute this view, demonstrating that they represented two distinct species: *D. alba* and *D. luteocincta*, respectively. Our records of *D. luteocincta* prior to the taxonomic revision by Furfaro et al. [29] include individuals that are now identified as *D. alba*.

(13) *Flabellina lineata* was reassigned to the genus *Fjordia* by Korshunova et al. [31] following molecular and morphological analyses that redefined the family Flabellinidae and established several new genera within Coryphellidae. However, a subsequent comprehensive revision of the family by Ekimova et al. [32] proposed a more conservative approach, arguing that excessive splitting—especially in allopatric taxa—led to taxonomic instability. As a result, they synonymized several recently erected genera, including *Fjordia*, under an expanded concept of *Coryphella*, currently accepted as the valid name in taxonomic databases like WoRMS.

(14) First report of *Dendrodoris temarana* in the PNMMBT was recorded on 30 June 2025 at Platja de Pals by Marta N.P. (MINKA—https://minka-sdg.org/observations/510533—accessed on 7 July 2025). Galià-Camps et al. [33] have recently reinstated this species, originally described by Pruvot-Fol in 1953 but considered, until now, synonymous with *D. grandiflora*.

(15) Furfaro et al. [34] revealed that *Doriopsilla areolata* (sensu lato) represents a Mediterranean cryptic species complex, including the reinstated *D. rarispinosa* (previously a synonym) and at least one putative lineage (*Doriopsilla* sp1). True *D. areolata* (s.s.) is currently confirmed only in the Adriatic Sea, whereas morphologically similar Atlantic and western Mediterranean individuals likely belong to the still-undescribed taxa *Doriopsilla* sp1. Our records in the PNMMBT correspond strictly to *D. rarispinosa*.

(16) First report of *Geitodoris portmanni* in the PNMMBT area of influence was recorded on 16 July 2015 at Cala Aiguafreda by Xavier Salvador (MINKA—https://minka-sdg.org/observations/24820—accessed on 7 July 2025).

(17) First report of *Paradoris indecora* in the PNMMBT was recorded on 26 December 2017 at Cala Montgó by Xavier Salvador (MINKA—https://minka-sdg.org/observations/34361—accessed on 7 July 2025).

(18) First report of *Taringa armata* in the PNMMBT was recorded on 18 February 2021 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/74256—accessed on 7 July 2025).

(19) Dayrat's [35] revision of Discodorididae consolidated several morphologically similar species into broader taxa, including the synonymization of the Mediterranean *Discodoris maculosa* under the circumtropical *Tayuva lilacina*. However, molecular studies [36] revealed *T. lilacina* to be a cryptic species complex. Mediterranean individuals were reassigned to *Tayuva maculosa* (Bergh, 1884), while northeastern Atlantic populations were resurrected as *Tayuva confusa* [37]. The study also identified a close phylogenetic relationship between *Tayuva* and *Peltodoris*, noting historical synonymies that warrant further genomic investigation. We adopt the classification of this species as *Tayuva maculosa*, currently accepted by WoRMS.

(20) First report of *Doto cervicenigra* in the PNMMBT was recorded on 18 February 2019 in the port of L'Estartit by Xavier Salvador (MINKA—https://minka-sdg.org/observations/40684—accessed on 7 July 2025).

(21) First report of *Doto pygmaea* in the PNMMBT was recorded on 20 July 2024 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/306188—accessed on 7 July 2025).

(22) Recent work by Toso et al. [38] proposed the reclassification of *Amphorina andra* as a junior synonym of *Eubranchus viriola*, citing occurrences of *A. andra* in brackish habitats as supporting evidence. However, this conclusion has been met with significant reservations. Martynov (pers. comm., 2025) highlights several critical concerns, including potential misidentification of individuals and the well-documented morphological and epigenetic distinctions of *A. viriola*, a taxon originally described from the brackish transition zone between the North and Baltic Seas [39]. Notably, *A. viriola* exhibits consistent phenotypic differences in this unique habitat, reinforcing its separation from *A. andra*. Given the lack of comprehensive molecular or ecological analysis in the proposed synonymy, we propose to provisionally keep the validity of *A. andra* until further studies are conducted to demonstrate whether it is *Eubranchus viriola*, or not. First report of *Amphorina andra* in the PNMMBT was recorded on 3 February 2021 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/74245—accessed on 7 July 2025).

(23) First report of *Eubranchus exiguus* in the PNMMBT was recorded on 2 November 2020 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/42343—accessed on 7 July 2025).

(24) The current classification of Fionoidea reflects a fundamental dichotomy in systematic philosophy. One perspective advocates for narrowly circumscribed genera based on fine-scale morphological and molecular distinctions, an approach that frequently results in monotypic genera. While this methodology serves to highlight proposed autapomorphies, it has been criticized for promoting taxonomic inflation and instability, particularly when such distinctions are not supported by robust synapomorphic evidence. An alternative framework favors the recognition of broader, more inclusive genera, emphasizing stability and practical utility. This approach is particularly justified in groups where much of the diversity remains undescribed or poorly charac-

terized. By maintaining larger, morphologically cohesive units, this system reduces nomenclatural disruption while still reflecting evolutionary relationships. A prudent course of action would be to adopt a conservative classification that recognizes well-supported clades without unnecessary splitting. Genera should be subdivided only when supported by unambiguous synapomorphies and comprehensive phylogenetic evidence. This balanced approach would maintain scientific rigor while ensuring the classification remains accessible to both specialists and non-specialists alike. This would provide much-needed stability while still allowing for future refinements as our understanding of fionid phylogeny improves. We currently adopt the classification of former *Amphorina farrani* as *Eubranchus farrani*, currently accepted by WoRMS.

(25) First report of *Facelina dubia* in the PNMMBT was recorded on 24 July 2022 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/73574—accessed on 7 July 2025).

(26) *Facelina vicina* is often confused with *Facelina bostoniensis*, an amfiatlantic species initially described on the shores of Massachusetts and Maine (USA), and also present in the Atlantic European shores from Norway to the Iberian Peninsula (Cantabria and Portugal). According to Carmona [40], reports of *F. bostoniensis* from the Mediterranean Sea correspond to *Facelina vicina* (Bergh, 1882).

(27) *Fiona pinnata* is a cosmopolitan species that has been reported from all the world's oceans. In Catalonia, it has consistently been found associated with floating objects that reach the coast. First report in the PNMMBT influence area was recorded on 11 August 2024 by Xavier Salvador (MINKA—https://minka-sdg.org/observations/326651—accessed on 7 July 2025).

(28) Originally described from Pico Island in the Azores [41], *Goniodoridella picoensis* has shown an exceptionally rapid spread across the Mediterranean Sea. Since the first Iberian record in La Herradura, southern Spain [42], it has been reported in numerous locations from the Alboran Sea to Israel within months, as detailed by Trainito et al. [43]. It reached Catalonia (Tamariu) by June 2021, the Balearic Islands by early 2022, and by 2023 had become frequent along the Catalan coast, including the PNMMBT.

(29) *Onchidoris albonigra* was originally described from the Mediterranean, but its poorly defined diagnosis led to confusion. Schmekel & Portmann [44] attempted a redescription based on Gulf of Naples material, yet inconsistencies persisted. Subsequent records, including those by Perrone [45] and Betti et al. [46], likely refer to *Atalodoris pictoni* or *A. pusilla*. Catalan individuals identified as *O. albonigra* (OPK, 2012) have since been confirmed as *A. pusilla* through both morphology and molecular data. Given the lack of type material and overlapping features—especially in mantle pigmentation and gill/rhinophore structure—Furfaro et al. [47] regarded *O. albonigra* as a junior synonym of *A. pusilla* following ICZN guidelines.

(30) *Atalodoris pictoni* was recently described after being long misidentified as *Onchidoris pusilla* due to shared external features such as a dark brown dorsum and white rhinophores. However, it differs in having dark gills matching the body color, unlike the white gills of *O. pusilla*. Hallas & Gosliner [48] restructured the Onchidorididae, merging *Onchidoris* and *Adalaria* (with median rachidian tooth) and creating *Knoutsodonta* for species lacking it. However, they overlooked the earlier genus *Atalodoris* Iredale & O'Donoghue, 1923—whose type species, *Doris pusilla*, also lacks a median tooth—rendering *Knoutsodonta* a junior synonym. Of the fifteen species listed under *Knoutsodonta* by Furfaro & Trainito [49], six are Mediterranean; Ortea [50] proposes transferring all species to *Atalodoris* in line with taxonomic priority.

(31) Furfaro et al. [47] introduced a new genus *Idaliadoris* Furfaro & Trainito, 2022 (type species *Idaliadoris neapolitana*) grouping eight species with finger-like dorsal papillae, more or less swollen, and with a common egg spawn shape. According to Furfaro et al. [47], the shape of the egg masses was revealed to be a useful diagnostic character allowing distinction between genera in the Onchidorididae systematics. First report of *Idaliadoris depressa* in the area of influence of the PNMMBT was recorded on 11 September 2015 at Punta de la Creu, Begur by Xavier Salvador (MINKA—https://minka-sdg.org/observations/4013—accessed on 7 July 2025).

(32) *Limacia iberica* is morphologically very similar to *Limacia clavigera*, with which it has been probably confused due to the poor description by Müller [51], who in 1776 described it with six words, literally, although the author later expanded the description with further information and illustrations in 1788 and 1806. These species differ in that *Limacia clavigera* has far fewer lateral papillae (20–24) and, in addition, they are much shorter and with an orange tip (not white as in *L. iberica*). *Limacia clavigera* has a tuberculated and much less spiculated dorsum, while in *L. iberica* there is a single mid-dorsal row of eight tubercles, and the mantle spicules are so long and abundant that they "break" the skin and can be seen with the naked eye. The tail of *Limacia clavigera* is longer and more stylized and with distinct yellow spots. The rhinophores are shorter and have fewer lamellae (10–14). A specimen with mixed traits between *L. iberica* and *L. clavigera* was found at Punta Salines (L'Estartit, Spain) on 19 September 2019 by Glenn Biscop (OPK—https://opistobranquis.info/wp-content/uploads/2019/10/Limacia-cf.-iberica-with-mixed-traits-with-L.clavigera-@-Punta-Salines-LEstartit-19.09.2019-by-Glenn-Biscop-P9190364LR.jpg—accessed on 7 July 2025).

(33) Historically misidentified with *Limacia clavigera*, according to the study by Toms et al. [52], the species *L. clavigera* appears to be strictly distributed in Atlantic waters from Norway to the coasts of western Andalusia (Spain), while the individuals of *L. inesae*, smaller in size, are distributed throughout the Mediterranean, Canary Islands, Madeira, and the Azores.

(34) *Martadoris mediterranea* closely resembles *M. limaciformis*, originally described in the Red Sea, with both species exhibiting a deep saffron-red body with scattered pale spots. However, *M. limaciformis* is distinguished by purple tips on the rhinophores and gills [53,54]. To rule out the hypothesis of a Lessepsian introduction, Domínguez et al. [55] conducted phylogenetic analyses confirming that *M. mediterranea* is a distinct species. It was subsequently assigned to the newly established genus *Martadoris* by Willan & Chang [56]. The first record of *Martadoris mediterranea* in the PNMMBT was recorded by Elena Bretaudeau on 1 July 2024, at a depth of 50 meters (OPK—https://opistobranquis.info/wp-content/uploads/2024/07/image_123650291-1.jpg—accessed on 7 July 2025).

(35) As with the family Eubranchidae, Trinchesiidae illustrates the broader debate between narrowly splitting genera based on fine-scale morphological and molecular differences and maintaining more inclusive, morphologically cohesive groups. In this case, we adopt the terminology proposed by several authors and currently accepted by WoRMS, transferring the Mediterranean species formerly placed in *Trinchesia* to the genus *Tenellia*, pending future studies that may resolve their taxonomic position. As previously emphasized, a balanced approach—splitting taxa only when shared, unambiguous traits are clearly supported—maintains scientific rigor while ensuring the classification remains accessible to both specialists and non-specialists. Historically, *Tenellia caerulea* and *T. cuanensis* were considered the same species due to their overall morphological and coloration patterns similarities. However, Korshunova et al. [57] demonstrated,

through an integrative approach combining molecular and morphological data, that these represent distinct species. Each shows consistent genetic divergence and subtle but stable differences in radular morphology and body coloration, supporting their recognition as separate taxa.

First report of *Tenellia cuanensis* in the area of influence of the PNMMBT was recorded (as *Cuthona caerulea*) on 14 February 2015 at Punta del Romaní, L'Escala by Guillem Mas and Josep Lluís Peralta (MINKA—https://minka-sdg.org/observations/474948—accessed on 7 July 2025).

(36) First report of *Tenellia foliata* in the area of influence of the PNMMBT was recorded on 2 July 2015 at Punta del Romaní, L'Escala by Guillem Mas (MINKA—https://minka-sdg.org/observations/476475—accessed on 7 July 2025).

(37) Historically, *Tenellia morrowae* and *T. caerulea* were considered the same species due to their overall morphological and coloration patterns similarities. However, Korshunova et al. [57] demonstrated, through an integrative approach combining molecular and morphological data, that these represent distinct species. Each shows consistent genetic divergence and subtle but stable differences in radular morphology and body coloration, supporting their recognition as separate taxa.

(38) *Candiella odhneri* was originally described by J. Tardy [58] as *Duvaucelia odhneri*, later transferred to *Tritonia* as *Tritonia odhneri* (Tardy, 1963). However, this name was preoccupied by *Tritonia odhneri* Marcus, 1959, from the Chilean Pacific. To resolve the homonymy, Eveline Marcus [59] proposed the replacement name *Tritonia nilsodhneri*, which remained in use until late 2020. At that time, Korshunova & Martynov [60] reinstated the genus *Duvaucelia* to accommodate small Tritoniidae species characterized by a non-bilobed oral veil and a moderate number of lateral radular teeth, mainly found in temperate and subtropical European waters. More recently, De Vasconcelos et al. [61] demonstrated that the original description of *Duvaucelia gracilis* (type species of *Duvaucelia*) actually referred to a specimen of *Marionia blainvillea*, not *Duvaucelia manicata* as previously assumed. Consequently, *Duvaucelia* is no longer considered a valid genus, and the name *Candiella* has been reinstated, based on its type species *Candiella plebeia*.

(39) *Berthella aurantiaca* has traditionally been confused with *Berthellina edwardsii* due to their remarkably similar external morphology—so much so that they are virtually indistinguishable by eye alone. Reliable differentiation between the two requires examination of the radula and mandibular structures. In *B. edwardsii*, the radula bears over 150 finely denticulate teeth per half-row, and the jaws are elongated with smooth mandibular plates. In contrast, *Berthella aurantiaca* has significantly fewer radular teeth (typically 50–80 per half-row), shorter jaws, and mandibular plates with lateral denticles. Adult individuals may also be distinguished by shell size: in *B. edwardsii*, the internal shell never exceeds 5.5 mm even in animals up to 60 mm long, as shell growth ceases around 15 mm body length (Jakov Prkić, pers. comm.). In *B. aurantiaca*, the shell is proportionally larger—Vayssière reported a 15 mm shell in a 30 mm individual—as it continues to grow and encloses the entire visceral mass. We have no reason to question the *B. aurantiaca* identifications of historical records, and therefore consider the records of this species in the PNMMBT to be valid. However, our observations over the years along the Catalan coast indicate that all examined individuals corresponded to *Berthellina edwardsii*.

(40) Following the study by Ghanimi et al. [62] on the *Berthella stellata* species complex, it has been shown that the species previously identified as *Berthella plumula* (Montagu, 1803) actually comprises two distinct taxa. The name *B. plumula* is retained for Atlantic

populations, while the Mediterranean individuals are now referred to as *Berthella perforata* (Philippi, 1844).

(41) First report of *Creseis acicula* in the PNMMBT was recorded on 19 April 2025 at Cala Montgó, L'Escala by Enric Badosa (MINKA—https://minka-sdg.org/observations/441760—accessed on 7 July 2025).

(42) First report of *Ringicula conformis* in the PNMMBT was recorded on 14 July 2024 at Cala Montgó, L'Escala by Xavier Salvador (MINKA—https://minka-sdg.org/observations/299037—accessed on 7 July 2025).

(43) There is a report of what the observer believes is *Runcina ornata* in the PNMMBT, recorded on 26 December 2017 at Cala Montgó, L'Escala by Xavier Salvador (MINKA—https://minka-sdg.org/observations/34349—accessed on 7 July 2025). However, there are several authors [63–65] that already hinted at the possibility that Mediterranean individuals traditionally assigned to *R. ornata* might not correspond to the original species described from New Zealand. They acknowledge the lack of consistent diagnostic features and raise the issue of potential cryptic diversity and the need for further taxonomic work.

(44) First report of *Placida viridis* in the PNMMBT was recorded on 5 February 2021 at Griells by Xavier Salvador (MINKA—https://minka-sdg.org/observations/74253—accessed on 7 July 2025).

(45) First report of *Oxynoe olivacea* in the PNMMBT was recorded on 2 November 2024 at Cala Montgó, L'Escala by Eduardo Pérez (MINKA—https://minka-sdg.org/observations/397576—accessed on 7 July 2025).

(46) The genus *Elysia* accounts for approximately one-third of sacoglossan diversity, yet its species composition in the northeastern Atlantic and Mediterranean has remained poorly understood. To address this gap, Martín-Hervás et al. [66] conducted an integrative study combining molecular phylogenetics, morphology, literature review, and species delimitation methods. Their analyses confirmed the presence of five European *Elysia* species: *E. viridis*, *E. timida*, *E. flava*, *E. margaritae*, and *E. rubeni*. Crucially, they revalidated *Elysia gordanae* as a distinct species, rejecting the synonymy with *E. margaritae* proposed by Ortea et al. [67], which had been questionable due to stark differences in adult size. Furthermore, they re-examined the status of *Elysia hetta*, originally described by Perrone [68] based on morphological traits now recognized as falling within the intraspecific variability of *E. gordanae*. Martín-Hervás et al. concluded that *E. hetta* is likely a junior synonym of *E. gordanae*, supported by photographic and descriptive comparisons with both the original material and the subsequent literature.

(47) First report of *Scyllaea pelagica* in the PNMMBT was recorded on 7 August 2025 at Ponedora de Sípies by Boris Weitzmann (MINKA—https://minka-sdg.org/observations/537411—accessed on 7 July 2025).

4. Discussion and Conclusions

The long-term study of marine biodiversity within national parks and protected areas plays a fundamental role in establishing ecological baselines, detecting environmental changes, and evaluating the effectiveness of conservation measures. This is particularly relevant in marine ecosystems, where protected zones such as the Parc Natural del Montgrí, les Illes Medes i el Baix Ter (PNMMBT) serve as reference sites for monitoring community dynamics and assessing anthropogenic impacts.

Furfaro et al. [30] documented 23 species of nudibranchs during a two-year survey at "Scoglio del Corallo," located within the Tuscan Archipelago National Park, Italy. Similarly, Goddard et al. [69] reported over 12,000 marine heterobranch individuals representing

55 species from the intertidal zone of Naples Point, Santa Barbara County, California, during a 17-year period (2002–2019). In a subsequent study, Goddard et al. [70] recorded 52 distinct species in the intertidal zone of Tar Pits, also in Santa Barbara County, over 12 years (2008–2019).

A study geographically and methodologically comparable to this study was conducted by Trainito & Doneddu [63] in the Tavolara–Punta Coda Cavallo Marine Protected Area, located on the north-eastern coast of Sardinia, Italy. Their 26-year survey (1989–2015), covering 62 sites down to 50 m in depth, recorded 99 species of nudibranchs. Another comparable study by Vitale et al. [71] investigated the sea slug fauna of Faro Lake, part of the Capo Peloro Lagoon Nature Reserve in north-eastern Sicily. Conducted over six years using visual surveys, underwater photography, and manual specimen collection, this study identified 47 different species. More recently, Lipej et al. [72] published a comprehensive account of the biodiversity, ecology, and zoogeography of sea slugs along the Slovenian coast of the Adriatic Sea. Using a combination of methods—including visual surveys, SCUBA diving, substrate sampling, dredging, plankton nets, and community science photography—the authors reported 2229 sea slug records representing 157 species along Slovenia's 46 km coastline, based on data collected between 1970 and 2023.

Over the nine years of this study (2010–2019), a slight but progressive increase in both species richness and the individual abundance of heterobranch sea slugs was recorded in the PNMMBT. This upward trend likely reflects a combination of factors: the relatively healthy condition of the reserve, a gradual improvement in sampling efficiency, and increased observer expertise—evidenced by the rising number of individuals recorded per hour (Table 2). Sea slug specialists have long known that certain years are better than others in terms of the abundance and diversity of sea slugs. We do not know the reason for this, which we assume must be a very complex phenomenon associated with both biotic and abiotic factors. Most sea slug species living in temperate environments have an annual or subanual cycle, and the development of their food species greatly influences their presence. In general, increased sampling effort also increases the number of species that can be observed, but this increase is never linear, as can be seen between 2011 and 2012 and between 2013 and 2014. Notably, the years 2011, 2016, and 2017 exhibited peak specimen counts, possibly in response to optimal ecological conditions such as favorable seawater temperatures and nutrient availability, or as part of broader recovery processes following the mass mortality events caused by positive thermal anomalies in 1999 and 2003 [73–75]. In contrast, years with low specimen counts (e.g., 2012 and 2014) may be attributed to reduced sampling effort or less experienced participants. However, every sampling session included at least two to three experienced observers, and the stability of the Shannon–Wiener diversity index across years supports the reliability and consistency of species identification throughout the study. In our work, we must take into account that not all locations were sampled with the same intensity. Some included 93 h of sampling (Ferranelles) and others only 5–6 h (Baix de Cols, Illa Pedrosa, La Foradada, La Reina), while at La Ponedora de Sípies, only one diver sampled for 1 hour. The physiognomy of the seabed at each location must also be taken into account, i.e., the inclination of the rocky substrate, its orientation, and depth. This makes it impossible to compare absolute abundance levels among locations, but some conclusions can be drawn regarding abundance per sampling unit. When comparing sites within the PNMMBT, a notable pattern emerges: observation rates were slightly higher along the Montgrí coast (average of 20 individuals/hour) than around the Medes Islands (average of 16 individuals/hour). This difference may be linked to diver-induced disturbances in the Medes Islands, a popular diving destination that receives high levels of tourism. Such pressure has been shown to negatively impact benthic communities [76]. In contrast, the Montgrí coastline—less accessible and therefore less frequented—remains relatively undisturbed, which may explain its higher sea slug densities.

Although mollusks traditionally used as bioindicators have primarily belonged to the Bivalvia due to their filter-feeding habits and ability to accumulate contaminants [77], our study suggests that marine heterobranchs also hold promise as indicators of environmental quality. Population fluctuations in certain species may reflect changes in prey availability or broader environmental stressors. For instance, the decline of *Felimare californiensis* in southern California was attributed to the loss of its sponge prey *Dysidea amblia*, itself a casualty of anthropogenic pollution [78]. Importantly, the ecological specificity of sea slugs makes them potentially valuable indicators of ecosystem health. Many species inhabit oligotrophic, well-oxygenated waters and are considered markers of unpolluted environments. However, this is not universally true: several taxa display a surprising resilience to pollution and can thrive in eutrophic or degraded habitats. A compelling example is the sea slugs found in the heavily urbanized Barcelona Forum bathing area, where 73 species were recorded despite substantial anthropogenic pressure [15]. This apparent contradiction suggests that while some sea slugs may serve as indicators of pristine conditions, others may act as sentinels of specific pollutants or degrees of eutrophication. Further studies are needed to identify species tolerant of particular contaminants, such as cadmium, and to establish reliable sea slug-based bioindication models.

From a methodological perspective, this work highlights the challenges and value of sustained biodiversity monitoring. On the subject of the degree of training of the observers in the different sampling surveys, the authors have to say that the observers who accompanied us on the scuba dives always had a high level of knowledge of sea slugs and experience in observing marine species. In addition, each pair of divers carried at least one underwater camera with which they photographed the doubtful species that were subsequently identified by the authors of this manuscript, who have wide and long experience in the knowledge of this group of mollusks. The observational protocol—relying solely on visual and photographic censuses without substrate sampling—likely underrepresents small or cryptic species, yet still yielded nearly 100 identified species. This figure represents approximately 38% of all known heterobranch sea slug species on the Catalan coast, and the 76 nudibranch species alone constitute 51% of the region's recorded nudibranch fauna [11,12]. The sampling restrictions existing in the PNMMBT have prevented the taking of quantitative and qualitative samples of different types of substrates in which species with cryptic shapes and/or colors or small sizes that can go unnoticed with the naked eye can live, so the data obtained in our study are a part, although important, of the reality of the biodiversity of these mollusks. Given that the PNMMBT covers just 10 km of coastline plus the Medes Islands—compared to the entire 580 km Catalan coast—this density of diversity is exceptional. Furthermore, the data collected over nine years allowed us to assess the relationships between sea slug distributions and key environmental variables. Depth (as a proxy for light availability) and food source availability emerged as primary structuring factors. While seawater temperature played a secondary role during the study, continued warming could profoundly impact prey taxa such as cnidarians and algae, thereby shifting trophic balances and driving long-term community changes.

Since very recently, so-called citizen science has become increasingly important in our understanding of the biodiversity of organisms at a global level. In the marine environment, the almost exponential increase in the number of divers and observers, together with the facilities provided by technical improvements in underwater photography, have made it possible to add tens of thousands of observations to those provided by the scientific community. Recent publications attest to this, for example in the establishment of lists of sea slug species [79] and for the detection of non-indigenous species [80]. Observations contributed by citizen science groups and individuals, and uploaded to platforms like MINKA (https://www.minka-sdg.org—accessed on 7 July 2025) [27] or iNaturalist (https://www.inaturalist.org/—accessed on 7 July 2025) [81], play a crucial role in expanding our understanding of the biodiversity within the Parc Natural del Montgrí, Illes Medes i Baix Ter (PNMMBT). These scientifically validated records significantly enhance the breadth and depth of biodiversity data available, offering insights that would otherwise be difficult to obtain through professional monitoring alone. Thanks to these collaborative efforts, we gain a more comprehensive picture of the health and dynamics of coastal ecosystems. This collective knowledge serves not only as a valuable scientific resource, but also as a practical tool for the ongoing management and protection of our shared natural heritage.

In conclusion, this study represents the most comprehensive long-term dataset on marine heterobranch sea slugs in Catalonia and the Iberian Peninsula to date. It demonstrates the scientific value of citizen science, highlights the sensitivity of sea slug communities to environmental change, and underscores the importance of ongoing ecological monitoring in MPAs. As marine ecosystems continue to face increasing pressure from climate change and tourism, research efforts like this one are crucial for informing conservation strategies and ensuring the resilience of biodiversity hotspots like the PNMMBT.

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