

## Article

# The Inland Water Copepod Fauna of a Traditional Rural Landscape in a Mediterranean Island (Crustacea, Copepoda)

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**Abstract:** Although the Mediterranean area is a well-known hotspot of biological diversity, the crustacean assemblages inhabiting inland waters of the Mediterranean islands are to date unevenly known, and detailed information is missing for most taxa and areas. In the frame of this paper, we provide a checklist and a characterization of the copepod fauna of the lentic water bodies occurring in a traditional rural landscape of Sicily, where the co-existence of agriculture, woodlands, and pastoral activities lead to the presence of a wide range of different aquatic habitats. Overall, 22 copepod species belonging to the orders Calanoida, Cyclopoida, and Harpacticoida have been found in the 92 surveyed sites, stressing the conservation value of the area. In the study area, species widespread in the west Palaearctic region co-exist with strictly Mediterranean elements and a small but biogeographically significant group of species with northern or Balkan affinities, which support the role of the investigated area as a refugium for species that colonised Sicily during Pleistocene climate fluctuations and are now restricted to the more wet parts of the island. A single non-native species has been found, and its distribution is currently limited to permanent, man-made reservoirs.

**Keywords:** Calanoida; Cyclopoida; Harpacticoida; inland waters; Sicily; biological invasions; temporary ponds



**Citation:** Marchese, M.; Vecchioni, L.; Bazan, G.; Arculeo, M.; Marrone, F. The Inland Water Copepod Fauna of a Traditional Rural Landscape in a Mediterranean Island (Crustacea, Copepoda). *Water* **2022**, *14*, 2168. <https://doi.org/10.3390/w14142168>

Academic Editor: Artem Y. Sinev

Received: 16 June 2022

Accepted: 6 July 2022

Published: 8 July 2022

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## 1. Introduction

Thanks to a complex combination of climatic, geological, and paleogeographic factors, the Mediterranean Basin, characterised by a pronounced seasonality and a mosaic of ecosystems and communities, is a well-known hotspot of biological diversity [1]. However, the biota inhabiting the inland waters of the Mediterranean area is unevenly known, with several taxa and areas poorly known or data-deficient. This is particularly unfortunate since inland water bodies host a high biological diversity due to the intrinsically fragmented nature of these habitats, which promotes endemism and differentiation phenomena [2]. The inland waterbodies of the Mediterranean area can thus be correctly considered “hotspots within hotspots”. Unfortunately, Mediterranean inland water biota is nowadays highly threatened by a combination of climatic change, biological invasions, and anthropic pressure, and several taxa are exposed to local or global extinction even before their presence is surveyed or they are formally described [3]. A sound assessment of the biodiversity of Mediterranean inland waters is thus urgent to describe and characterise this unique biota before it vanishes and to create a sound reference point which allows to explore the long-term biological changes that might interest the area.

Copepod crustaceans are amongst the most relevant organisms in inland waters in terms of diversity, numbers, and biomass and constitutes one of the major groups among inland water microcrustaceans, where they are represented by three orders of mostly free-living species: Calanoida, Cyclopoida, and Harpacticoida [4]. In Sicilian inland waters, calanoids have been sufficiently investigated, with special reference to the families

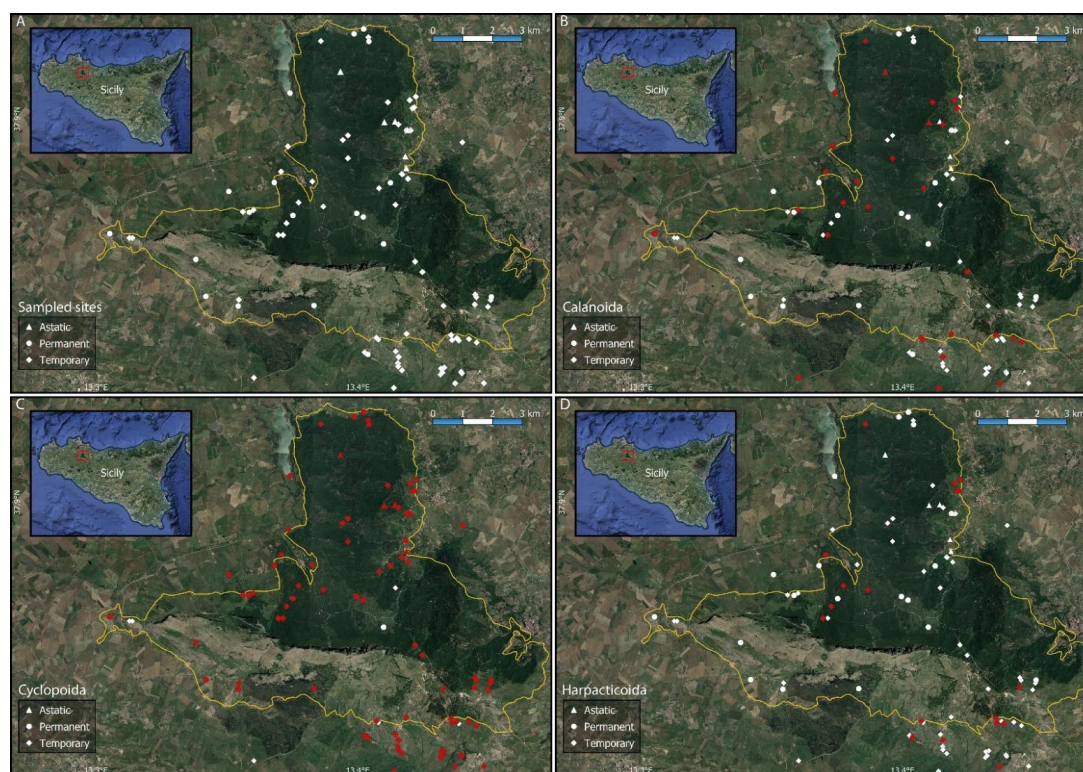
Diaptomidae (e.g., [5–10]) and Pseudodiaptomidae [11]. Conversely, the cyclopoid and harpacticoid copepods inhabiting the surface inland waters of Sicily have been to date the object of few dedicated studies (e.g., [12–15]), and most of the available records are occasionally included in papers dealing with other topics (e.g., [5,16–18]).

In the frame of this work, we provide a checklist and distribution of the copepods occurring in an area characterised by a mixed agricultural, rangeland, and wood landscape, which can be considered representative of the land use, climate, and physiography of the hilly and mountainous inner part of Sicily, the largest island of the Mediterranean region and a renowned “crossroad” for circum-Mediterranean freshwater microcrustaceans ([19,20] and references therein). The crustacean fauna inhabiting the surface lentic inland water bodies of Sicily is in fact a prime example of an understudied but greatly interesting group, and no recent synoptical data are available for Sicilian cyclopoid and harpacticoid copepods. Moreover, the few available lists should be critically revised, and the realisation of sound checklists supported by accurate, possibly geo-referenced, distributional data is highly desirable.

## 2. Materials and Methods

### 2.1. The Study Area

The study area occurs within the province of Palermo, and it is included approximately between 37.82° and 37.92° latitude N and 13.30° and 13.45° longitude E, within an altitudinal range comprised between 350 and 1613 m a.s.l. Most of the investigated water bodies are located within the Nature Reserve “Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago”, one of the largest protected areas of Sicily (Figure 1).



**Figure 1.** Distribution of the sampling sites in the study area (A) and local distribution of Calanoida (B), Cyclopoida (C), and Harpacticoida (D). The solid yellow line shows the boundaries of the Nature Reserve “Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago”.

The landscape of the area is dominated by broadleaf woods, rangelands, agricultural fields, and rocky outcrops occurring on calcareous, siliceous, and clayey substrates. The average annual rainfall in the study area ranges between 700 and 1000 mm  $y^{-1}$  and



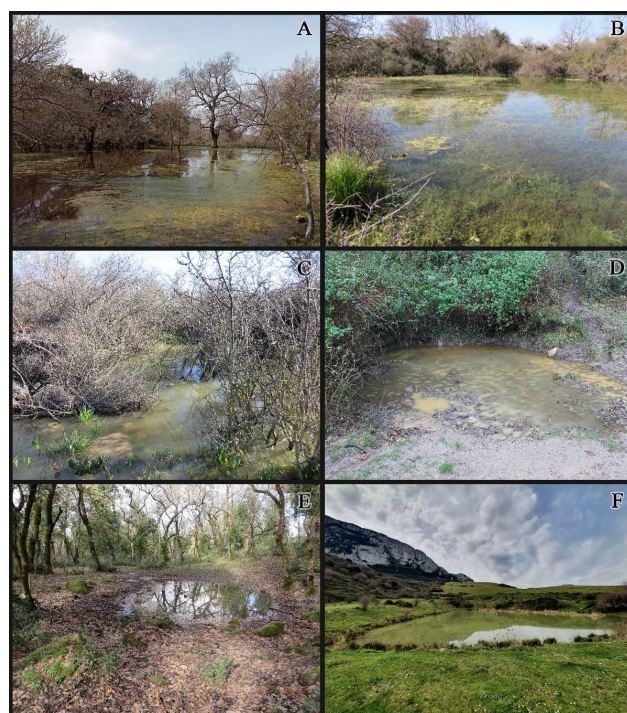
the average annual temperature from 10 to 16 °C; the bioclimate ranges from the thermo-Mediterranean lower subhumid to the supra-Mediterranean humid belts [21,22]. A detailed characterization of the climate, flora, vegetation, and geology of the area is provided by Gianguzzi and La Mantia [22], and further information can be retrieved in Gianguzzi [23], whereas an extensive census of both lentic and lotic water bodies of the study area and their botanical characterization is provided by Caldarella [24]. Despite its long-term anthropic exploitation, the area still maintains a high level of plant diversity and a well-preserved rural landscape [25,26], hosting a peculiar and rare flora [27].

To date, some information is available for the ostracod [28,29], branchiopod [30], and malacostracan ([31,32] and references therein) faunas of the study area. Conversely, apart from the occasional records of two copepod species by Calvo et al. [15] and Marrone et al. [33], no information is currently available for Copepoda.

Sparse information is also available for freshwater molluscs (e.g., [34]), water mites [35], leeches [36], and insects (e.g., [37,38]). Among the aquatic vertebrates, some information is available for amphibians (See references in Lo Valvo et al. [39]), the Sicilian pond turtle *Emys trinacris* [40,41], and the freshwater blenny *Salariopsis fluviatilis* (Asso, 1801) (sub *Salaria fluviatilis* in [42,43]; see Vecchioni et al. [44]).

## 2.2. Sampling Methods

In the frame of this survey, only surface lentic water bodies ranging from a large dam reservoir to small pools on dirt roads were investigated (Figure 2). Both natural (pools and ponds) and man-made (reservoirs and concrete channel) water bodies with different hydroperiods were included in the sampling campaigns. Distribution maps were realised using the QGIS freeware software v. 3.18 (QGIS Development Team, 2022 [45]).



**Figure 2.** An example of the different habitat type sampled (see Table 1 and Appendix A for further details). (A) PA124 on 17 March 2022 (inhabited by *Mixodiaptomus kupelwieseri*, *Cyclops divergens*, *Diacyclops lubbocki*, *Attheyella trispinosa*); (B) PA214 on 7 March 2021 (*Diaptomus cyaneus*, *Megacyclops viridis* s.l.); (C) PA238 on 24 April 2021 (*C. divergens*); (D) PA246 on 7 March 2021 (*Cyclops ankyrae*); (E) PA253 on 13 February 2021 (no copepods); (F) PA312 on 17 March 2021 (*Acanthocyclops americanus*).

**Table 1.** List of the sampled sites. When available, the codes used by Caldarella [24] are included between brackets. Geographical coordinates are expressed as decimal degrees (Map Datum: WGS84). Hydroperiod = A, astatic; P, permanent; T, temporary.

Code	Site Name	Latitude N	Longitude E	Elevation (m a.s.l.)	Habitat Type	Hydroperiod
PA009	Gorgo dei palermitani (SSP1)	37.875203	13.385595	770	Pond	T
PA012	Valle Maria 1	37.884058	13.417820	614	Pool	T
PA079	Gorgo Cerro (SSP2)	37.889991	13.394688	750	Pond	T
PA080	Gorgo di Glaviano (SSP6)	37.895409	13.438412	470	Pond	T
PA081	Gorgo Lungo (SP1)	37.901131	13.408438	904	Pond	A
PA082	Gorgo Tondo (Gorgo del Drago, SP2)	37.901389	13.412501	854	Pond	A
PA084	Pozza degli incidenti	37.882777	13.381256	680	Pool	T
PA085	Pozza di C.da Castellaccio	37.893280	13.371701	593	Pool	T
PA086	C.da Cannitello (PT18)	37.900496	13.413772	868	Pool	T
PA087	Pozza dello Zù Santino (PT20)	37.907907	13.417980	845	Pool	T
PA091	Gorgo Margiazzu (PT10)	37.925365	13.383588	526	Pond	T
PA120	Laghetto Coda di Riccio 1 (AI16)	37.872286	13.400995	876	Reservoir	P
PA121	Laghetto Coda di Riccio 2 (AI15)	37.873333	13.398449	870	Reservoir	P
PA124	Gorgo di Gaetanello (PT7)	37.885585	13.369187	671	Pond	T
PA133	Pozza di Rocca Argenteria (FIA1)	37.864722	13.311705	553	Pool	T
PA181	Invaso dell' Arcera (SCA3)	37.916233	13.391296	596	Reservoir	A
PA198	Stagno agricolo del Frattina (AI1)	37.865893	13.304113	482	Reservoir	P
PA204	Stagno sotto cozzo Bileo (AZ9)	37.907135	13.409628	943	Pond	T
PA212	Pozza 1 della Busambra	37.835266	13.407517	831	Pool	T
PA213	Pozza 2 della Busambra	37.835778	13.406812	837	Pool	T
PA214	Pozza 3 della Busambra (SPP4)	37.837101	13.418269	859	Pond	T
PA235	Casa Franco (SSP5)	37.898886	13.417320	782	Reservoir	A
PA236	Casa Franco (AI23)	37.898747	13.417050	749	Reservoir	P
PA237	C.da Balata (PT6)	37.866354	13.368611	918	Pool	T
PA238	Laghetto forestale di C.da Ramusa (AI12)	37.872371	13.374066	807	Reservoir	P
PA239	C.da Sovarita (PT23)	37.909001	13.420300	832	Pool	T
PA240	Gorgo della Porcaria (PT9)	37.876317	13.376156	752	Pool	T
PA241	C.da Cannitello (PT21)	37.905479	13.419079	817	Pool	T
PA242	C.da Cannitello 2 (PT22)	37.905731	13.419733	812	Pool	T
PA243	C.da Balata (AZ5)	37.866396	13.370395	940	Pond	T
PA244	C.da Cannitello (AZ17)	37.898713	13.418518	780	Pond	T
PA245	Marosella-Ramusa	37.820679	13.413760	713	Pond	T
PA246	Pozza 3 del recinto	37.831756	13.414239	795	Pool	T
PA247	Pozza Pippinello bassa	37.830114	13.415278	750	Pool	T
PA248	Pozza Pippinello alta	37.830064	13.415484	752	Pool	T
PA249	Pozza Junchi	37.831304	13.402387	747	Pool	T
PA250	Pozza ai cipressi	37.822586	13.448174	718	Pond	T
PA251	C.da Ramusa (PT8)	37.870010	13.371656	832	Pool	T
PA252	Strada Pno Tramontana (DCT1)	37.845778	13.432219	1165	Pool	T
PA253	Valle Maria (ANT1)	37.876156	13.413202	802	Pool	T
PA256	Piano Carduna (PT12)	37.895505	13.392657	706	Pool	T
PA258	Zotta Frascino (PT14)	37.896893	13.394595	773	Pool	T
PA259	Pozza profonda	37.830691	13.403638	742	Pool	P
PA261	C.da Bivieri (SSP3)	37.890910	13.416672	653	Pond	A
PA264	Stagno artificiale del vivaio forestale (AI19)	37.882770	13.411161	651	Reservoir	P
PA265	Stagno presso vivaio forestale (AZ8)	37.881071	13.406820	706	Pond	T
PA266	Stagno artificiale sopra Alpe Cucco (AI18)	37.864211	13.408923	1002	Reservoir	P
PA267	Lago Scanzano	37.909439	13.372096	518	Reservoir	P
PA268	Piano Prani 1 (AZ21)	37.859039	13.421083	1068	Pool	T
PA269	Piano Prani 2 (AZ24)	37.855905	13.423935	1071	Pond	T
PA270	Pozza "strada Corleone"	37.823028	13.360222	838	Pool	T
PA271	C.da Bivieri (AZ15)	37.887333	13.417115	613	Pond	A
PA272	Laghetto agricolo Massariota	37.929219	13.399892	615	Reservoir	P
PA273	C.da Massariota (AI14)	37.927702	13.396248	598	Pond	P
PA274	Pozza di C.da Pertuso (PT16)	37.926722	13.401774	669	Pool	T

Table 1. Cont.

Code	Site Name	Latitude N	Longitude E	Elevation (m a.s.l.)	Habitat Type	Hydroperiod
PA275	Laghetto di Piano Cancemi (AI17)	37.925492	13.401974	677	Reservoir	P
PA276	Strada Valle Agnese 1	37.885479	13.415342	610	Pool	T
PA277	Strada Valle Agnese 2	37.885430	13.415636	610	Pool	T
PA278	Rocca Argenteria (FIA2)	37.864707	13.312803	568	Pool	T
PA292	Gorgo 4 Tummini (SSP7)	37.835880	13.442202	925	Pond	T
PA293	Pozza Tonda (PPS2)	37.835343	13.438344	891	Pool	T
PA294	Pozza Grande	37.836062	13.437582	890	Pool	T
PA295	Pozza Bosco Acero	37.836986	13.435305	913	Pool	T
PA296	Pozza Rofo	37.835482	13.435739	887	Pool	T
PA297	Pozza Carrareccia Giardinello	37.825890	13.439420	742	Pool	T
PA298	Canaletta della gebbia	37.825462	13.439689	738	Concrete channel	T
PA299	Pozza 4 Giardinello	37.822380	13.437167	662	Pool	T
PA300	Pozza 5 Giardinello	37.827061	13.432886	715	Pool	T
PA301	Pozza 6 Giardinello	37.826803	13.431717	703	Pool	T
PA302	Pozza 7 Giardinello	37.825008	13.431589	665	Pool	T
PA303	Pozza 8 Giardinello	37.825619	13.432246	675	Pool	T
PA304	Letto fiume alto 1	37.828162	13.415172	765	Pool	T
PA305	Letto fiume alto 2	37.827262	13.415334	702	Pool	T
PA306	Letto fiume alto 3	37.827196	13.415326	702	Pool	T
PA308	Letto fiume alto 5	37.826046	13.416791	677	Pool	T
PA309	Stagno di Piano Guddemi (AI26)	37.834858	13.445156	951	Reservoir	T
PA311	Stagno artificiale	37.879307	13.349360	651	Reservoir	P
PA312	Contrada Bifarera (AI11)	37.873129	13.357364	790	Reservoir	P
PA313	Contrada Bifarera (PT3)	37.873220	13.354886	798	Pool	T
PA314	Stagno artificiale	37.882280	13.366696	672	Reservoir	P
PA315	Contrada Bifarera (PPS1)	37.873802	13.358911	757	Pond	T
PA317	C.da Pirrello (AI13)	37.845225	13.382714	891	Reservoir	P
PA318	C.da Casale (AI4)	37.858561	13.337228	784	Reservoir	P
PA319	C.da Casale 1 (AI5)	37.847380	13.341298	547	Reservoir	P
PA320	C.da Casale 2 (AI10)	37.844661	13.353724	710	Reservoir	P
PA321	C.da Casale 3	37.846572	13.353964	715	Pool	T
PA322	Pozza	37.846346	13.444175	1097	Pool	T
PA323	Pozza Roccia	37.848604	13.444704	1069	Rock pool	T
PA324	Pizzo Angelo (ANT3)	37.849362	13.444248	1030	Reservoir	T
PA325	C.da Acqua Jenco (AZ26)	37.848741	13.450455	928	Reservoir	P
PA326	C.da Acqua Jenco 1 (PT27)	37.847783	13.450237	959	Pool	T
PA327	C.da Acqua Jenco 2 (PT26)	37.845733	13.449234	1023	Pool	T

The majority of sites were sampled only once, whereas about 20% of the sampled sites were visited several times in different months and years in order to account for the seasonal successions and the possible inter-annual differences of the copepod assemblages (e.g., [46]). The coordinates of the sampled water bodies were registered with GPS along with information about their hydroperiods and the possible occurrence of vertebrate predators (i.e., fish or *Xenopus laevis* tadpoles). In each site and on each sampling date, electric conductivity and water temperature were recorded with a Hanna Instrument HI9835 multiprobe; moreover, an estimate of the abundance of macrophytes and of water turbidity was assessed by using three arbitrary qualitative classes (see Marrone et al. [47]).

Studied crustacean samples originate from two different sampling campaigns: from 2004 to 2019, samples were collected with a 200 µm hand net in littoral areas and with a 100 µm towing net in the open waters of larger water bodies. In the frame of a second sampling campaign (2020–2022), samples were collected with 250 µm hand and towing nets. In both cases, attention was paid to collect samples in all the microhabitats possibly present in each site. All used nets were manufactured and provided by NHBS Ltd. (Totnes, UK—<https://www.nhbs.com/>). Samples collected prior to 2010 were preserved in 4% buffered formalin, while those collected from 2010 to 2022 were preserved in 90% ethanol. All samples are now stored in Federico Marrone crustacean collection at the Department “STEBICEF” (Scienze e Tecnologie Biologiche Chimiche e Farmaceutiche—University of Palermo, Palermo, Italy) and are available for loan on request.

Identification of collected copepods was performed based on Dussart [48,49], Kiefer [50], Einsle [51,52], Karaytug [53], Hołyńska et al. [54], Hołyńska [55], Alekseev and Defaye [56], and Miracle et al. [57]. Copepod nomenclature here follows Ruffo and Stoch [58], with the

exceptions of the genera *Arctodiaptomus* Kiefer, 1932, and *Acanthocyclops* Kiefer, 1927, for which we follow Alfonso et al. [59] and Miracle et al. [57], respectively. Notwithstanding the doubts raised by some authors (e.g., [60,61]), we here consider *D. bicuspidatus* (Claus, 1857) and *D. lubbocki* (Brady, 1869) as different taxa of species level.

Sample-based rarefaction curves [62] and the rarefaction curve of the mean values of “uniques” (i.e., species present only in a single sample) were computed to evaluate if sampling effort was exhaustive enough to be representative of the total copepod diversity of the study area. The non-parametric species richness estimators ICE (Incidence Coverage-based Estimator), Jack1 (first order Jackknife-based estimator), and the bias-corrected formula of Chao2 were calculated. Analyses were done using the EstimateS software version 9.1.0 (Boulder, USA - <http://viceroy.eeb.uconn.edu/EstimateS> - accessed on 1 May 2022), based on the analytical formulas of Colwell et al. [63].

### 3. Results

Overall, 122 samples were collected in 92 lentic water bodies characterised by different origin (68 natural and 24 man-made sites) and hydroperiod (66 temporary, 6 astatic, and 20 permanent sites), located from 470 to 1165 m a.s.l. (Table 1). A synopsis of the environmental data and collected copepods for each site and sampling date is reported in Appendix A, Table A1.

Copepods were observed in 88 out of the 92 sampled sites. All the copepod taxa could be identified to species level with the exceptions of the diaptomid *Arctodiaptomus* sp., a species new to science whose formal description is still pending (see Alfonso et al. [59]), and a cyclopoid species belonging to the genus *Megacyclops* Kiefer, 1927. The *Megacyclops* populations studied in the frame of this survey showed a morphology close but not identical to *M. viridis* (Jurine, 1820). Pending a revision of the genus *Megacyclops*, we have thus conservatively opted for identifying the *Megacyclops* populations of the study area as *Megacyclops viridis* s.l.

The obtained checklist includes 22 species belonging to 18 genera. Calanoid, cyclopoid, and harpacticoid copepods were observed in 29, 85, and 18 of the sampled water bodies, respectively (Figure 1). The occurrence sites for each of the recorded species are listed in Table 2 and shown in Appendix B, Figures A1–A4; synoptical data on the number of occurrence localities (N) and the observed altitudinal, electric conductivity (EC), and hydroperiod ranges of each species are reported in Table 3.

**Table 2.** Checklist and distribution of the copepods collected in the study area.

Calanoida	Occurrence Sites
<i>Arctodiaptomus</i> sp.	PA309
<i>Copidodiaptomus numidicus</i> (Gurney, 1909)	PA198; PA267
<i>Diaptomus cyaneus</i> Gurney, 1909	PA214; PA247; PA269; PA292; PA295; PA309
<i>Diaptomus serbicus</i> Gjorgjevič, 1907	PA084; PA212; PA213; PA245; PA299; PA270
<i>Hemidiaptomus gurneyi</i> (Roy, 1927)	PA079; PA309
<i>Mixodiaptomus kupelwieseri</i> (Brehm, 1907)	PA009; PA079; PA081; PA085; PA086; PA087; PA091; PA124; PA181; PA204; PA240; PA241; PA243; PA245; PA265; PA270; PA299; PA315
Cyclopoida	
<i>Acanthocyclops americanus</i> (Marsh, 1893)	PA272; PA273; PA311; PA312
<i>Cyclops ankyrae</i> Mann, 1940	PA012; PA246
<i>Cyclops divergens</i> Lindberg, 1936	PA079; PA080; PA081; PA082; PA082; PA086; PA087; PA091; PA124; PA181; PA204; PA237; PA238; PA240; PA242; PA244; PA250; PA256; PA258; PA267; PA268; PA272; PA275; PA276; PA277; PA304; PA305; PA309; PA315; PA320; PA322; PA327
<i>Diacyclops bicuspidatus</i> (Claus, 1857)	PA081
<i>Diacyclops bisetosus</i> (Rehberg, 1880)	PA079; PA251; PA261
<i>Diacyclops lubbocki</i> (Brady, 1869)	PA009; PA012; PA079; PA084; PA085; PA086; PA124; PA204; PA239; PA240; PA241; PA243; PA245; PA247; PA265; PA274; PA292; PA295; PA296; PA300; PA302; PA304; PA305; PA313; PA323



Table 2. Cont.

Calanoida	Occurrence Sites
<i>Eucyclops serrulatus</i> (Fischer, 1851)	PA081; PA082; PA085; PA120; PA121; PA198; PA236; PA242; PA249; PA271; PA294; PA297; PA298; PA301; PA317; PA318; PA319; PA324; PA325
<i>Macrocyclus albidus</i> (Jurine, 1820)	PA236; PA264; PA297; PA321
<i>Megacyclus viridis</i> s.l. (Jurine, 1820)	PA009; PA080; PA081; PA082; PA091; PA204; PA214; PA235; PA240; PA241; PA242; PA247; PA248; PA249; PA259; PA261; PA269; PA295; PA296; PA301; PA303; PA306; PA308; PA309; PA315; PA319; PA326; PA327
<i>Mesocyclops leuckarti</i> (Claus, 1857)	PA264; PA303
<i>Metacyclus minutus</i> (Claus, 1863)	PA080; PA087; PA213; PA248; PA252
<i>Microcyclus varicans</i> (Sars, 1863)	PA299
<i>Thermocyclops dybowskii</i> (Landé, 1890)	PA198
<i>Tropocyclops prasinus</i> (Fischer, 1866)	PA314
Harpacticoida	
<i>Attheyella trispinosa</i> (Brady, 1880)	PA009; PA091; PA124; PA213; PA237; PA239; PA247; PA259; PA295; PA299
<i>Canthocamptus staphylinus</i> (Jurine, 1820)	PA087; PA240; PA241; PA242; PA247; PA251; PA293; PA296; PA322

**Table 3.** Ranges of environmental conditions under which the collected copepod species were found in the study area. N, number of occurrence localities; EC, electrical conductivity ( $\mu\text{S}/\text{cm}$ ). Hydroperiod = A, astatic; P, permanent; T, temporary.

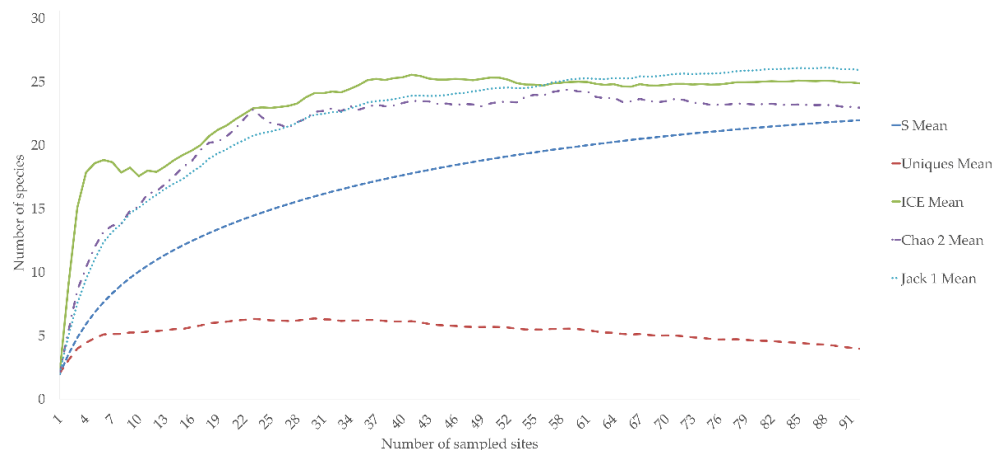
Taxon	N	Elevation (m a.s.l.)		EC ( $\mu\text{S}/\text{cm}$ )		Water Temperature ( $^{\circ}\text{C}$ )		Hydroperiod
		Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	
<b>Calanoida Sars, 1903</b>								
<i>Arctodiaptomus</i> sp.	1	951		39		13		T
<i>Copidodiaptomus numidicus</i>	2	482–518	500 $\pm$ 25.5	419–482	450.5 $\pm$ 44.5	12.1–15	13.5 $\pm$ 2	P
<i>Diaptomus cyaneus</i>	6	750–1071	847 $\pm$ 114.8	39–1405	666.6 $\pm$ 588.6	9.9–15.7	13.3 $\pm$ 1.9	T
<i>Diaptomus serbicus</i>	6	662–838	760 $\pm$ 83.9	50–1305	613.3 $\pm$ 463.4	10–13	11.8 $\pm$ 1.1	T
<i>Hemidiaptomus gurneyi</i>	2	750–951	850 $\pm$ 142.1	93–208	123.5 $\pm$ 119.5	13–13.4	13.2 $\pm$ 0.3	T
<i>Mixodiaptomus kupelwieseri</i>	18	526–943	769 $\pm$ 109.1	50–1124	299.4 $\pm$ 300.6	6–18.8	11.7 $\pm$ 3.9	A-T
<b>Cyclopoida Burmeister, 1834</b>								
<i>Acanthocyclops americanus</i>	4	598–790	663 $\pm$ 87.2	478–626	523.7 $\pm$ 69.1	10–18.3	14.8 $\pm$ 3.8	P
<i>Cyclops ankyrae</i>	2	614–795	704 $\pm$ 128	250–1335	792.5 $\pm$ 767.2	10–14.5	12.2 $\pm$ 3.2	T
<i>Cyclops divergens</i>	31	470–1097	774 $\pm$ 151.7	20–4130	407.3 $\pm$ 797.8	6–21	10.2 $\pm$ 4.2	A-P-T
<i>Diacyclops bicuspidatus</i>	1	904		109		18.8		A
<i>Diacyclops bisetosus</i>	3	653–832	741 $\pm$ 89.5	71–585	272 $\pm$ 274.7	8–13.6	11.5 $\pm$ 3.1	A-T
<i>Diacyclops lubbocki</i>	25	593–1069	780 $\pm$ 108.5	40–992	237.1 $\pm$ 254.9	4.8–18	10.5 $\pm$ 3.1	T
<i>Eucyclops serrulatus</i>	19	482–1030	786 $\pm$ 139.1	21–714	232.1 $\pm$ 228.8	5–23.5	11 $\pm$ 5.4	A-P-T
<i>Macrocyclus albidus</i>	4	651–749	714 $\pm$ 44.6	27–317	136.7 $\pm$ 157.4	5.7–12.6	8.8 $\pm$ 3.5	P-T
<i>Megacyclus viridis</i> s.l.	27	470–1071	790 $\pm$ 130.9	39–1287	315.4 $\pm$ 356.1	6–17	10.9 $\pm$ 3.3	A-P-T
<i>Mesocyclops leuckarti</i>	2	651–675	663 $\pm$ 17	83–317	200 $\pm$ 165.5	9.6–12.6	11.1 $\pm$ 2.1	P-T
<i>Metacyclus minutus</i>	5	470–1165	814 $\pm$ 248.4	170–1028	606.6 $\pm$ 370.6	5.7–14.5	10.1 $\pm$ 3.4	T
<i>Microcyclus varicans</i>	1	662		90		9		T
<i>Thermocyclops dybowskii</i>	1	482		182		15		P
<i>Tropocyclops prasinus</i>	2	672		296		11.2		P
<b>Harpacticoida Sars, 1903</b>								
<i>Attheyella trispinosa</i>	9	526–918	775 $\pm$ 108.5	40–1405	369.5 $\pm$ 490.1	9–17	12.3 $\pm$ 2.7	P-T
<i>Canthocamptus staphylinus</i>	10	750–1097	850 $\pm$ 98.7	20–992	226 $\pm$ 343.1	7–13	9.9 $\pm$ 2.1	T

The most frequently occurring copepod species within the study area (i.e., those occurring in at least 20% of the sampled sites) were the cyclopoids *Cyclops divergens* Lindberg, 1936; *Megacyclus viridis* s.l.; *Diacyclops lubbocki* (Brady, 1869); *Eucyclops serrulatus* (Fischer, 1851); and the calanoid *Mixodiaptomus kupelwieseri* (Brehm, 1907) (Table 2).

The occurrence in the study area of both the copepod species reported in the literature, i.e., the diaptomid *Hemidiaptomus gurneyi* (Roy, 1927) and the cyclopoid *Diacyclops bicuspidatus* (Claus, 1857), was confirmed during the present survey.

Rarefaction curves and species richness estimators are reported in Figure 3. The sample-based rarefaction curve of mean species richness based on the collected data approaches the asymptote without reaching it, thus suggesting that the recorded species richness is a bit lower than the real copepod diversity occurring in the study area. The trend of uniqueness is stable at four species. The implemented non-parametric species richness

estimators show an expected overall species richness between 23 (bias-corrected formula of Chao2 equation—Chao2) and 26 (first-order Jackknife richness estimator—Jack1) in the study area. These values are slightly higher than the recorded copepod species richness value of 22.



**Figure 3.** Species accumulation curves (S Mean) and performance of estimators of copepod species richness (ICE Mean, Jack 1 Mean, Chao 2 Mean) and of uniqueness (Uniques Mean). Number of sampled sites is on the x-axis; cumulative species richness is on the y-axis.

#### 4. Discussion

The current crustacean fauna of Sicily is characterised by the sympatric (but mostly allopatric) coexistence of mesophilous taxa of northern and north-eastern origin, which likely colonised the island during Pleistocene climatic fluctuations and are now confined to higher altitudes and microthermal refuges, and termophilous taxa of southern origin, which colonised Sicily during the Holocene and whose expansion in the island is still underway [20]. Due to its physiography, geology, and climate, the study area is expected to be characterised by the occurrence of taxa with a northern or north-eastern affinity, as also suggested by its flora and vegetation [24].

Most of the collected harpacticoid and cyclopoid copepods are here ascribed to euryecious species, which are rather widespread in the west Palaearctic region and thus biogeographically poorly informative. However, the unresolved taxonomy of most copepod taxa belonging to these orders leads to overestimate their distribution ranges and ecological niches, thus biasing any ecological and biogeographical analysis [64], and it is likely that under several binomia are actually lumped complexes of species characterised by narrower distribution areas and ecology (e.g., [65,66]). The only cyclopoid species with a restricted distribution range collected in the frame of the present survey is *Cyclops ankyrae* Mann, 1940, belonging to a Turanic-Mediterranean chorotype *sensu* Vigna Taglianti et al. [67]. Conversely, the relatively stable taxonomy of the Calanoida and the fairly accurate degree of knowledge about their large-scale distribution allow to draft some biogeographical inferences. Within this group, the occurrence of species with European (*Mixodiaptomus kupelwieseri*) or Balkan (*Hemidiaptomus gurneyi*, *Diaptomus serbicus* Gjorgjjevič, 1907, and *Arctodiaptomus* sp.) distribution barycentres confirms the role of the area as a refugium where relic copepod taxa that colonised the island during the Pleistocene glaciations might have survived during the current post-glacial phase, as also observed for other aquatic taxa in the same area (e.g., [35,68]). This group of mesophilous species occurs in association with some primarily west Mediterranean species linked with Mediterranean “rainy areas” (*sensu* Gauthier [69], see also Marrone et al. [70]), here represented by the diaptomids *Copidodiaptomus numidicus* (Gurney, 1909) and *Diaptomus cyaneus* Gurney, 1909.

In accordance with the expectations, no strictly Maghrebian elements are present in the study area since these are confined to the arid and semi-arid parts of the island [5,6].



Based on the currently available data, the copepod fauna of the study area is thus composed by a numerically small but biogeographically significant group of taxa with a Balkan affinity, a few Mediterranean taxa, and a larger group of species with wider distribution areas.

The absence of consolidated checklists for Sicilian cyclopoids and harpacticoids prevents from a sound comparison between the regional fauna and that of the study area. However, most of the species reported for Sicilian surface waters by Ruffo and Stoch [58] were collected also in the frame of this study, whereas the identity of some taxa listed by Ruffo and Stoch [58] but not found in the study area needs to be thoroughly verified; e.g., the populations of *Cyclops abyssorum* G.O. Sars, 1863, reported by Calvo et al. [15] are possibly to be ascribed to *C. divergens*, a species occurring in the study area.

With reference to the order Calanoida, for which more representative data are available (cf. Alfonso et al. [59] for the Diaptomidae and Vecchioni et al. [11] for the Pseudodiaptomidae), only 6 of the 11 species reported for Sicily were found in the frame of this study. Only those species restricted to highly mineralised water bodies, such as *Arctodiaptomus salinus* (Daday, 1885) and *Calanipeda aquaedulcis* Kritschagin, 1873, and those linked with arid and semi-arid areas, such as *Hemidiaptomus ingens* (Gurney, 1909) and *Metadiaptomus chevreuxi* (Guerne and Richard, 1894), along with and *Arctodiaptomus kerkyrensis* (Pesta, 1935), a rare species currently known for a single site in eastern Sicily, proved to be absent.

Based on the available data, the study area is thus characterised by a noteworthy copepod diversity and high conservation value. Moreover, as suggested by the sample-based rarefaction curves and the non-parametric species richness estimators, further sampling surveys might bring to the finding of further copepod species, with an estimated occurrence of one to four species more than those currently known.

All the collected copepod species are already known to occur in Sicily (see references above), but most of them are regionally rare. In fact, except for *E. serrulatus*, *T. prasinus* (Fischer, 1866), *M. viridis*, *C. divergens*, and *D. lubbocki*, all the other observed copepod species were to date known in Sicily from few sites each, and their status and distribution on the island are currently unknown. Among the Cyclopoida, the finding of *Cyclops ankyrae*, a rare cyclopoid species currently known to occur in temporary water bodies in Sicily [17], peninsular Italy [58,71,72], the southern Balkan peninsula [47], Turkey [55], and Iran [52] is particularly noteworthy; however, it is probable that the populations of *C. furcifer* Claus, 1857, a mostly North European species reported for Sicilian temporary ponds by Margaritora et al. [12], are in fact to be ascribed to *C. ankyrae* so that the regional distribution of the species could be underestimated. As already stressed for *Cyclops abyssorum*, the copepod populations belonging to the genus *Cyclops* in Sicily need a careful revision to ascertain their actual identity.

All the calanoid copepods observed in the study area were collected in astatic or temporary water bodies, with the only exception of the diaptomid *Copidodiaptomus numidicus*, which was collected only in permanent reservoirs. Among the Cyclopoida, six species were only observed in temporary or astatic ponds, three were only observed in permanent ones, and five species were collected both in permanent and temporary water bodies (Table 3). *Cyclops ankyrae* and *Metacyclops minutus* were usually observed in small, temporary water bodies. Conversely, *Tropocyclops prasinus*, *Acanthocyclops americanus* (Marsh, 1893), and *Thermocyclops dybowskii* (Landé, 1890) were only observed in permanent water bodies. However, the limited number of occurrence localities available for several cyclopoid species prevents from any sound ecological inference for the Sicilian populations of these taxa, and it is desirable that further distribution and ecological data are collected. *Acanthocyclops americanus* is the only non-native copepod species found in the study area. It is a widespread invader of Nearctic origin, which colonised most of the Palaearctic region from Madeira to Central Siberia, where it became one of the dominant zooplankters in eutrophic reservoirs [73,74]. In the study area, *A. americanus* was found in four permanent reservoirs, where it was often the only occurring copepod. In Sicily, the species was already reported for a concrete reservoir within the city of Palermo (Schifani et al. [18], sub *A. trajani*

Mirabdullayev and Defaye, 2004), thus confirming the preference of this non-native species for permanent, man-made water bodies; in fact, artificial reservoirs are known to act as invasion hubs favouring invasive species because of their recent origin and the lack of structured biological communities [75,76]. *A. americanus* is currently limited to the western and northern fringes of the study area, and its possible colonisation of the natural water bodies of the area should be monitored. However, it should also be stressed that, although the synonymy of *A. trajani* and *A. americanus* and their non-native status in the Palaearctic region are accepted by most authors (e.g., [57,73,74]), these issues have been discussed and criticized by Anufrieva et al. [77], and further research should desirably be performed to test these hypotheses.

Only two harpacticoids have been found in the frame of this survey, i.e., *Attheyella trispinosa* (Brady, 1880) and *Canthocamptus staphylinus* (Jurine, 1820). Both species were collected mostly in temporary water bodies although *A. trispinosa*, was also found in a single permanent site out of the nine occurrence localities of the species. Prior to this survey, both species had been only occasionally recorded in Sicily [17,78]; however, they proved to be rather common in the study area, thus suggesting that their alleged rarity on the island might be ascribed to the lack or paucity of samplings aimed at collecting harpacticoids in Sicily rather than to their actual rarity.

## 5. Conclusions

The results of present work stress the noteworthy diversity of the copepod fauna of the investigated traditional rural landscape and the magnitude of the so-called Wallacean and Hutchinsonian shortfalls (see Hortal et al. [79]), which are hindering current knowledge and comprehension of the inland water biota of the Mediterranean islands. Apart for a few studies [19,29,30,80–85], the non-malacostracan inland water crustacean fauna of Mediterranean islands is to date scarcely known, and synoptical data are missing. We hope that this paper might stimulate further, detailed faunistic studies, which are the necessary bases for any further ecological, taxonomical, and biogeographical inference, and help to better understand and manage the unique inland water biological diversity of the Mediterranean area.

**Author Contributions:** Conceptualization, F.M. and M.A.; methodology, M.M., L.V., G.B. and F.M.; writing—original draft preparation, M.M., L.V., G.B. and F.M. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was partly supported by the Research Project MEMOLA—Mediterranean Mountainous Landscapes: a historical approach to cultural heritage based on traditional agrosystems, funding from the European Union’s Seventh Framework Programme for Research, Technological Development, and Demonstration under grant agreement no. 613265.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** NHBS Ltd. ([www.nhbs.com](http://www.nhbs.com)) is kindly acknowledged for having provided the nets used in the frame of this survey. The authors wish to thank Fabio Stoch (Université libre de Bruxelles, Belgium) for the stimulating discussions about inland water copepods and Federica Vicari, Luca Montevago, and Francesco Barna for the support they provided in the frame of the fieldwork. Orazio Caldarella is warmly acknowledged for the information he generously shared about the location and characteristics of the water bodies occurring in the study area. The comments of three anonymous reviewers allowed to improve the first draft of the manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Collected copepods and ecological characteristics of the sampled sites at different sampling dates. EC, electrical conductivity ( $\mu\text{S}/\text{cm}$ ); TEMP, water temperature ( $^{\circ}\text{C}$ ); n.a., not available. FM, Federico Marrone; FV, Federica Vicari; LM, Luca Montevago; LV, Luca Vecchioni; MM, Marta Marchese.

Code	Sampling Date	Calanoida	Cyclopoida	Harpacticoida	EC	TEMP	Collector(s)
PA009	09/03/2004	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l., <i>D. lubbocki</i>	<i>A. trispinosa</i>	112	10	FM
PA009	08/05/2015	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l.	<i>A. trispinosa</i>	140	17	FM
PA009	30/04/2019	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l.	<i>A. trispinosa</i>	n.a.	n.a.	FV and LM
PA009	24/04/2021	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l.	<i>A. trispinosa</i>	180	16	MM
PA012	20/12/2003		<i>C. ankyrae</i> , <i>D. lubbocki</i>		250	10	FM
PA079	10/03/2004	<i>M. kupelwieseri</i>	<i>D. lubbocki</i>		53	6	FM
PA079	02/05/2004	<i>M. kupelwieseri</i>	<i>D. lubbocki</i>		300	18	FM
PA079	28/01/2012	juveniles	<i>D. lubbocki</i>		309	4.8	FM
PA079	06/03/2012	<i>H. gurneyi</i> , <i>M. kupelwieseri</i>	<i>D. lubbocki</i>		208	13.4	FM
PA079	03/01/2021		<i>C. divergens</i> , <i>D. bisetosus</i>		71	8.0	MM
PA080	20/12/2003		<i>M. viridis</i> s.l., <i>C. divergens</i> , <i>M. minutus</i>		340	9	FM
PA081	02/05/2004	<i>M. kupelwieseri</i>	<i>C. divergens</i> , <i>D. bicuspidatus</i>		109	18.8	FM
PA081	27/05/2010	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l., <i>E. serrulatus</i>		145	16	FM
PA081	26/04/2019	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l.		n.a.	n.a.	FV and LM
PA081	03/01/2021	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l., <i>E. serrulatus</i>		94	6.0	MM
PA082	06/05/2018		<i>M. viridis</i> s.l., <i>C. divergens</i> , <i>E. serrulatus</i>		n.a.	n.a.	FM
PA082	26/04/2019		<i>C. divergens</i> , <i>E. serrulatus</i>		n.a.	n.a.	FV and LM
PA082	03/01/2021				1372	7.5	MM
PA082	06/05/2010				678	18	FM
PA082	08/05/2015		<i>C. divergens</i>		340	21	FM
PA084	19/04/2021	<i>D. serbicus</i>	<i>Diacyclops lubbocki</i>		467	13	MM, FM, LV
PA085	22/02/2005	<i>M. kupelwieseri</i>	<i>D. lubbocki</i>		565	9.2	FM
PA085	13/02/2021	<i>M. kupelwieseri</i>	<i>E. serrulatus</i>		543	12	MM
PA086	26/04/2019	<i>M. kupelwieseri</i>	<i>D. lubbocki</i> , <i>C. divergens</i>		n.a.	n.a.	FV and LM
PA086	03/01/2021				160	8	MM
PA087	20/12/2003	<i>M. kupelwieseri</i>	<i>C. divergens</i> , <i>M. minutus</i>	<i>C. staphylinus</i>	170	9	FM
PA091	01/11/2010	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l., <i>C. divergens</i>	<i>A. trispinosa</i>	n.a.	n.a.	FM
PA120	10/10/2020		<i>E. serrulatus</i>		n.a.	n.a.	FM
PA121	21/08/2008		<i>E. serrulatus</i>		273	23.5	FM
PA124	17/03/2022	<i>M. kupelwieseri</i>	<i>C. divergens</i> , <i>D. lubbocki</i>	<i>A. trispinosa</i>	158	11.3	FM and LV
PA133	29/11/2020				230	13.0	MM
PA181	01/11/2010	<i>M. kupelwieseri</i>	<i>C. divergens</i>		1124	n.a.	FM
PA198	09/01/2013		<i>E. serrulatus</i>		714	10	FM
PA198	19/04/2021	<i>C. numidicus</i>	<i>T. dybowskii</i>		482	15	MM, FM, LV
PA204	17/03/2022	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l., <i>C. divergens</i> , <i>D. lubbocki</i>		222	6.5	FM and LV
PA212	29/01/2021	<i>D. serbicus</i>			1305	11.2	MM
PA213	29/01/2021	<i>D. serbicus</i>	<i>M. minutus</i>	<i>A. trispinosa</i>	1028	12.5	MM
PA214	07/03/2021	<i>D. cyaneus</i>	<i>M. viridis</i> s.l.		314	15.4	MM
PA235	26/04/2019		<i>M. viridis</i> s.l.		n.a.	n.a.	FV and LM
PA236	26/04/2019		<i>M. albidus</i> , <i>E. serrulatus</i>		n.a.	n.a.	FV and LM
PA237	30/04/2018		<i>C. divergens</i>	<i>A. trispinosa</i>	n.a.	n.a.	FV and LM
PA238	30/04/2019		<i>C. divergens</i>		n.a.	n.a.	FV and LM
PA238	24/04/2021		<i>C. divergens</i>		159	18.5	MM
PA239	n.a.		<i>D. lubbocki</i>	<i>A. trispinosa</i>	n.a.	n.a.	FV and LM
PA240	30/04/2019	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l., <i>D. lubbocki</i>	<i>C. staphylinus</i>	n.a.	n.a.	FV and LM
PA240	03/01/2021	<i>M. kupelwieseri</i>	<i>C. divergens</i> , <i>D. lubbocki</i>		121	9.2	MM
PA241	26/04/2019	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l.	<i>C. staphylinus</i>	n.a.	n.a.	FV and LM
PA241	13/02/2021	<i>M. kupelwieseri</i>	<i>D. lubbocki</i>	<i>C. staphylinus</i>	142	8.7	MM
PA242	13/02/2021		<i>C. divergens</i> , <i>M. viridis</i> s.l.		290	9.5	MM
PA242	n.a.		<i>E. serrulatus</i> , <i>M. viridis</i> s.l.	<i>C. staphylinus</i>	n.a.	n.a.	FV and LM
PA243	30/04/2019	<i>M. kupelwieseri</i>	<i>D. lubbocki</i>		n.a.	n.a.	FV and LM
PA244	26/04/2019		<i>C. divergens</i>		n.a.	n.a.	FV and LM
PA245	29/03/2020	<i>D. serbicus</i> , <i>M. kupelwieseri</i>	<i>D. lubbocki</i>		470	12	MM
PA246	07/03/2021		<i>Cyclops ankyrae</i>		1335	14.5	MM
PA247	29/03/2020	<i>D. cyaneus</i>			1369	14	MM
PA247	29/01/2021	<i>D. cyaneus</i>	<i>M. viridis</i> s.l., <i>D. lubbocki</i>	<i>C. staphylinus</i>	992	10.8	MM
PA247	12/02/2021	<i>D. cyaneus</i>	<i>D. lubbocki</i>		960	9.9	MM
PA247	07/03/2021	<i>D. cyaneus</i>	<i>M. viridis</i> s.l.		1287	15.7	MM
PA247	05/04/2021	<i>D. cyaneus</i>		<i>A. trispinosa</i>	1405	14.5	MM
PA248	12/02/2021				734	9.8	MM
PA248	05/04/2021		<i>M. viridis</i> s.l., <i>M. minutus</i>		935	14.5	MM
PA249	22/11/2020		<i>M. viridis</i> s.l., <i>E. serrulatus</i>		360	13	MM
PA250	12/02/2021		<i>C. divergens</i>		541	15	MM
PA251	24/04/2021		<i>D. bisetosus</i>	<i>C. staphylinus</i>	160	13	MM
PA252	13/02/2021		<i>M. minutus</i>		560	5.7	MM
PA253	13/02/2021				64	6.2	MM
PA253	19/04/2021				246	16.2	MM, FM, LV

Table A1. Cont.

Code	Sampling Date	Calanoida	Cyclopoida	Harpacticoida	EC	TEMP	Collector(s)
PA256	19/04/2021		<i>C. divergens</i>		4130	10.2	MM, FM, LV
PA258	03/01/2021		<i>C. divergens</i>		112	8.0	MM
PA259	29/01/2021		<i>M. viridis</i> s.l., <i>T. prasinus</i>	<i>A. trispinosa</i>	491	11.2	MM
PA261	13/02/2021		<i>M. viridis</i> s.l., <i>D. bisetosus</i>		585	13.6	MM
PA264	19/04/2021		<i>M. albidus</i> , <i>M. leuckarti</i>		317	12.6	MM, FM, LV
PA265	19/04/2021	<i>M. kupelwieseri</i>	<i>D. lubbocki</i>		220	15	MM, FM, LV
PA266	19/04/2021				413	12.1	MM, FM, LV
PA267	19/04/2021	<i>C. numidicus</i>	<i>C. divergens</i>		419	12.1	MM, FM, LV
PA268	19/04/2021		<i>C. divergens</i>		123	13	MM, FM, LV
PA269	19/04/2021	<i>D. cyaneus</i>	<i>M. viridis</i> s.l.		219	13.2	MM, FM, LV
PA270	07/03/2020	<i>D. serbicus</i> , <i>M. kupelwieseri</i>			360	10	MM
PA271	13/02/2021		<i>E. serrulatus</i>		535	13	MM
PA272	24/04/2021		<i>C. divergens</i> , <i>A. americanus</i>		626	18.3	MM
PA273	24/04/2021		<i>A. americanus</i>		486	17.5	MM
PA274	24/04/2021		<i>D. lubbocki</i>		89	16	MM
PA275	24/04/2021		<i>C. divergens</i>		301	16.2	MM
PA276	13/02/2021		<i>C. divergens</i>		83	10.5	MM
PA277	13/02/2021		<i>C. divergens</i>		64	10	MM
PA278	29/11/2020				190	13.0	MM
PA292	05/12/2021	juveniles	-		43	11.4	MM
PA292	05/01/2022	<i>D. cyaneus</i>	<i>D. lubbocki</i>		41	14	MM
PA293	05/12/2021			<i>C. staphylinus</i>	41	12	MM
PA294	05/12/2021		<i>E. serrulatus</i>		n.a	n.a.	MM
PA295	05/12/2021	juveniles	<i>M. viridis</i> s.l., <i>D. lubbocki</i>	<i>A. trispinosa</i>	51	9.4	MM
PA295	05/01/2022	<i>D. cyaneus</i>	<i>D. lubbocki</i>	<i>A. trispinosa</i>	40	12.5	MM
PA296	05/12/2021		<i>M. viridis</i> s.l., <i>D. lubbocki</i>	<i>C. staphylinus</i>	57	9	MM
PA297	19/12/2021		<i>M. albidus</i> , <i>E. serrulatus</i>		27	8	MM
PA298	19/12/2021		<i>E. serrulatus</i>		21	8.7	MM
PA299	19/12/2021	juveniles	<i>M. varicans</i>	<i>A. trispinosa</i>	90	9	MM
PA299	05/01/2022	<i>D. serbicus</i> , <i>M. kupelwieseri</i>			50	12.3	MM
PA300	19/12/2021		<i>D. lubbocki</i>		40	9.2	MM
PA301	19/12/2021		<i>M. viridis</i> s.l., <i>E. serrulatus</i>		94	9.3	MM
PA302	19/12/2021		<i>D. lubbocki</i>		98	9.6	MM
PA303	19/12/2021		<i>M. viridis</i> s.l., <i>M. leuckarti</i>		83	9.6	MM
PA304	19/12/2021		<i>C. divergens</i> , <i>D. lubbocki</i>		97	9.5	MM
PA305	19/12/2021		<i>C. divergens</i> , <i>D. lubbocki</i>		123	8.8	MM
PA306	19/12/2021		<i>M. viridis</i> s.l.		120	8.8	MM
PA308	19/12/2021		<i>M. viridis</i> s.l.		98	8.2	MM
PA309	05/01/2022	<i>H. gurneyi</i> , <i>D. cyaneus</i> , <i>Arctodiaptomus</i> sp.	<i>M. viridis</i> s.l., <i>C. divergens</i>		39	13	MM
PA311	17/03/2022		<i>A. americanus</i>		505	13.5	FM and LV
PA312	17/03/2022		<i>A. americanus</i>		478	10	FM and LV
PA313	17/03/2022		<i>D. lubbocki</i>		152	12.2	FM and LV
PA314	17/03/2022		<i>T. prasinus</i>		296	11.2	FM and LV
PA315	17/03/2022	<i>M. kupelwieseri</i>	<i>M. viridis</i> s.l., <i>C. divergens</i>		1100	10.2	FM and LV
PA317	02/05/2021		<i>E. serrulatus</i>		438	20	MM
PA318	19/03/2022		<i>E. serrulatus</i>		56	5	MM
PA319	19/03/2022		<i>M. viridis</i> s.l., <i>E. serrulatus</i>		64	6	MM
PA320	19/03/2022		<i>C. divergens</i>		54	6	MM
PA321	19/03/2022		<i>M. albidus</i>		66	5.7	MM
PA322	20/03/2022		<i>C. divergens</i>	<i>C. staphylinus</i>	20	7	MM
PA323	20/03/2022		<i>D. lubbocki</i>		66	6.8	MM
PA324	20/03/2022		<i>E. serrulatus</i>		45	7.2	MM
PA325	20/03/2022		<i>E. serrulatus</i>		73	7.5	MM
PA326	20/03/2022		<i>M. viridis</i> s.l.		45	7.3	MM
PA327	20/03/2022		<i>M. viridis</i> s.l., <i>C. divergens</i>		60	7.2	MM



## Appendix B



**Figure A1.** Distribution maps of the six collected calanoid copepod species ((A) *Arctodiaptomus* sp.; (B) *Copidodiaptomus numidicus*; (C) *Diaptomus cyaneus*; (D) *Diaptomus serbicus*; (E) *Hemidiaptomus gurneyi*; (F) *Mixodiaptomus kupelwieseri*). The solid yellow line shows the boundaries of the Nature Reserve “Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago”.





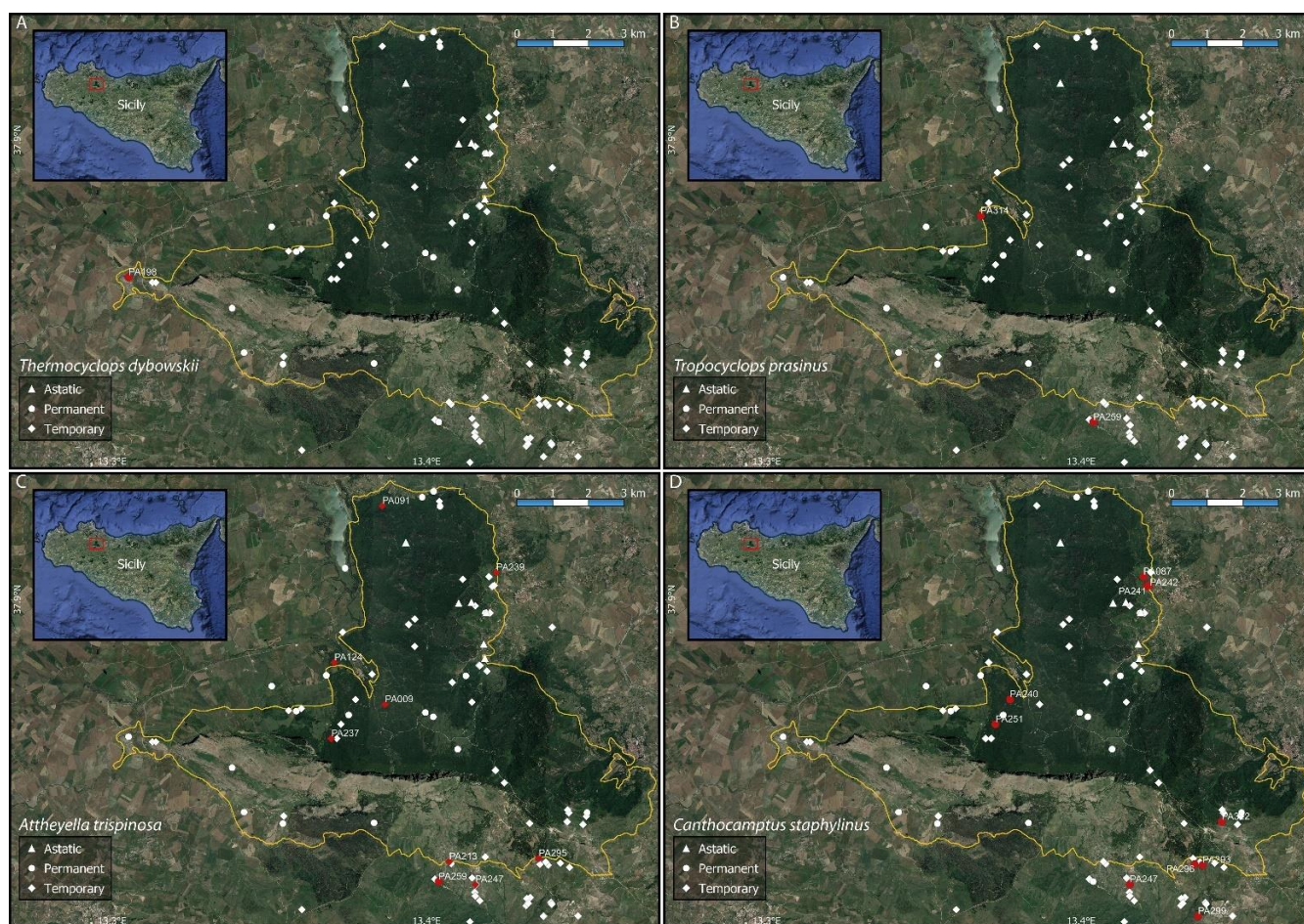
**Figure A2.** Distribution maps of some of the collected cyclopoid copepod species ((A) *Acanthocyclops americanus*; (B) *Cyclops ankyrae*; (C) *Cyclops divergens*; (D) *Diacyclops bicuspidatus*; (E) *Diacyclops bisetosus*; (F) *Diacyclops lubbocki*). The solid yellow line shows the boundaries of the Nature Reserve “Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago”.





**Figure A3.** Distribution maps of some of the collected cyclopoid copepod species ((A) *Eucyclops serrulatus*; (B) *Macrocyclus albidus*; (C) *Megacyclus viridis* s.l.; (D) *Mesocyclops leuckarti*; (E) *Metacyclus minutus*; (F) *Microcyclus varicans*). The solid yellow line shows the boundaries of the Nature Reserve “Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago”.





**Figure A4.** Distribution maps of *Thermocyclops dybowskii*, (A), and *Tropocyclops prasinus*, (B), (Cyclopoida) and *Attheyella trispinosa*, (C), and *Canthocamptus staphylinus*, (D), (Harpacticoida). The solid yellow line shows the boundaries of the Nature Reserve “Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago”.

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