Research trend on marine zooplankton in Indonesian Waters: a systematic review

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Abstract. Research on marine zooplankton in Indonesian waters was conducted in the 19th century. However, there is limited information regarding evaluating the research trends and notable scientists involved in this area. This study aims to know the research trend on marine zooplankton research in Indonesian waters. This study analyzed publications that were included in the Scopus database from 1900 to 2021. A systematic review was undertaken using a three-stage procedure including identification, screening, and final following PRISMA chart. The final list was analysed in terms of topics of research, keywoards, location, time of publication, and authorship.. We found that the research trend was changed. During the early stages of the study, there was a prevalent focus on studying both taxonomy copepods and parasite Copepods. However, in recent times, there has been a shift towards favoring the plankton ecology. Despite being a hotspot for marine biodiversity, Indonesia only had a few taxonomists, therefore it was overlooked when marine zooplankton was discovered in its seas. We also found that most of the new finding species come from copepods whereas the other taxa of zooplankton remain undescribed or misidentification. Additionally, young scientists pay less attention to the study of taxonomy. To address these problems, priority is given to intensive training for early-career scientists. Comprehensive approaches using morphological traits and genetic tools will solve this issue.

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1 Introduction

Considering that the Earth's surface is predominantly covered by oceans, which represent around 70%, our current understanding of biodiversity patterns, particularly related to marine zooplankton, remains limited. The role of marine zooplankton in the marine ecosystem is of greatest significance and it plays a crucial part in various essential aspects of the oceans [1]. Marine zooplankton serves as the dominant consumer of primary production within aquatic ecosystems. Within this particular framework, the significance of zooplankton lies in its ecological role within marine food webs [2,3]. Zooplankton is a fundamental link between phytoplankton as the primary producers and higher trophic levels such as fish larvae [4,5]. In addition, because zooplankton are short-lived and sensitive to climate change, they can also be used as an indicator in marine ecosystems [6–8] with the significant component being copepods. Considering their significant role within the ecosystem, it is imperative to undertake an in-depth review of zooplankton biodiversity.

Indonesia, located through the Coral Triangle in the western Pacific Ocean, boasts a remarkable level of marine biodiversity [9,10]. This region has a significant range of marine biodiversity, encompassing zooplankton, which refers to the small organisms commonly found near the surface in aquatic habitats [11–15]. The biodiversity of zooplankton in southeast Asia was conducted under the Japan Society for Promotion of Sciences (JSPS) during 2001-2010 [16]. There are many experts on zooplankton joining this project across countries. Twenty-nine planktonic copepods and 16 meroplanktonic or nonplanktonic copepods have been identified as new to science [17].

The literature review of marine zooplankton in the Indo-Pacific, particularly in Indonesia waters, has been done by [17]. [18] state that the significance of a literature review is enhanced by the participation of any other scientist who contributes vital information regarding methodology and innovation, reduces duplicate research and ensures academic standards are encountered. Further, [19] explained the difference between the literature review and Systematic Review (SR). They describe eight different methodological stages e.g., the focus of the review, methods for data collection, methods for data extraction, number of papers included in the review, methods for data analysis, methods for data presentation, publication, and outcome.

The objective of this study is to delineate the zooplankton research trends in Indonesian waters, including authorship and future research. It is expected that this study will be useful to other parties conducting marine zooplankton research in Indonesia.

2 Materials and method

2.1 Data collection and multistage process

The systematic review method has been used in studies of phenotypic plasticity in marine invertebrates and plants [20], marine-based species distribution model [21], natural hazards [22], and negotiating new regulation for conservation and sustainable marine diversity [23]. We collected data and created our sample in a three-stage process. First, we developed keywords and undertook a search in the Scopus database (scopus.com) to obtain relevant publications on marine research of zooplankton in Indonesia. Articles published between 1900 and the cutoff date of 13 April 2021 with the research term “zooplankton”, “copepods”, “copepoda”, “jellyfish”, “meroplankton”, and “Indonesia”. Non-English publications were excluded from our search. This strategy resulted in 120 articles. The process of selecting articles to include in our review started with a screening abstract. Grey literature, non-English publications, articles that are not directly conducted in Indonesian waters, and articles describing freshwater zooplankton were excluded (Fig. 1). In total, 51 publications were selected for further analysis.

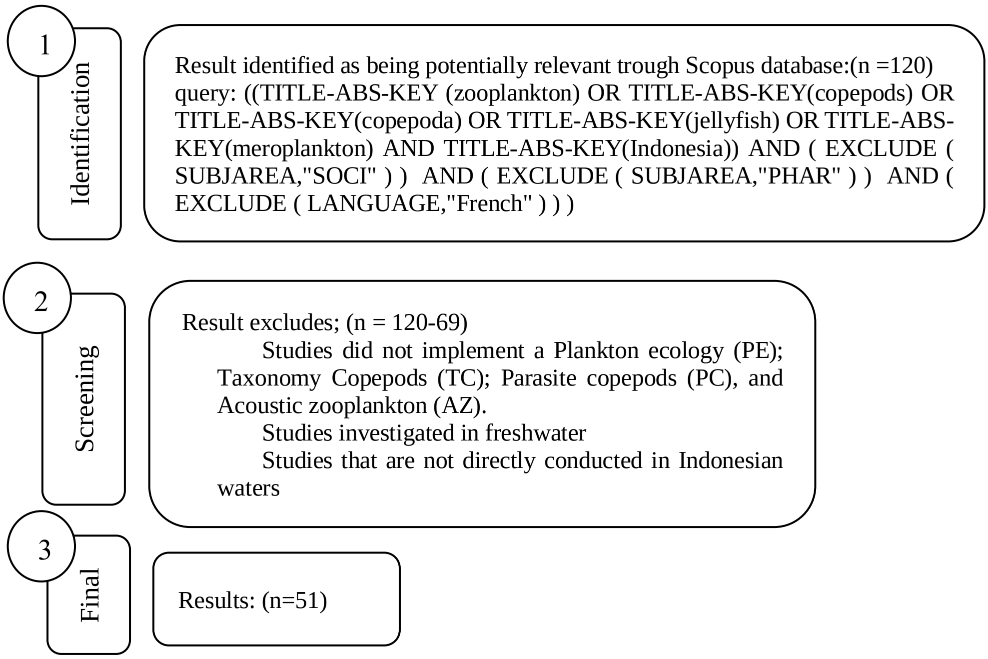

Fig. 1. The multistage process of inclusion and exclusion of Scopus article database focusing on specific keywords.

2.2 Data analysis

After three stage procedure following the PRISMA Chart (Figure 1) [90], a total of 51 articles were sorted into two categories namely research topic and trend, authorship, and affiliation. We used Scopus features to analyse search results, such as the article metric module and author profile pages. Further, the research topic and trend are classified into 4 topics plankton ecology (PE); taxonomy copepods (TC); parasites copepods (PC); and acoustic zooplankton (AZ). The gap analysis was made to identify the research problems and figure out this problem in future research.

2.3 Research topics and trend

We classified the research topics of marine zooplankton in Indonesia between the time range 1986-2021 into four topics. Details of research topics were shown in **Figure 2**.

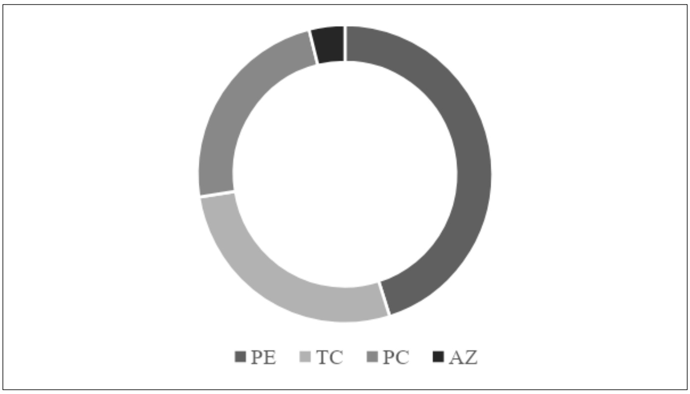

Fig 2. Research Topics of marine zooplankton in Indonesia between 1990-2021 (PE: Plankton Ecology; TC: Taxonomic Copepods; PC: Parasite Copepods; AZ: Acoustic Zooplankton)

The PE topics contributed nearly half of the total. PE reveals the abundance and community structure of zooplankton and jellyfish. PE became the most familiar research topic in marine zooplankton over the period of observation. In the second position, TC accounts for 27% of the total. TC articles describing a new species and a new record of copepods from Indonesian waters. Calanoid copepods, Pontellidae from Indonesian waters have several publications. PC constitutes 24% of the total and takes the third position. PC describes the parasites of copepods in mangrove crabs, fish, and polychaeta. While the last topic is AZ, accounts for only 3% of the total. AZ topics are less familiar compared to other topics in marine zooplankton research during this time period.

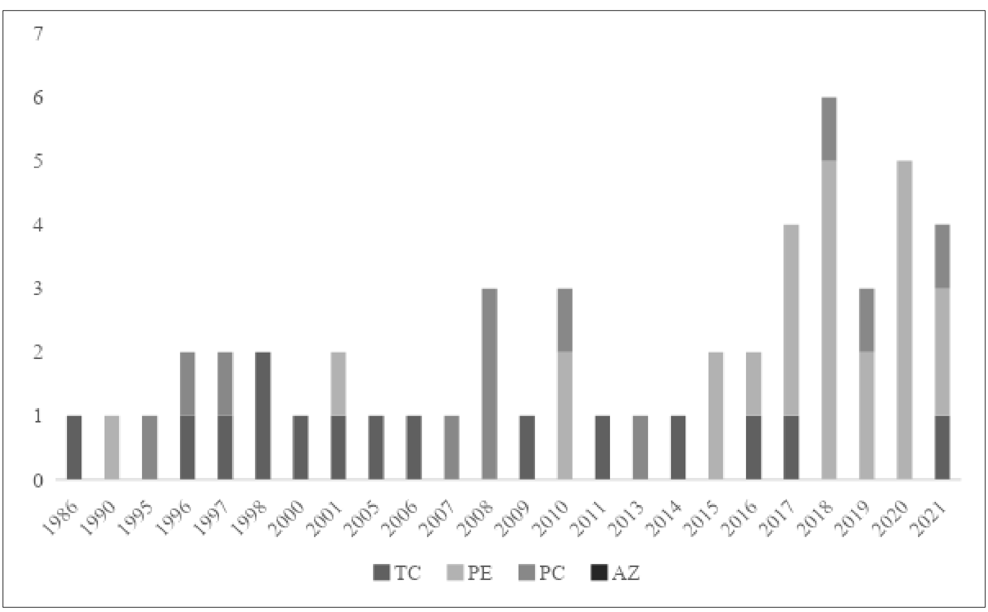

Fig 3. Research trend on marine zooplankton in Indonesia between 1986-2021

The research trend under observation was dynamics (Fig 3). In the beginning (1986-2008), taxonomy studies (both TC and PC) were common. However, in the last few periods (2005-2021), the research trend has changed. The PE topic is more attractive, replacing the

TC topic. Several factors that may be related to these issues are taxonomy studies are underfunded, there is a lack of professional taxonomist scientists in Indonesia, and there is less training for young scientists. In global, taxonomy studies have similar problems [24], despite the fact that taxonomy is important to worldwide conservation [25].

The Wallace area is the most interesting region to conduct research on marine zooplankton in Indonesian waters (**Figure 4**). There consists of all topic studies (TC, PE, PC, and AZ) and a higher number of publications compared to the other regions. [26] describe the significant genetic difference between oceanographic regions, in which communities in the north as well as south of the Java and Flores Seas yet differ by a significant genetic split. The west area is in the second rank, followed by the eastern area in the last position. Although there are fewer articles in the eastern region, this may be due to the Scopus database's limitation to record earlier publications from the Challenger Expedition (1872–1876) in the Arafura, Banda Sea, and Buru Island, where Brady (1883) published articles on calanoid copepods, and the Siboga Expedition (1898–1990), where Carl (1907) published articles on copepods from Ambon Bay and Scott (1909) published copepods from the eastern area [17].

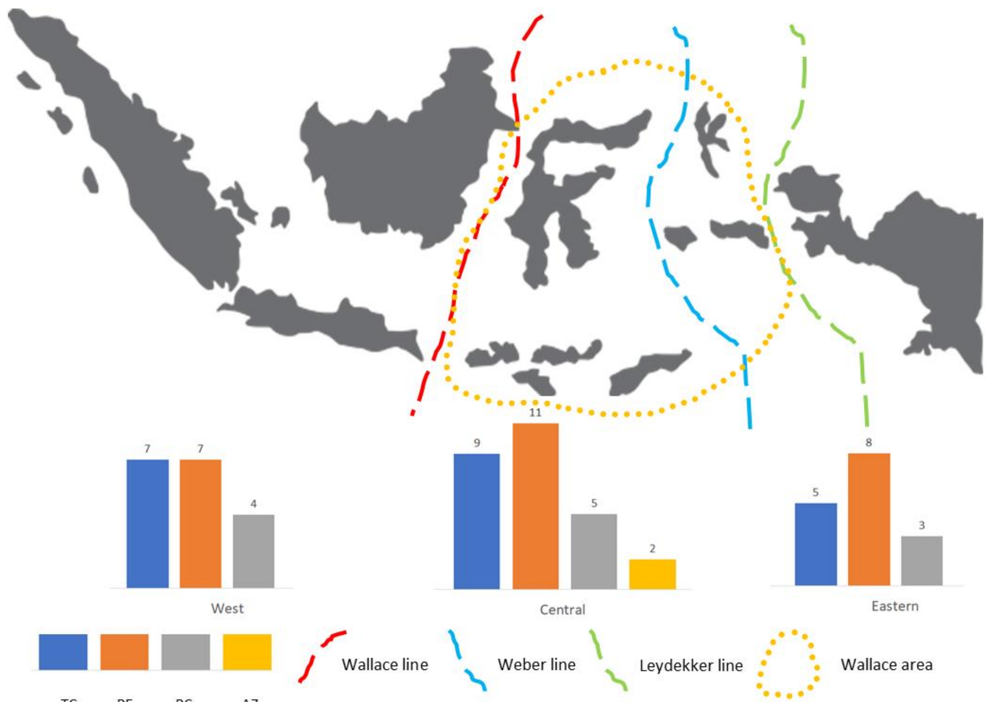

Fig 4. Marine zooplankton research in Indonesian waters (1900-2021).

3 Results and discussion

3.1. Plankton ecology

Marine plankton has a suitable role in marine pelagic ecosystems [1], where their distribution, composition, and abundance are affected by environmental factors [27–29]. Plankton ecology has long been a fundamental topic in limnology and biological oceanography due to its essential functions in ecosystems. The PE topics shown in **Table 1**.

Table 1. PE topic in marine zooplankton in Indonesian waters.

No	Taxa/ groups	Aims/ discussion	References
1	*Crambione mastigophora*	Population dynamics of scypozoan *C. Mastigophora* in Saleh Bay. The biomass trend was rapidly deteriorating. Overexploitation of jellyfish was seen.	[30]
2	*Crambione mastigophora*	The continuity of the indigenous tomato jellyfish (*Crambione mastigophora*) at Saleh Bay, Sumbawa Island, Indonesia.	[31]
3	Plankton	Diversity plankton in Manta ray feeding habitat. Copepods is the dominance zooplankton	[32]
4	Mesozooplankton	Mesozooplankton communities in the epipelagic zone. Calanoid and Cyclopoid copepods were dominant.	[33]
5	Plankton	Diversity and abundance of plankton. *Sagena* is the dominant zooplankton. Temperature as an important feature.	[34]
6	Zooplankton	Zooplankton community in Seagrass ecosystem. Copepods and protozoans are dominant.	[35]
7	Jellyfish *Mastigias papua*	Populations of *Mastigias papua* displayed strong genetic among lakes, and morphological structure, with potential novel Subspecies.	[36]
8	Plankton	Plankton communities in Spermonde estuary.	[37]
9	Plankton	Plankton Communities in Pandeglang, Banten.	[38]
10	Zooplankton	Zooplankton communities in Lembeh Strait and Wori Beach. Copepods become dominant taxa.	[39]
11	Zooplankton	Zooplankton composition in Lembeh Strait. Copepods is dominant taxa.	[40]
12	Copepods	Abundance of copepods in Banda Sea	[15]
13	Jellyfish	the possibility for jellyfish products from Indonesia towards becoming food and medicine.	[41]
14	Jellyfish	Jellyfish Lakes at Misool Islands, Raja Ampat, West Papua, Indonesia	[42]
15	*Acrocalanus* sp	Acrocalanus sp., a blue-pigmented Calanoid Copepod, was identified for the first record in Cendrawasih Bay.	[43]
16	Plankton	Diversity of plankton in Karangsong mangrove conservation area.	[44]
17	Plankton	Spatial distribution of Plankton in Riau.	[45]

18	Bacterioplankton and Jellyfish	Bacterioplankton and bacterial communities associated with jellyfish were found in Indonesian marine lakes.	[46]
19	Jellyfish	Jellyfish lakes in Misool, Raja Ampat	[47]
20	Jellyfish Cambrionella	The commercially harvested new species Crambionella (Scyphozoa) from jellyfish Indonesia's central Java	[48]
21	Mesozooplankton (Calanoid copepods)	Distribution of mesozooplankton in the Spermonde Archipelago (Indonesia, Sulawesi), with particular emphasis on the Calanoida (Copepoda)	[49]
22	Jellyfish	edible jellyfishes collected from Southeast Asia	[50]
23	Jellyfish	Jellyfish fisheries in southeast Asia	[51]
24	Copepods	Grazing in copepods by gut fluorescence measured in Banda Sea	[52]

Copepods are the most dominant taxa [32,33,38–40,49] in the whole of zooplankton communities. However, there are numerous taxa in the zooplankton community identified as dominant taxa, e.g., copepods and protozoans [35]; genus *Sagena* [34]; crustaceans and protozoans [45]. This matter may relate to differences in plankton net mesh size, e.g., 20 µm [32], 23 µm [45], 53 µm [35], 50 and 153 µm [34], 80 and 133 µm [38], 100 µm [15], 200 µm [49,52], 300 µm [33,39], and 505 µm [53]. Varying on the mesh size of the plankton net has different results depending on the target size, research aims, and purposes.

Edible jellyfish from Indonesian waters were reported [30,31,41,48,50,51]. While the other jellyfish known as "Jellyfish lakes" identified from Misool, Raja Ampat *Mastigias papua* was newly reported [47], and three jellyfish lakes, *M. papua*, *Aurelia* sp., and *Cassiopea ornata* [42], were associated with bacterioplankton and jellyfish from Kakaban and Maratua Island, East Kalimantan [46]. A molecular approach was used to reveal the genetic population of the jellyfish *Mastigias papua* in Misool [36]. The edible jellyfish and marine lake jellyfish have been initiated for study, but the harmful jellyfish remain unrevealed.

3.2. Taxonomy copepods

Copepods are the most common zooplankton found in marine environments [54,55]. The taxonomy of copepods (TC) is one of the top two topics studied in Indonesia compared to others. There are 55 new records and 13 new species found in Indonesian waters [17]. As a mega biodiversity country, Indonesia consists of at least 338 species of copepods out of the marine zooplankton known around the world. The discovery of new marine zooplankton species is described by their morphological appearances (**Table 2**).

Table 2. Discoveries of new species marine copepods from Indonesian waters.

No	Species	Location	References
1	*Labidocera Baliensis*	Bali coastal waters	[56]
2	*Labidocera gagensis*	Gag Island	[56]
3	*Tortanus (Atortus) indonesiensis*	Tanjung Merah, North Sulawesi	[14]
4	*T. (A.) omorii*	Tanjung Merah, North Sulawesi	[14]

5	*T. (A.) processus*	Tanjung Merah, North Sulawesi	[14]
6	*T. (A.) lukmani*	Tanjung Merah, North Sulawesi	[14]
7	*T. (A.) sulawesiensis*	Tanjung Merah, North Sulawesi	[14]
8	*T. (A.) manadoensis*	Tanjung Merah, North Sulawesi	[14]
9	*T. (A.) bilobus*	Tanjung Merah, North Sulawesi	[14]
10	*Labidocera kaimanaensis*	Arguni Bay, West Papua	[13]
11	*Pontella papuaensis*	Arguni Bay, West Papua	[13]
12	*Kelleria indonesiana*	Cilacap Bay, Central Java	[12]
13	*Kelleria javaensis*	Off Surabaya, East Java	[12]
14	*Hemicyclops javaensis*	Off Tegal, Java Sea	[57]
15	*Hemicyclops minutus*	Off Tegal, Java Sea	[57]
16	*Paramacrochiron amboinense*	Ambon Bay, Maluku	[57]
17	*Pseudodiaptomus ishigakiensis*	Likupang, Northern coastal Sulawesi	[58]
18	*Labidocera javaensis*	Off Labuan, West Java	[59]
19	*Labidocera muranoi*	Cilacap Bay, Central Java	[59]
20	*Pontella labuanensis*	Coastal of Labuan, West Java	[59]
21	*Calanopia asymmetrica*	Off Labuan, West Java	[60]

There are taxonomic issues with four of the Pontella species that Scott (1909) identified in Indo-Malayan waters [61]. Misidentified *Pontella* species include *P. alata*, *P. cerami*, *P. denticaudata*, and *P. forficula*. Using morphological characteristics, two species of *Ivellopsis* Claus, 1893, and *Pontella* Dana (1849), both found in Indonesian waters, were redescribed and illustrated. Clarifying some synonymies, as well as talking about the various species groups and their patterns of regional distribution, are some additional significant tasks that the author suggests.

Traditional identification methods based on zooplankton morphology require specialized knowledge, a significant amount of time, and a significant amount of work [62]. Nowadays, species can be described based on DNA barcoding according to a specific region of mitochondrial DNA (mtDNA) [63] or a full region of mtDNA for high resolution. Based on DNA sequence data, molecular techniques for species identification have enabled the quick detection, classification, and identification of cryptic or sibling species (e.g., zooplankton communities) [62,64,65]. This molecular approach can be beneficial in assessing cryptic species, which are common in the marine environment, as well as relating the many life cycle phases to the adult, which is difficult to do in the marine ecosystem [66].

A genetic approach has been widely used in Indonesia to reveal marine creatures species [67–70]. Meanwhile, there is no publication with the same approach used in Indonesian waters (marine ecosystems) revealed to assist the copepod species in the current study. Although copepod identification and classification have traditionally been based on morphological and anatomical criteria, it is crucial to use an efficient and promising approach for species identification for estimating copepod diversity [65]. A genetic approach, especially the DNA barcoding of marine zooplankton (e.g., copepods), needs to be progressively empowered in Indonesia as the home of a variety of copepod species.

3.3. Parasites copepods

More than one-third, or 35.33%, of all known copepods are symbiotic. In addition to being found in the five major Copepoda orders (Calanoida, Harpacticoida, Cyclopoida, Poecilostomatoida, and Siphonostomatoida), they are also found near all of the major marine animal phyla, from sponges to mammals [71]. In Indonesian waters, there are some hosts for copepods, e.g., bivalves, black coral, fish and rays, polychaeta, gastropods, and crabs (**Table 3**).

Table 3. Parasitic copepods in Indonesian waters

No	Taxa	Host	Location	References
1	Copepoda (not specific)	Mangrove crab (Scylla sp)	Banda Aceh	[72]
2	*Ergasilus kimi* sp. nov	Dasyatid Ray (*Himantura Oxyrhyncha*)	West Kalimantan	[73]
3	*Pseudocaligus uniartus*	Rabbit fish (*Siganus guttatus*)	South Sulawesi	[74]
4	Nauplii and developing eggs of copepods.	Black coral *Cirrhipathes* cfr. *anguina*	Siladen Island, Sulawesi	[75]
5	*Aequinoctiella cavallettii* sp. nov	Not describes	Tomea Island, Southwest Sulawesi	[76]
6	*Ceratosomicola coia* spec. nov	nudibranch	Sulawesi	[77]
7	*Ceratosomicola delicata* spec. nov	nudibranch	Sulawesi	[77]
8	*Ceratosomicola mammilata* spec. nov	nudibranch	Sulawesi	[77]
9	*Arthurius bunakenensis*	sacoglossan *Elysia pusilla*	Bunaken, Northern Sulawesi	[78]
10	*Nothobomolochus* sp	*Mugil cephalus*	Segara Anakan Lagoon	[79]
11	*Ergasilus* sp. 1	*Mugil cephalus*	Segara Anakan Lagoon	[79]
12	*Ergasilus* sp. 2	*Mugil cephalus*	Segara Anakan Lagoon	[79]
13	*Ergasilidae* gen. et sp. indet	*Mugil cephalus*	Segara Anakan Lagoon	[79]
14	*Caligus rotundigenitalis*	*Mugil cephalus*	Segara Anakan Lagoon	[79]
15	*Chalimus*	*Mugil cephalus*	Segara Anakan Lagoon	[79]
16	*Ergasilus* sp. 4	*Siganus javus*	Segara Anakan Lagoon	[79]
17	*Caligus epidemicus*	*Siganus javus*	Segara Anakan Lagoon	[79]
18	*Caligus* cf. *quadratus*	*Siganus javus*	Segara Anakan Lagoon	[79]
19	*Ergasilus* sp. 2	*Scatophagus argus*	Segara Anakan Lagoon	[79]

20	*Ergasilus* sp. 3	*Scatophagus argus*	Segara Anakan Lagoon	[79]
21	*Caligus acanthopagri*	*Scatophagus argus*	Segara Anakan Lagoon	[79]
22	*Caligus epidemicus*	*Scatophagus argus*	Segara Anakan Lagoon	[79]
23	*Pseudocaligus* sp	*Scatophagus argus*	Segara Anakan Lagoon	[79]
24	*Chalimus*	*Scatophagus argus*	Segara Anakan Lagoon	[79]
25	*Thysanote* sp	*Scatophagus argus*	Segara Anakan Lagoon	[79]
26	*Caligus* cf. *confusus*	*Caranx sexfasciatus*	Segara Anakan Lagoon	[79]
27	*Chalimus*	*Caranx sexfasciatus*	Segara Anakan Lagoon	[79]
28	*Peniculus* cf. *scomberi*	*Caranx sexfasciatus*	Segara Anakan Lagoon	[79]
29	*Eleutheronema tetradactylum*	*Lutjanus johnii*	Segara Anakan Lagoon	[79]
30	*Caligus phipsoni*	*Lutjanus johnii*	Segara Anakan Lagoon	[79]
31	*Parapetalus hirsutus*	*Lutjanus johnii*	Segara Anakan Lagoon	[79]
32	*Chalimus*	*Lutjanus johnii*	Segara Anakan Lagoon	[79]
33	*Naobranchia* cf. *polynemi*	*Lutjanus johnii*	Segara Anakan Lagoon	[79]
34	*Lernanthropus polynemi*	*Lutjanus johnii*	Segara Anakan Lagoon	[79]
35	*Caligus* sp	*Johnius coitor*	Segara Anakan Lagoon	[79]
36	*Chalimus*	*Johnius coitor*	Segara Anakan Lagoon	[79]
37	*Lernanthropus* sp	*Johnius coitor*	Segara Anakan Lagoon	[79]
38	*Peniculus* cf. *scomberi*	*Johnius coitor*	Segara Anakan Lagoon	[79]
39	*Caligus* cf. *epinepheli*	*Epinephelus coioides*	Segara Anakan Lagoon	[79]
40	*Pennellidae* gen. et sp	*Epinephelus coioides*	Segara Anakan Lagoon	[79]
41	Poecilostomatoida: *Leptinogaster digita*	Bivalvia	Irian Barat (eastern area)	[80]
42	Poecilostomatoida: *Anthessius saecularis*	Bivalvia	Irian Barat (eastern area)	[80]
43	Poecilostomatoida: *Lichomolgus hoi* n. sp	Bivalvia	Irian Barat (eastern area)	[80]

44	Poecilostomatoida: *Pseudanthessius dimorphus* n .sp	Bivalvia	Irian Barat (eastern area)	[80]

The PC articles mostly described the symbionts between parasite copepods on commercially available hosts. The edible marine biota comes from fish (*Epinephelus coioides*, *Caranx sexfasciatus, Siganus guttatus, Mugil cephalus, Siganus javus*) and crab (*Scylla* sp) which have economic significance. However, in Indonesian waters, little is known about the symbionts between copepods and other marine biota with less economic value. According to [81], 18 copepods in the waters of Europe are symbionts of polychaetes. .Parasitic copepods are frequently found on both farmed and wild marine finfish, with a significant body of literature detailing their classification, life cycles, and the variety of hosts they infect [91]. The significance of certain species as disease-causing agents has been apparent with the advancement of semi-intensive and intensive aquaculture, despite their long-known propensity to impact the growth, fertility, and survival of their hosts. The Caligidae species are responsible for most disease outbreaks that caused high mortality. Advancements in treatments and management approaches have significantly decreased fatality rates from parasites copepods infections.

3.4. Acoustic zooplankton

For several decades, acoustic techniques have been employed to monitor and evaluate fish populations in the marine pelagic ecosystem, [92, 93]. As the interest in the overall condition of the ocean environment grows, there is a larger demand for monitoring different groups, such as zooplankton [94, 95]. In Indonesian waters, detecting the behavior of zooplankton using acoustic instruments has been done by Dwinovantyo and his colleagues [82,83]. The moored and mobile acoustic Doppler current profiler (ADCP) was set up to provide insight into the upward movement of zooplankton.

DVM in zooplankton is an expected behavior that is affected by oceanographic factors. ADCP measurements could capture this movement through the mean volume backscattering strength (MVBS) [82]. The MVBS datasets were recorded from the bottom mooring ADCP, looking upward at 750 kHz at 15 meters in the deep layer. The highest scattering volume is -57 dB, and the lowest range is -89 dB. ADCP instruments could provide continuous backscattering data on time-series observations. The limitation of this acoustic approach is that it could not detect the size and determine the species of zooplankton from acoustic signals; the material near the seabed that reflected the highest acoustic signal could affect the data quality.

The acoustic instrument was used to determine the DVM of zooplankton in Lembeh Strait. The zooplankton in Lembeh Strait was moving upward to the shallower layer during the night and down to the deeper layer during the daylight [83]. Combining traditional sampling gear (plankton nets), the composition of zooplankton was identified. The dominant taxa of zooplankton were *Oithona* sp and *Paracalanus* sp. Although the nauplii are abundant, they were excluded from analysis because their size is small and they could not be detected by an acoustic signal. The biological data was important to verify the acoustic data. The MVBS and biological datasets are needed to calculate the specific target strength (TS) in each taxon of zooplankton.

4 Authorship and Affiliation

Authorship and affiliation can provide valuable information, such as professional researcher expertise, their institutional or university home base, and research group or colleagues. Authorship of publications related to marine zooplankton in Indonesian waters from 1986 to April 2021 was categorized into three based on the origin of all authors. Authorship publication which only comes from Indonesian scientists is categorized as "INA", collaboration between domestic scientists and foreign scientists as "BOTH", and authorship only comes from foreign scientists known as "NON" (**Figure 5**).

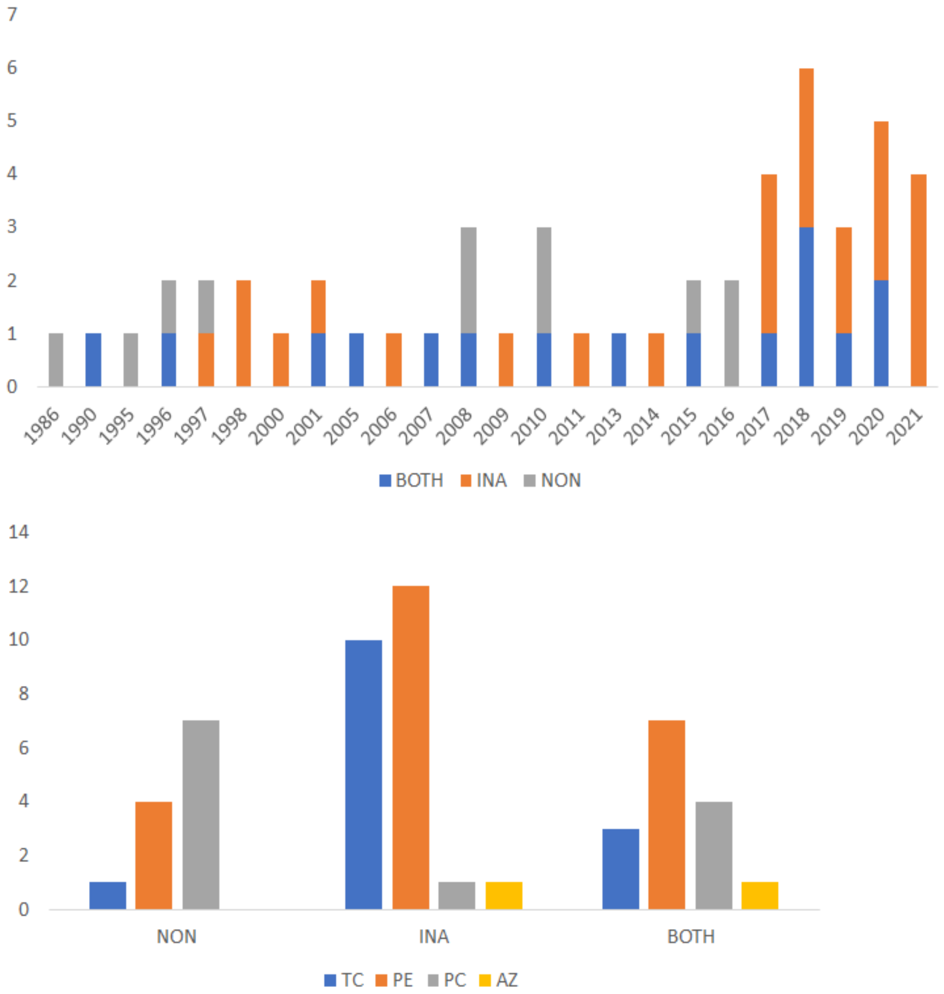

Fig 5. Marine zooplankton authorship based on the origin of all authors (BOTH: foreign and Indonesian author; INA: Indonesian author; Non: foreign authors). Above: authorship in timelines, below: authorship in each topic research

According to **Figure 5**, the highest number of authorship publications (INA) is contributed by Indonesian scientists, followed by collaborative efforts between foreign and Indonesian scientists (BOTH), and finally, publications authored solely by foreign scientists (NON). However, in the beginning, foreign scientists published an article on the TC topic per se [84]. This suggests that there is potential to enhance the participation of Indonesian authors in writing about diverse topics concerning TC and a higher chance to advance knowledge of marine plankton.To accelerate research on coastal and marine areas, the governments of Indonesia and Japan conducted joint research through JSPS projects, e.g., coastal marine science in 2001–2010, Asian Core–ACORE COMSEA in 2011–2015, and Core–to-Core in 2016–2018 [85]. This extensive effort makes a substantial contribution towards the elucidation of marine zooplankton biodiversity in Indonesian waters. As a part of the JSPS, a new species of commercial jellyfish, *Cambrionella* from Central Java [48], and two new species of copepods, *Labidocera* from Gag and Bali Island [56], will be beneficial. The PC aspect has been revealed primarily by foreign scientists. Increased participation of Indonesian authors in global publications is necessary, requiring targeted efforts to improve writing, publishing, and communication abilities.

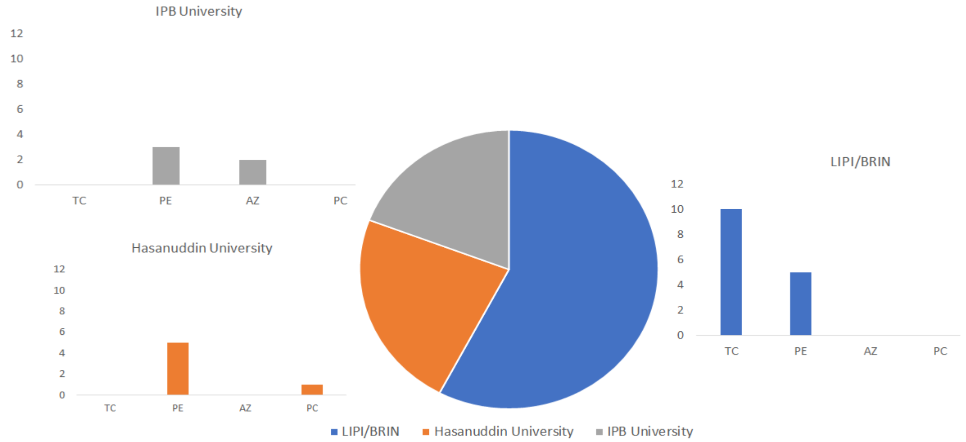

Fig 6. Top 3 research institutes and universities that conduct research on marine zooplankton in Indonesian waters

The top three leading research institutions and universities that conduct research on marine zooplankton in Indonesian waters are LIPI/BRIN, Hasanuddin University, and IPB University (Figure 6). LIPI/BRIN constitutes more than half, with the topic interests being TC and PE. There are many discoveries of new records and new species in copepods from Indonesian waters [12–14,56,57,59–61]. Interestingly, both universities have different research expertise. Hasanuddin University has a researcher whose research domain is rare in the world "parasitic copepods,", while IPB University has an expert who promotes an acoustic approach to reveal zooplankton behavior.

Considering the expertise of the researchers, their network, and the current research on marine zooplankton is essential for developing a strategy. Identifying their current projects or research activities can reduce duplication and budgetary excess. The other researcher with a similar interest or passion could conduct collaborative research to continue solving the current problems.

5 Prospective research and capacity building initiative

The data and information about research trends in marine zooplankton in Indonesian waters from 1980 to 2021 are enormous. According to research trends, some of the present gaps have been identified. The PE topic is the most attractive compared to other topics. The authors explained the diverse taxa of copepods, jellyfish, and zooplankton as a whole community. Edible jellyfish and marine lake jellyfish have been initiated to be revealed, but harmful jellyfish are understudied. However, the varying mesh sizes of the measurements give different results. It is difficult to compare the results and to use the data more carefully in terms of the framework of coastal and marine resource management.

TC topics concern discoveries of the new record and new species of copepods using morphological features. Despite the tiny creatures of copepods, identifying the key organs is challenging and requires more time. Sometimes, it is confusing for young researchers. Without supervision, practice, and training from an expert, it is overwhelming for a beginner. To attract students and young researchers interested in studying taxonomy, it should be stimulated by intensive capacity-building programs.

Addressing the present gaps, the authors suggest future research on revealing the diversity of marine zooplankton using comprehensive approaches. Nowadays, DNA barcoding and environmental DNA are broadly used to reveal the biodiversity of marine ecosystems [86–89]. DNA barcoding could be used to identify the early stages of marine zooplankton, which is a common problem in morphological taxonomy. Environmental DNA (eDNA) is a promising tool for biodiversity assessment by detecting rare species in marine ecosystems that are usually undetected by conventional plankton net methods. Combining morphological features, DNA barcoding, and environmental DNA is prospective. The second finding examines the authorships and organizations, indicating that the progress in research and publication is lower and the number of professional expert scientists is limited. Collaborative research among Indonesian and foreign scientists should be improved. Training programs in taxonomy aspects must be accelerated. Capacity building for young scientists is urgent to improve their knowledge and skills to reveal the biodiversity of marine zooplankton in Indonesian waters.

6 Conclusion

Research topic of marine zooplankton in Indonesian waters including plankton ecology, taxonomy copepods, parasite copepods and acoustic zooplankton. There has been a shift towards of the research trend from Taxonomy study to plankton ecology.

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HAM is preparing a database of marine zooplankton from the Scopus database and drafting whole manuscripts. LMIS and FR analyze the screening process; DGB, M, MJ, and HM supervise and contribute to the final decision on the whole manuscript. All authors contribute equally.

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