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People's contribution to the knowledge of Pycnogonida: citizen science in the case of a "problematic" taxon

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SUMMARY

Pycnogonida is a poorly known class of marine arthropods represented by nearly 1350 species described worldwide. We examined data about these organisms available on seven websites for photographs and information sharing among recreational naturalists. We found 384 observations, mainly with data about locality and date. Photos about 65 of them resulted correctly identified to the species level with certainty. The others refer to species whose identification requires a more in-depth analysis under a microscope. Unfortunately, this problem is common to a high percentage of pycnogonids. Therefore it seems unlikely that citizen scientists could contribute significantly to their knowledge. Nevertheless, for some species this would be possible and data on the presence of the taxon could be useful for more general studies at community level.

INTRODUCTION

Pycnogonida is a poorly known class of marine arthropods represented by nearly 1350 species described worldwide (Bamber et al., 2021). Due to their morphology, pycnogonids are commonly named "sea spiders". They range from shallow waters to very deep seas and their size goes from few mm of leg-span of interstitial or littoral species to large, deep-sea *Colossendeis*, with leg spans up to 75 cm (Bamber et al., 2021). Their identification to species level is often rather difficult due to some issues: the need to analyze adult specimens, sexual dimorphism, a strong intraspecific variability in some species and the need to carefully examine several diagnostic characters that sometimes differ among genera (see Arango, 2002; Arango & Wheeler, 2007). For more general information on this taxon, see King (1973) and Arnaud & Bamber (1987).

In the last decades citizen science projects in the naturalistic field (Silvertown, 2009) have become more and more frequent. Most of the scientific papers based on data collected by "citizen scientists" concern charismatic taxa such as butterflies (De Felici et al., 2021; Sanderson et al., 2021) and birds (La Sorte & Somveille, 2020; Robinson et al., 2020). Others deal on the monitoring of the spread of alien invasive and/or pest species (Lehtiniemi et al., 2020; Sousa et al., 2020; Werenkraut et al., 2020; Encarnação et al., 2021; Farina et al., 2021; Pataki et al., 2021; Seidel et al., 2021). Citizen science data, moreover, have proven to be effective and reliable also for the biodiversity assessment of certain habitats such as the stormwater ponds (Johansson et al., 2020). Marine citizen science projects occurred on geographical scales ranging from local to global, with the majority acting at national level; most of them focused on coastal environments and were aimed at outlining species distribution (Earp & Liconti, 2019). Obviously, there is a bias among marine fauna taxa in terms of detectability and ease of identification (see Chengeux et al., 2020), with an imbalance towards vertebrates, but also some invertebrate groups are the subject of specific campaigns (Earp & Liconti, 2019; Krželj et al., 2020; Sandahl & Tøttrup, 2020; Garcia-Soto et al., 2021): for instance, "Crab Watch" is a citizen science project monitoring Europe's crab species (Website 1). In particular, divers represent a heterogeneous group of people in terms of interests and culture (see Hermoso et al., 2020, 2021) but due to their high number and global distribution they potentially can give a significant contribution to research, especially on shallow and coastal water environments.

Pycnogonida have never been subject of any citizen science project and they often go unnoticed to non-specialists due to the already mentioned tiny size of coastal species. Moreover, morphological characters useful for species identification are often very difficult to examine by eye and even in photos of good quality. Therefore, they are poor candidates for research based on observations by volunteers. In this paper, to assess the potential of amateur naturalists' websites (blogs, forums) in order to obtain data at least on the distribution of pycnogonids, we examined data available (until 10th April 2021) on some of them.

MATERIALS AND METHODS

Our aim was to verify the availability and reliability of data about Pycnogonida collected by scuba-divers and occasional observers and uploaded on non-specialist sites on the net. We looked at seven websites (from 2 to 8 in the references) through which recreational naturalists share photographs of specimens, searching for pycnogonids pics and related data. Most of the observations were drawn from iNaturalist (website 2), because of its data richness and active users (more than 150.000 people uploaded data and photos on this platform in April 2021).

In particular, we checked for the following information:

1. Is the photograph accompanied by relative data on locality (site, depth, habitat) and date?
2. Is the photograph useful for the identification to the species level?
3. Was the species identified by the author, by a professional marine biologist or by a specialist?
4. Was the identification correct/reliable?

Point 2 and 4 were addressed based on the information about specific diagnoses available in the taxonomical literature on Pycnogonida. In particular, in Figure 1 we highlighted the main diagnostic characters to identify these organisms: chelifores and palps are the most useful features (usually) to reach at least the genus level. Observations were considered useful for the identification when diagnostic characters were clearly visible. To clarify this issue, in Figure 2 are given an example of "good" (both palps and chelifores are visible, for instance) and "bad" photo for the identification purpose.

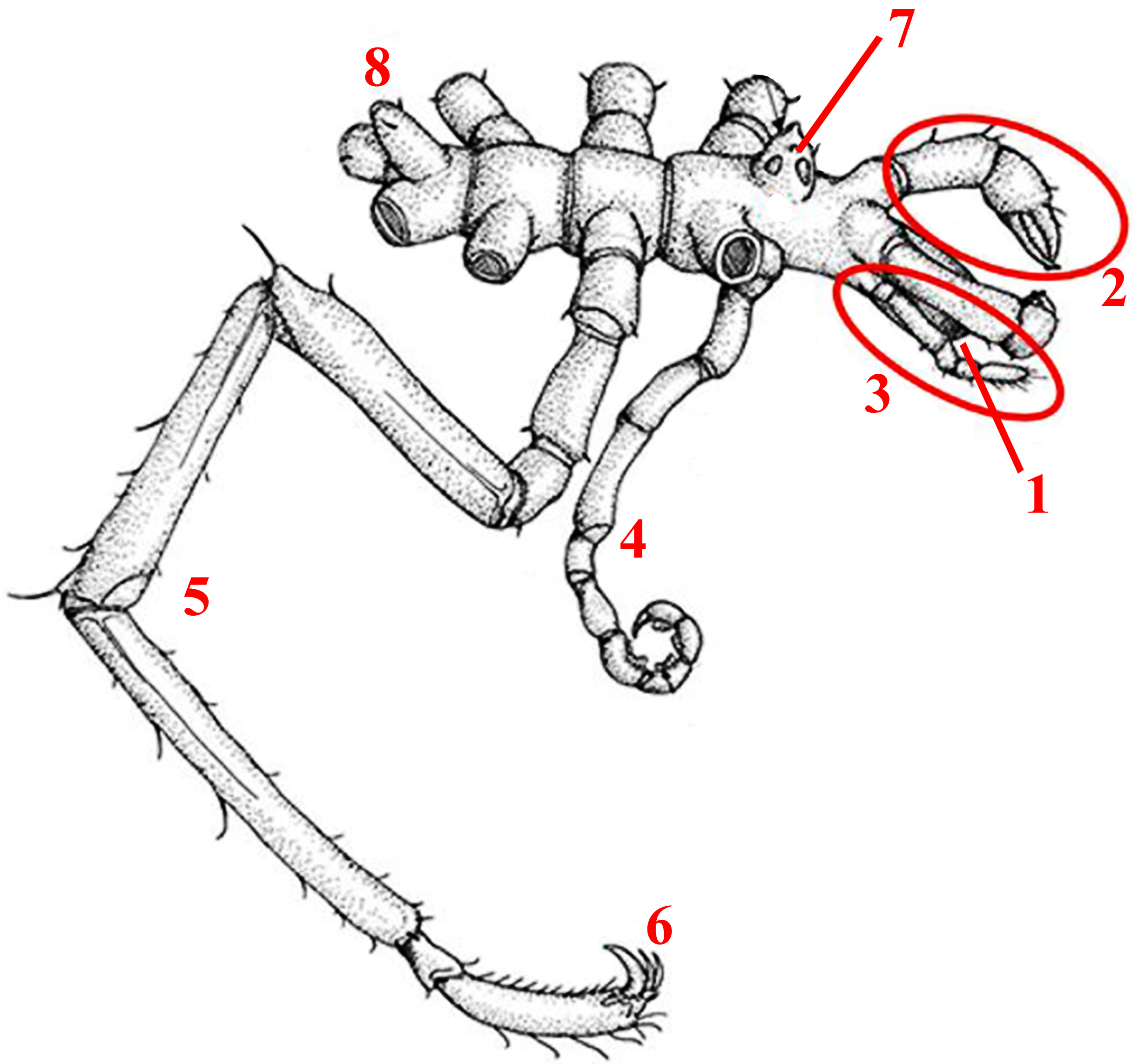

Figure 1. Main diagnostic characters in Pycnogonida: 1: proboscis; 2: cheliphore; 3: palp; 4: oviger; 5: leg; 6: main and auxiliary claws; 7: ocular tubercle; 8: abdomen (modified from Child, 1992).

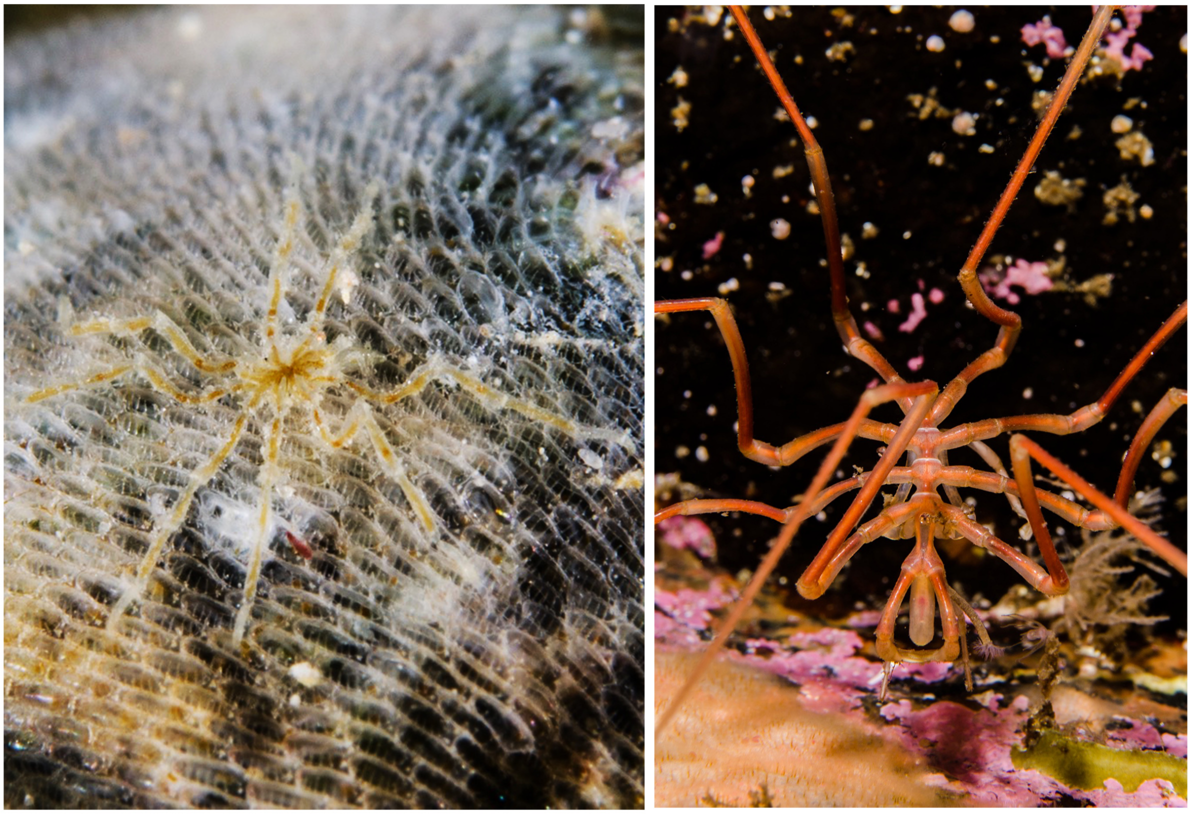

Figure 2. "Unclear" (left) and "good" (right) photo of pycnogonids for identification purpose. Diagnostic characters such as palps and chelifores are well visible only in the right photo. These two details, combined to the other characteristics of the body, allow identification of this specimen as a *Nymphon* sp. (Photos by Federico Betti).

Moreover, to assess the possibility for a "citizen-scientist" to benefit from support of the commonly used photo-identification application of "iNaturalist" to identify pycnogonids, we took some photographs of specimens kept in our collection of Mediterranean species and in the collection of National Antarctic Museum (Museo Nazionale dell'Antartide, MNA) and we used the application "Seek" (spin-off of "iNaturalist") on them.

RESULTS AND DISCUSSION

In the seven websites examined we found 384 observations on Pycnogonida (Table 1), all taken by non-specialist. Their geographic distribution is shown in Figure 3. The summary graph on seasonality of observations available on iNaturalist, the main source of the data we examined, shows that most of observations were made in the period April-June. The chronology diagram shows that the observations of this taxon are growing up in a fluctuating way from 2014, with a peak in May 2018 and January 2020, both with 25 records. Overall, the observations are usually accompanied by data on locality and date, but rather often they lack habitat or depth information.

Generally, the outcomes of citizen science projects show a strict correlation between human population density and data distribution (Johnston et al., 2020, Lloyd et al., 2020). In our case, it is almost impossible to find global data on the distribution of scuba-divers, which activity is likely variable during the year and who are not strictly limited to their area of residence. Some general data are available on the distribution of the diving centers and of recreational dive sites (see for example Lew, 2013). However, it seems that the distribution shown in Figure 3 does not fully match that of the most visited dive sites: for example, no data comes from the Central-South American and Red Sea coral reefs.

In websites from 3 to 8, data collected are few (as shown in table 2): websites 4 and 6 have fifteen and twenty-nine observations respectively and most of the latter have not been identified (see table 1 for details). However, the six species found in website 4 have been all correctly identified to genus level.

Table 1. Data on pycnogonids collected by non-professional observers on the net. Species are listed for each website in alphabetical order. Web: websites (see references for numbering); Nr obs: number of observations; Loc: locality; Gen: genus correctly identified; Spec: species correctly identified; Y: yes; N: No; ?: the photos do not allow a correct identification.

Web	Identified as	Nr obs	Loc	Date	Gen	Spec
2	*Achelia assimilis* (Haswell, 1885)	1	Y	Y	?	?
2	*Achelia echinata* Hodge, 1864	1	Y	Y	?	?
2	*Achelia shepherdi* Stock, 1973	1	Y	Y	N	N
2	*Ammothea australiensis* (Flynn, 1919)	2	Y	Y	?	?
2	*Ammothea hilgendorfi* (Böhm, 1879)	30	Y	Y	Y	?
2	*Ammothella biunguiculata* (Dohrn, 1881)	2	Y	Y	?	?
2	*Anoplodactylus erectus* Cole, 1904	1	Y	Y	N	N
2	*Anoplodactylus evansi* Clark, 1963	20	Y	Y	Y	Y
2	*Anoplodactylus lentus* Wilson, 1878	2	Y	Y	Y	?
2	*Anoplodactylus maritimus* Hodgson, 1914	3	Y	Y	Y	?
2	*Anoplodactylus pygmaeus* (Hodge, 1864)	1	Y	Y	Y	?
2	*Anoplodactylus viridintestinalis* (Cole, 1904)	1	Y	Y	Y	?
2	*Ascorhynchus simile* Fage, 1942	1	Y	Y	Y	?
2	*Boreonymphon abyssorum* (Norman, 1873)	1	Y	Y	Y	Y
2	*Callipallene brevirostris* (Johnston, 1837)	3	Y	Y	Y	?
2	*Callipallene californiensis* (Hall, 1913)	1	Y	Y	Y	?
2	*Colossendeis megalonyx* Hoek, 1881	1	Y	Y	Y	?
2	*Colossendeis proboscidea* (Sabine, 1824)	1	Y	Y	Y	?
2	*Decolopoda australis*	1	Y	Y	Y	Y
2	*Endeis flaccida* Calman, 1923	5	Y	Y	Y	?
2	*Endeis mollis* (Carpenter, 1904)	1	Y	Y	Y	Y

Web	Identified as	Nr obs	Loc	Date	Gen	Spec
2	*Endeis spinosa* (Montagu, 1808)	5	Y	Y	Y	?
2	*Meridionale ambigua*	1	Y	Y	Y	?
2	*Meridionale harrisi*	6	Y	Y	Y	Y
2	*Nymphon aequidigitatum* Haswell, 1885	1	Y	Y	Y	?
2	*Nymphon brevirostre* Hodge, 1863	2	Y	Y	Y	?
2	*Nymphon gracile* Leach, 1814	24	Y	Y	Y	?
2	*Nymphon leptocheles* Sars, 1888	1	Y	Y	?	?
2	*Nymphon pixellae* Scott, 1912	17	Y	Y	Y	?
2	*Nymphon signatum* Möbius, 1902	13	Y	Y	Y	?
2	*Nymphopsis* sp.	4	Y	Y	?	-
2	*Pallenella* sp.	1	Y	Y	N	-
2	*Pallenopsis macneilli* Clark, 1963	8	Y	Y	?	?
2	*Parapallene gowlettae* Staples, 2007	1	Y	Y	Y	Y
2	*Pentanymphon antarcticum* Hodgson, 1904	1	Y	Y	N	N
2	*Phoxichilidium femoratum* (Rathke, 1799)	5	Y	Y	?	?
2	*Pseudopallene variabilis* Arango & Brenneis, 2013	1	Y	Y	?	?
2	*Pycnogonum aurilineatum* Flynn, 1919	7	Y	Y	Y	Y
2	*Pycnogonum litorale* (Strøm, 1762)	8	Y	Y	Y	?
2	*Pycnogonum nodulosum* Dohrn, 1881	1	Y	Y	Y	N
2	*Pycnogonum rickettsi* Schmitt, 1934	2	Y	Y	Y	N
2	*Pycnogonum stearnsi* Ives, 1883	91	Y	Y	Y	?
2	*Pycnothea flynni* Williams, 1940	6	Y	Y	?	?
2	*Queubus jamesanus* Barnard, 1946	7	Y	Y	Y	Y
2	*Stylopallene cheilorhynchus* Clark, 1963	8	Y	Y	Y	Y
2	*Stylopallene tubirostris* Clark, 1963	9	Y	Y	Y	Y
2	*Tanystylum brevipes* (Hoek, 1881)	3	Y	Y	?	?
2	*Tanystylum californicum* Hilton, 1939	11	Y	Y	Y	?
2	*Tanystylum grossifemorum* (Hilton, 1942)	1	Y	Y	Y	Y

Web	Identified as	Nr obs	Loc	Date	Gen	Spec
2	*Tanystylum orbicolare* Wilson, 1878	2	Y	Y	Y	?
3	-	1	N	N	-	-
3	-	1	N	N	-	-
3	-	1	N	N	-	-
3	-*	1	Y	N	-	-
3	-	1	Y	N	-	-
3	-	1	N	N	-	-
3	*Achelia echinata* Hodge, 1864	1	Y	N	Y	?
3	*Anoplodactylus* sp.	1	Y	N	Y	-
4	-	1	N	N	-	-
4	-	1	N	N	-	-
4	*Ammothea longipes* (Hodge, 1864)	1	N	N	Y	?
4	*Anoplodactylus pygmaeus* (Hodge, 1864)	2	N	N	Y	Y
4	*Endeis spinosa* (Montagu, 1808)	1	N	N	Y	?
4	*Nymphon gracile* Leach, 1814	7	N	N	Y	?
4	*Pentapycnon geayi* Bouvier, 1911	1	N	N	Y	Y
4	*Tanystylum orbicolare* Wilson, 1878	1	N	N	Y	N
5	-	1	N	N	-	-
6	-	6	Y	Y	-	-
6	-	1	Y	Y	-	-
6	-	1	Y	Y	-	-
6	-	1	Y	Y	-	-
6	-	1	Y	Y	-	-
6	-	1	Y	Y	-	-
6	*Anoplodactylus* sp.	7	Y	Y	?	-
6	*Antennarius* sp.	1	Y	Y	Not a pycnogonid	-
6	*Nymphon gracile* Leach, 1814	2	Y	Y	Y	?
6	Pantopoda	2	Y	Y	-	-
6	*Pseudopallene* sp.	1	Y	Y	?	-
6	Pycnogonida	3	Y	Y	-	-
6	Pycnogonidae (fam)	1	Y	Y	Wrong family	-
6	Pycnogonids	1	Y	Y	-	-
7	Pycnogonid	1	N	N	-	-
8	-	1	Y	N	-	-
8	*Ascorhynchus* sp.	1	Y	N	Y	-
8	*Colossendeis* sp.	1	Y	N	Y	-

*The specimen belongs to genus *Pycnogonum* (probably *P. nodulosum*).

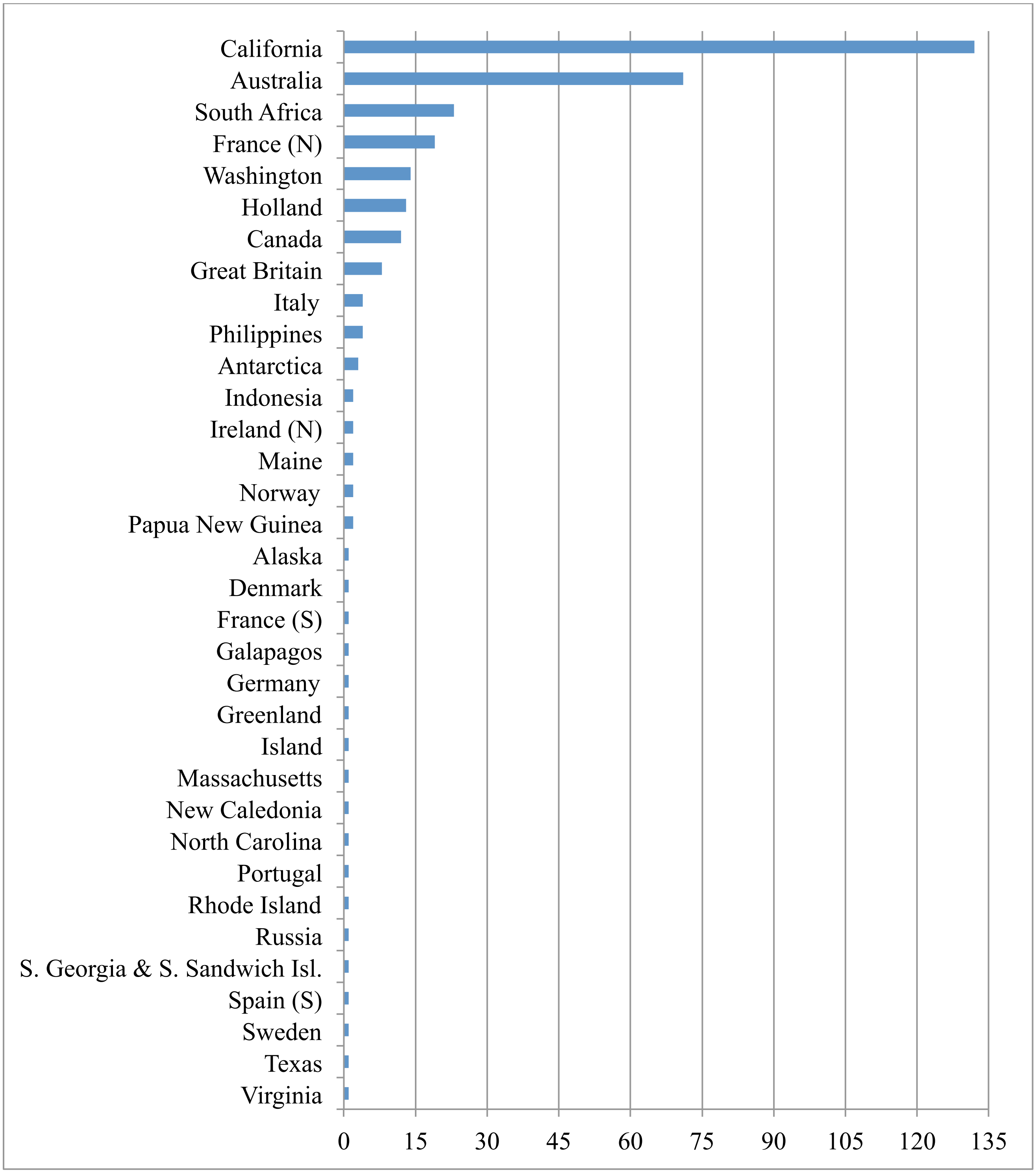

Figure 3. Geographic origin of pycnogonids observations by citizen scientists available on the net, ordered by number of observations, as reported on the x axis.

Table 2. Summary of data in table 1. For website 2 (iNaturalist), in addition to numerical data, percentages are also reported (lower part of the table). Web: websites (see references for numbering); Nr obs: number of observations; Gen: number of genera; GenY: genus correctly identified; %GenY: percentage of genera correctly identified; %Gen?: percentage of genera identified with uncertainty based on unclear pictures; Sp: number of species; SpY: species correctly identified; %SpY: percentage of species correctly identified; %Sp?: percentage of species identified with uncertainty; No id: observation without identification.

Web	Nr obs	Gen	GenY	Sp	SpY	No id
2	327	50	35	48	11	-
3	8	2	2	1	-	6
4	15	6	6	6	2	2
5	1	-	-	-	-	1
6	29	3	3	1	-	9
7	1	-	-	-	-	1
8	3	2	2	-	-	1

iNaturalist

Genera	%GenY	%Gen?	Species	%SpY	%SP?
50	70	22	48	22.9	66.6

Focusing on the website 2 (iNaturalist), more interesting data appear: 327 observations can be traced back to 50 genera and 48 species. The wrong identifications are few, only four genera and five species; besides, 70% of genera and 22% of species have been correctly identified.

Only 65 observations resulted reliable with certainty and, therefore, useful to improve the species distribution knowledge (Figure 4). In particular, these are related to 13 species only, easily recognisable from morphologic features without the need of special expertise on Pycnogonid fauna. For example, there are some species characterized by an iconic colour pattern (*Anoplodactylus evansi*, *Meridionale harrisi*, *Pycnogonum aurilineatum*, *Stylopallene cheilorhynchus* and *S. tubirostris*) or by striking morphological characteristics (few species like *Decolopoda australis* and *Pentapycnon geayi* have five pairs of legs instead of four). In addition, several observations can be considered valid at the genus level. It is often possible to identify genera based on accurate and good quality photographs showing diagnostic characters. In Table 3 some "easier" genera and their key features are listed. Species diagnosis is more complex. The colourful species mentioned above are an exception.

For some of the observations listed in Table 1, we found some incongruities. For instance on iNaturalist photographs of low quality and/or without focus on diagnostic characters are frequent (due to the absence of specialists of this taxon among the users). Although some species have been correctly identified, we found some cases of wrong taxon arrangement. For example, genus *Anoplodactylus* has been confused with *Endeis* or *Achelia*, and *Nymphon* with *Phoxichilidium* or *Pentanymphon* (which has five pairs of legs!).

Peter et al. (2019, 2021) and Callaghan et al. (2020, 2021) highlighted the defects but also the potential of citizen science in biodiversity and environmental research. Moreover, Changeux et al. (2020) demonstrated that, with the support of and after validation by professional scientists, data collected by volunteer naturalist scuba divers can be used to outline ecological biodiversity patterns, but with the taxonomical bias already evidenced in the introduction. Pycnogonida is one of the taxa most affected by the problems related to the difficulty of observation and identification. This makes it almost completely impracticable to use citizen scientists to collect reliable data on pycnogonids.

Despite this, on iNaturalist some observations are defined as “Research Grade” when they meet some requirements, for example accurate date and position, identification to species level, photographs or sounds attached, etc. Besides, another important feature to reach that level is “when 2/3 of identifiers agree on a taxon observation”. Unfortunately, this process is managed by non-specialists: some of the wrong or dubious observations of pycnogonids we detected are considered “Research Grade”. Another issue seems to be the almost complete lack, even for the larger and more colourful species, of a comparison photographic repository for the applications commonly used by recreational naturalists as an aid to specimen identification. Our attempts to identify specimens from our collection and from MNA collection using iNaturalist spin-off “Seek” failed. In the best cases the application suggested us the taxon “Pantopoda”, but usually it shows some spiders or scorpions as the most similar species it was able to find.

According to our expectations, to date it seems unlikely that citizen scientists could contribute significantly to pycnogonids research. Nevertheless, for some species this would be possible and data on the presence of identified families or genera could be useful for more general studies at community level. Photographs can also improve the knowledge about the eco-ethology of this group. Although species-level information is essential and most suitable for any kind of research, for some less known groups like pycnogonid, also data on specimens identified at a higher taxonomic level can be considered significant (some interesting insight on this topic is available in Qiao et al., 2017; Smith et al., 2019). The “easiest” way to optimize data collection would be to increase cooperation between research institutions and scuba-diving centers.

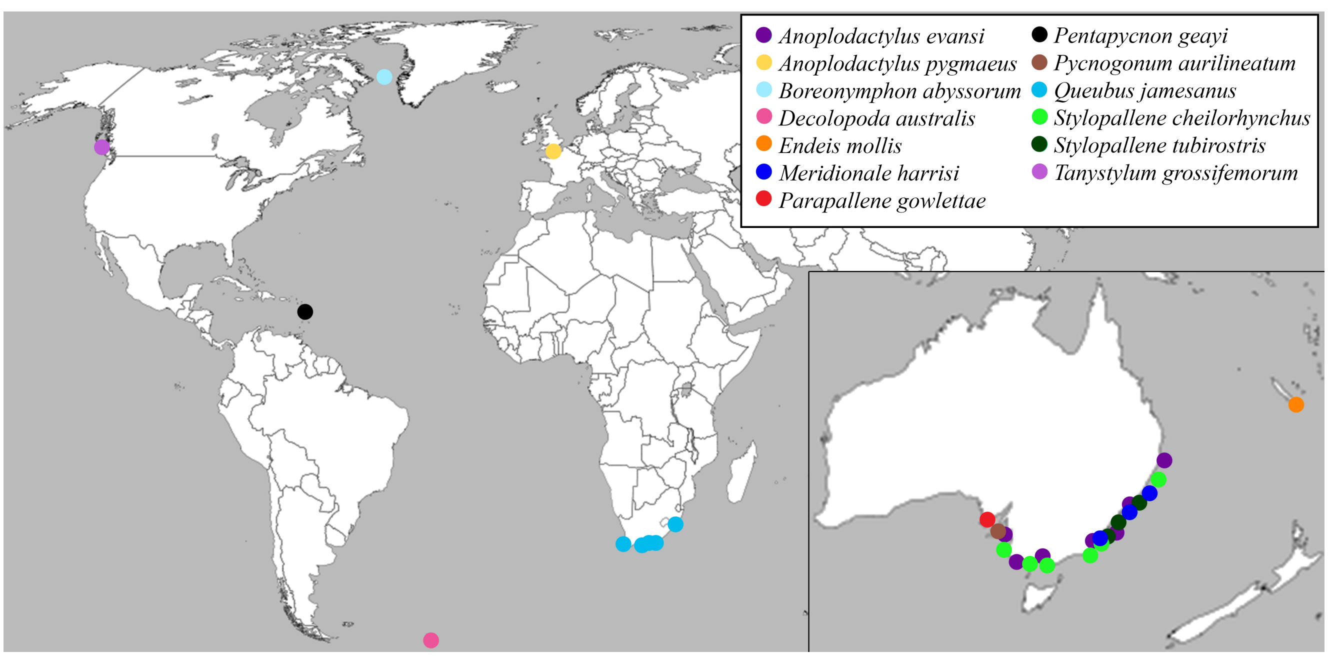

Figure 4. Geographic distribution of pycnogonids observations by citizen scientists available on the net and validated at the species level (mainly from Website 2, see Table 1). Species are listed in alphabetical order. Australian area is zoomed in to allow a more detailed inlustration of the numerous observations of various species made along its South-Eastern and Eastern coasts.

Table 3. List of some genera easily recognizable from medium-quality photographs ordered based on the number of legs, their species number (according to Bamber et al., 2021) and diagnostic characters.

Genera	Spp. Nr	Diagnostic characters
		8-legged species
Austrodecus	44	Cheliphores and palps absent; long proboscis shaped like a pipette, robust body
Austropallene	11	Cheliphores with smooth chela; palps and auxiliary claws absent; proboscis with pointed distal part
Colossendeis	72	Cheliphores absent; palps 9-10 segmented; body without dorsal segmentation
Endeis	18	Cheliphores and palps absent; slender body and thin legs
Pantopipetta	15	Cheliphores and palps absent; long proboscis shaped like a pipette; slender body
Pycnogonum	74	Cheliphores and palps absent; body and legs sturdy
Tanystylum	48	Rounded body without dorsal segmentation; reduced cheliphores without chelae
		10-legged species
Decolopoda	2	Cheliphores and palps present; auxiliary claws absent
Pentanymphon	1	Cheliphores, palps and auxiliary claws present (only one species: *P. antarcticum*)
Pentapycnon	3	Cheliphores and palps absent
		12-legged species
Dodecolopoda	1	Robust legs close to each other; small ocular tubercle (only one species: *D. mawsoni*)
Sexanymphon	1	Slender spaced legs (only one species: *S. mirabilis*)

Another way to bring scuba-divers closer to pycnogonids (or marine biology in general) would be to made available online for each area illustrated keys for genera and, when possible, species identification. In any case, in the absence of these tools, it is also expected that the continuous improvement of photo-identification software and of the degree of resolution of digital cameras may at least in part make the identification of more species accessible to non-specialists.

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Website 3: https://www.naturamediterraneo.com/forum/

Website 4: https://www.galerie-insecte.org/galerie/fichier.php#PYCNOGONIDA

Website 5: http://www.divegallery.com/sea_spider.htm

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Website 7: http://www.seaslugforum.net

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