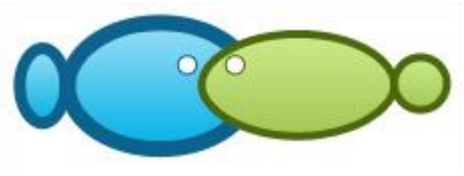

Systematic review of research trends on the endemic fish *Pterapogon kauderni*

[1]Fione Y. Yalindua, [1]Putri S. Ibrahim, [2]Sugeng P. Saputro, [1]Teguh Peristiwady, [3]Joan H. Lawalata

[1] Research Center for Oceanography-BRIN, Jakarta, Indonesia; [2] Research Center for Geotechnology-BRIN, Bandung, Indonesia; [3] Department of Biology, Faculty of Mathematics and Natural Science, Manado State University, Manado, Indonesia. Corresponding author: F. Y. Yalindua, yukitayalindua@gmail.com

Abstract. *Pterapogon kauderni*, also known as Banggai cardinalfish (BCF), is a popular high demand ornamental fish prevalent in Banggai Regency, Central Sulawesi Province, Indonesia which increase the catch process and cause the *P. kauderrni* specified in IUCN as a threatened species, with an estimated population decline of 90%. There are other factors that possibly endanger this population, such as the degradation and alteration of marine ecosystems, species susceptibility to predator, environmental change and the relatively limited size distribution. A major effort preventing *P. kauderni* extinction involves the adoption of conservation measures. This is because the fish exploitation is perceived as irrepressible, in terms of the socio-economic factors of the surrounding community in its endemic area Banggai. In this context, Indonesia is committed to conservation and related researches in ensuring adequate sustainability for this species. As a result, the need for data is important in relation to determining the status, trends and various similar researches. Literature reviews on *P. kauderni* provide channels to ascertain the extent of the research. This review assesses the research trends of *P. kauderni*, including the topic, applied methods, introduction status as a non-native species from trade activities either intentionally or unintentionally presented for cultivation purposes, progress of conservation efforts, and future risks potentially threatening aquatic survival. The evaluation of previous researches help to identify and characterize key aspects of the species' conservation process as well as detect vital information gaps for future considerations. A systematic review method was subsequently adopted in this research, while Google Scholar, Semantic Scholar, and Scopus served as databases to eliminate barriers to language differences in publications. The data analysis results showed that various research on *P. kauderni* have been conducted, which provided relevant conservation policies and recommendations. Poor collaboration with international researchers and language factors are possible hindrances to future development of this species. Furthermore, the data variations were due to inadequate standards and values necessary for a significant impact in research results. Conversely, researches on the effects of introductions in non-native areas and the local ecology are currently very limited.

Key Words: Banggai, endemic, introduction, *Pterapogon kauderni*.

Introduction. *Pterapogon kauderni* is a major endemic species initially found only in Banggai Regency, Central Sulawesi Province, Indonesia (Koumans 1933; Mabuchi et al 2014; Kuiter & Kozawa 2019). Locally known as Banggai cardinalfish (BCF), capungan Banggai or bebese tayung, the fish distribution appears limited to 34 out of 67 islands in Banggai Archipelago, with a habitat area covering 23 km^2 (Vagelli & Biondo 2017).

P. kauderni was originally discovered by Kaudern during an expedition in Banggai and subsequently stored in the Netherland Museum (Vagelli 2011). The scientific name "*Pterapogon kauderni*" was formulated by Koumans in 1933, as the only genus of *Pterapogon* from Apogonidae family. This species gained wide popularity in 1995 after the rediscovery by Allen during a Banggai expedition (Allen & Steene 1995), and subsequently became a major high demand ornamental fish. As a consequence, the exploitation process was considered very alarming, and was incorporated in IUCN as a threatened species (Allen & Donalson 2007). There has been a decline in the fish population estimated at 90%, according to current evaluation (Vagelli & Biondo 2017; Ndobe et al 2018b). Additional risk factors were also observed, including degradation and alteration of marine ecosystems, species susceptibility to predator and habitat change,

and its relatively limited distribution (Wibowo et al 2019). Also, the low larval dispersion ability is among the crucial reasons for the endangered status. Several populations reportedly experienced extirpation (Vagelli & Biondo 2017; Ndobe et al 2020; Moore et al 2021), although *P. kauderni* was not included in CITES in the two submitted proposals. A major trigger is the socio-economic factor of the surrounding Banggai community highly dependent on its trade benefits. Indonesia is obliged to engage conservation and related investigations aimed at ensuring natural sustainability. Diverse researches have been conducted on *P. kauderni* species, since its popularity in the mid-'90s. The results were published variously, such as journal articles, books and conference proceedings. Therefore, the need for relevant data in formulating conservation measures appears very significant, in terms of identifying the status, trends and similar analysis attempts.

This research investigates available literature targeted at the research trends of *P. kauderni* from its initial description (Koumans 1933) and rediscovery (Allen & Steene 1995) to become one of the currently preferred commercial aquarium species. The research review areas include the topic, applied methods, introduction status as a non-native species from trade activities either accidentally or intentionally presented for cultivation purposes, progress of conservation efforts, and future risks potentially threatening the fish survival. Therefore, the assessment of previous research provides an opportunity to identify and characterize key aspects of *P. kauderni* conservation as well as to detect the main information gaps for future research directions.

Method. This research review employed the systematic method from Moher et al (2009) and Pickering & Bryne (2014). Google Scholar, Semantic Scholar, and Scopus were used as the databases between May-July 2021 to host publications and gray literature in Indonesian and global. Based on the endemic nature of *P. kauderni*, several types of research were published in Indonesian which were not detected in other sources, due to the language barrier. The search keyword encompassed "*Pterapogon kauderni*", "*Pterapogon kauderni* Indonesia", as well as "Capungan Banggai". Furthermore, the papers cited in the review articles and book of Conant (2015), Direktorat Konservasi Dan Keaneka Ragaman Hayati Laut (2016), Ndobe et al (2018b), and Conant (2021) were revised to ensure the inclusion of all relevant materials. This research was performed in 2 steps:

(I) The database search results were filtered depending on the mentions or information on *P. kauderni* or Banggai Cardinalfish or Capungan Banggai, ornamental fish trade and conservation;

(II) Figure 1 shows the processes of identification, screening and assessment for eligibility as well as the final paper. The complete article was then downloaded and reviewed after screening, followed by the classification into two groups, termed "in" for articles on *P. kauderni* as the main topic and "out" for duplicate and less relevant pieces. Most publications only engaged *P. kauderni* species as an introduction or comparison and not as the main discussion topic.

In extracting available data, the required information includes the authors, title, publication year, main topic, research method, country, research area, authorship and language. The main topic section comprises several subsets, such as morphology, reproduction, population, growth, behavior, habitat, introduction status, disease and predation, conservation status, genetics, as well as captive breeding. Subsequently, the databases were analyzed to establish patterns, trends, and research gaps. This is followed by the use of Microsoft Excel to thoroughly examine the resulting data and generate a summarized sample based on publication trends, research topics and methods.

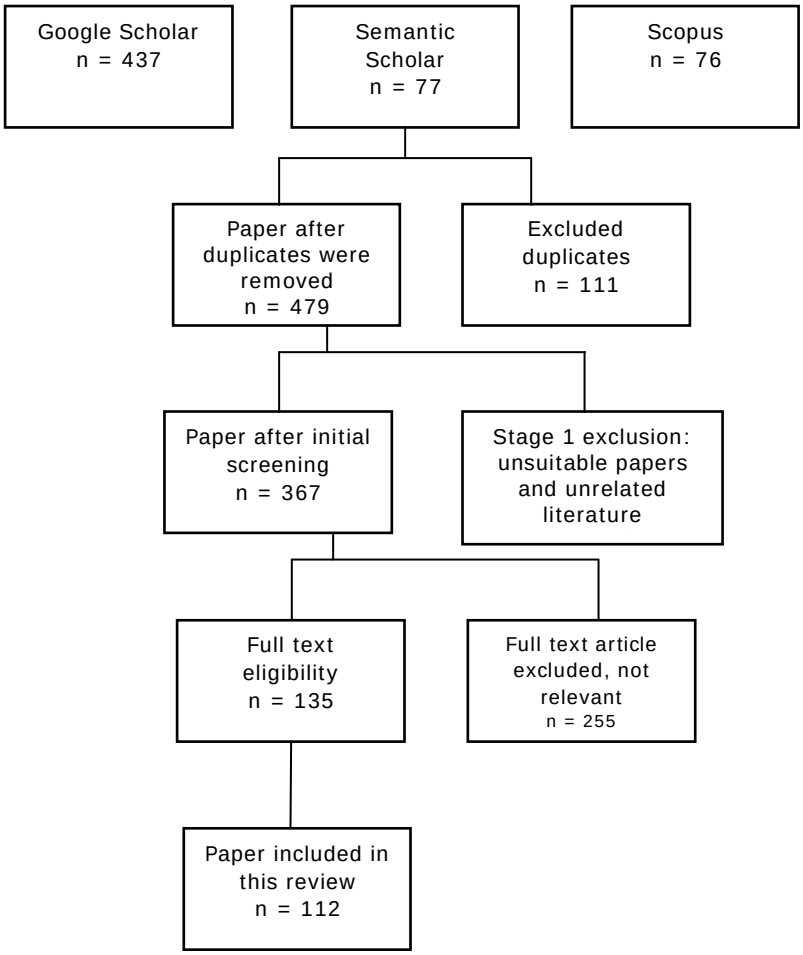

Figure 1. PRISMA diagram summarizing the numbers of papers included/excluded (Moher et al 2009).

Results

Research timeline and location. This research analyzed a total of 112 articles on *P. kauderni* between 1933-2021. The first sample was published in 1933 by Peter Koumans (Koumans 1933) and subsequently gained wider popularity in 1995 after rediscovery by Allen & Steene (1995), while the recording of publications commenced from 1999 (Vagelli 1999). Based on the research area, the species was relatively localized, due to its endemic nature, where around 63 papers (56.3%) originated from Indonesia. America holds the second largest research publication on *P. kauderni* with a contribution of 24 articles (21.4%), followed by Europe (France, Spain, Sweden, Switzerland, UK and Netherland) 12.5%, Asia (India, Iran, Japan, Malaysia, and Thailand) 5.4%, Australia 2.7%. The remainder is shared between countries in North America, specifically Canada 1.7%, as represented in Table 1 and Figure 2a. Furthermore, at initial publications between 1999-2004, external attempts outside Indonesia were dominated by the US, Sweden, Australia, UK, and Canada, while internal engagements commenced in 2005, with an annual increasing trend. As a consequence, Indonesia became the most predominant in subsequent years, with majority of the articles from Central Sulawesi region (Banggai Regency) estimated at 22 or 35.5%. This was followed by Jakarta 17.7%, and South Sulawesi 12.9%, while other locations contributed below 10%, as presented in Table 2 and Figure 2b.

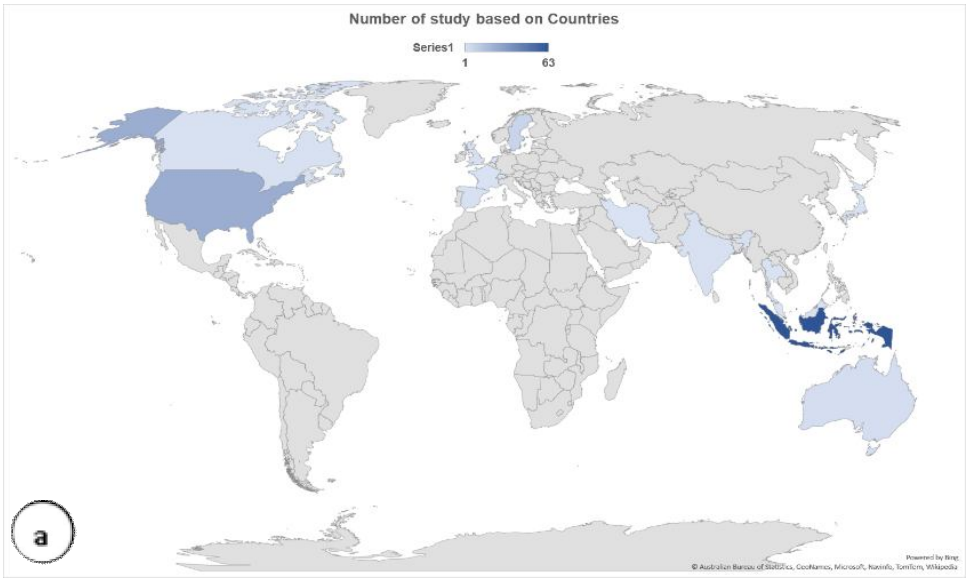

Figure 2. Number of research based on location: a. global; b. Indonesia.

Table 1

Proportion of the global research locations

Country	*Number*	*Percentage (%)*
Australia	3	2.7
Canada	2	1.7
France	1	0.9
India	2	1.8
Indonesia	63	56.3
Iran	1	0.9
Japan	1	0.9
Malaysia	1	0.9
Spain	2	1.8
Sweden	7	6.3
Switzerland	1	0.9
UK	2	1.8
USA	24	21.4
Thailand	1	0.9
Netherlands	1	0.9

Table 2

Proportion of Indonesian research locations

Region	*Total publication*	*Percentage (%)*
Maluku	1	1.6
Bali	4	6.5
North Sulawesi	6	9.7
West Java	2	3.2
Central Sulawesi	22	35.5
Jakarta	11	17.7
Southeast Sulawesi	1	1.6
South Sulawesi	8	12.9
East Java	6	9.7
West Nusa Tenggara	1	1.6
Total	62	100.0

Trends and composition of publication. Captive breeding topics or the optimization in captive conditions dominated the research on *P. kauderni* (17.9%, n = 20), followed by management and conservation (15.2%, n = 17) as well as trade (10.7%, n = 12). Despite its initial publication in 1933, intensive research on this species commenced in 1999, with focus on reproductive patterns, behavior, habitat, trade, and population until 2003. The research on the optimization of captive breeding and conditions, as well as genetics commenced in 2004 before management and conservation in 2008. In addition, the greatest increasing trends were reported in successive years. This is related to Indonesia's follow-up after the proposal to include *P. kauderni* in CITES in 2007 was subsequently withdrawn (Vagelli 2008; Ndobe et al 2012; Ndobe & Moore 2013; Ndobe et al 2013d; Soehartono & Mardiastuti 2020) (Figure 3).

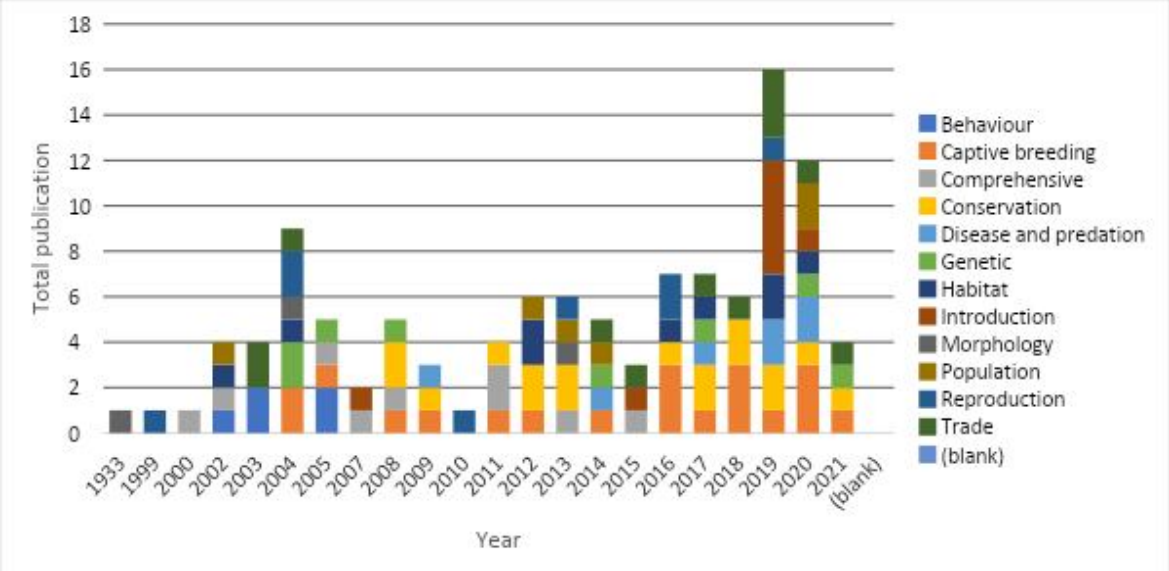

Figure 3. Trend and composition of the publications on *P. kauderni*.

The research publication on disease started in 2009 after discovering pathogen-related deaths in virtually all specimens, on a particular trade routes to US from 2003-2005 (Weber et al 2009). These investigations on diseases, parasites, and predation began to experience a growing trend in successive years. Introductory publications were briefly discussed as a comment on the introduction of *P. kauderni* in Lembeh Strait (Vagelli & Erdmann 2002). Subsequent publications, observed less research on this species, particularly in terms of introduction, except in 2007 (Moore & Ndobe 2007), but only increased in 2019. In general, research efforts on *P. kauderni* have expanded considerably in recent years. The average publication until 2017 occurred around 1-9

publications per year, but jumped to 16 in 2019, followed by a decrease to 12 the next year. Meanwhile, only four articles were available from the start of 2021 up to this current data collection. Figure 4 shows the possibility of a continuous increase until the end of the year.

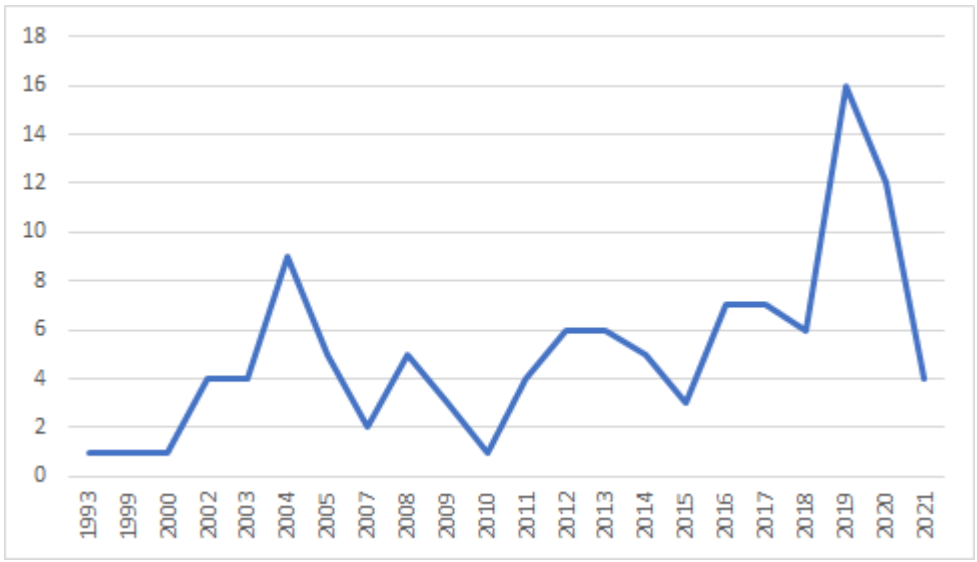

Figure 4. Trend on the number of publications over the years.

Figure 5 provides a graphical representation of the data collection method. Based on the illustration, *P. kauderni* research activities were mostly conducted in the laboratory (36%, n = 40),mainly in terms of its optimization under captive conditions, life history (reproduction, behavior, and disease), as well as genetics. The research in the form of desk research (34.2%, n = 38) primarily discussed conservation management and trade trends. Meanwhile, field investigations (21%, n = 24) were predominantly focused on habitat, population, added species, behavior and trade data. The remaining 9% (n = 10) was a combination of data collection in the field, laboratory and desk research, suitable for comprehensive researches that comprised multiple primary research/main topics, and relatively minimal management and conservation subjects.

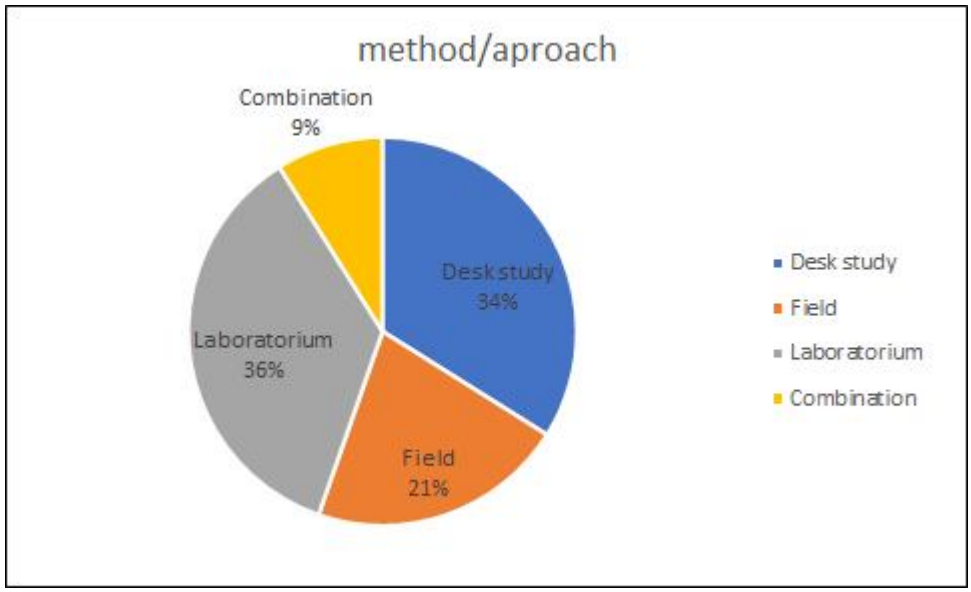

Figure 5. The data collection method.

Figure 6 represents the number of publications based on article type. According to the illustration, journals were significantly predominant (62.5%, n = 70), followed by

conference proceedings (17.86%, n = 20), and other types such as books (4.46% n = 5), bulletins (4.46% n = 5), reports (4.46% n = 5), and reviews (4.46% n = 5), as well as dissertation (1.79%, n = 2). This proportion showed that journal articles was the main publication choice for the research on *P. kauderni*. However, conference proceedings were also relatively large, particularly in terms of preliminary researches, developments in conservation activities and several recommendations from previous analyses.

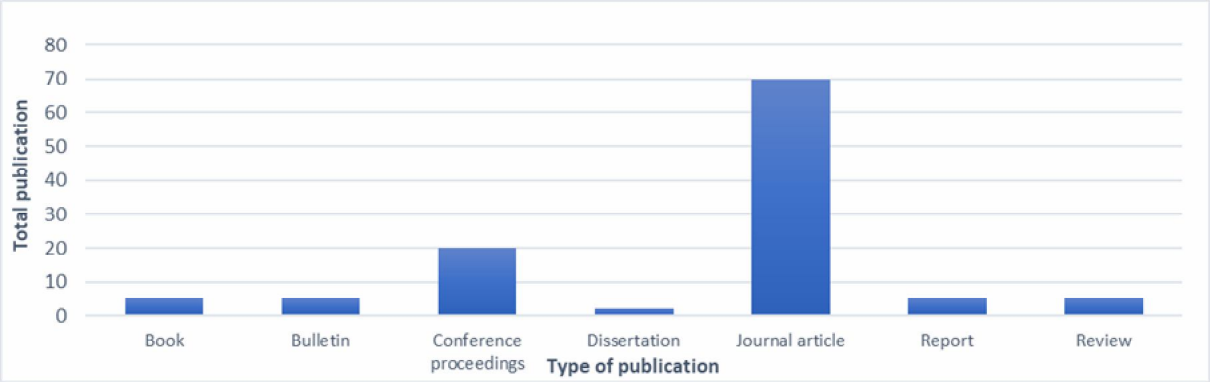

Figure 6. The number of publications based on article type.

Figure 7 represents the publications with author collaborations. Based on the chart, 2 co-authors dominated from a total of 35 papers, followed by a single author as well as 3, 4 and 5 co-authors or more.

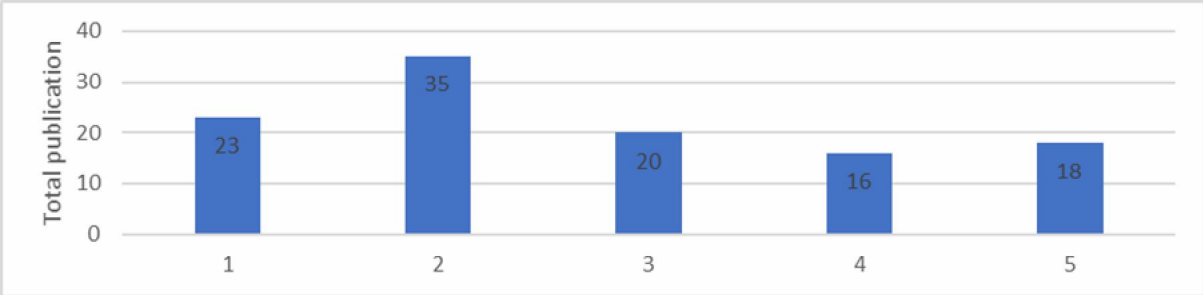

Figure 7. Number of publications with single or different joint authorship (note: 1 = single author; 2 = two co-authors; 3 = three co-authors; 4 = four co-authors; 5 = five or more co-authors).

Meanwhile, in the joint authorship trend in Figure 8, journals with 1 or 2 authors were most prevalent until 2010. There has been an increasing trend for the number of authors above 2, since 2011, with potentially high progression on yearly basis. This shows that the collaboration above 2 authors is becoming very extensive, compared to single status.

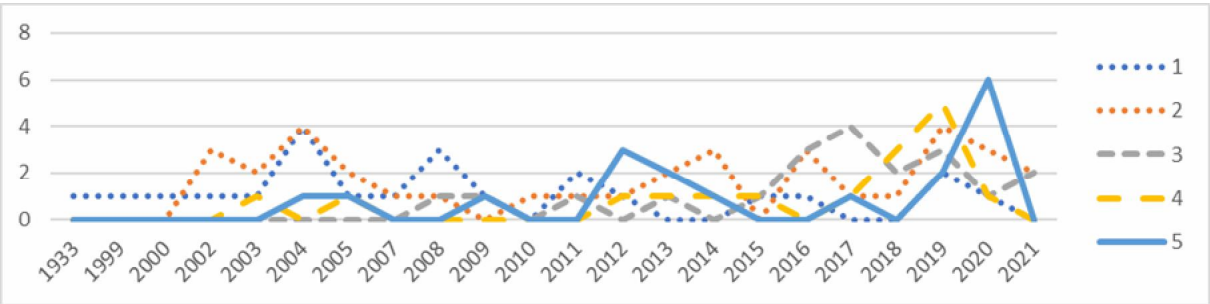

Figure 8. Publication distribution with single or different joint authorship over the years (note: 1 = single author; 2 = two co-authors; 3 = three co-authors; 4 = four co-authors; 5 = five or more co-authors).

Figure 9 shows the proportion of publications from a single author as well as collaborations from similar and separate countries/regions. The research on *P. kauderni* by co-authors in a particular country/region had the most occurrence (68%, n = 76), followed by single author (20%, n = 23) and collaborations overseas (12%, n = 13).

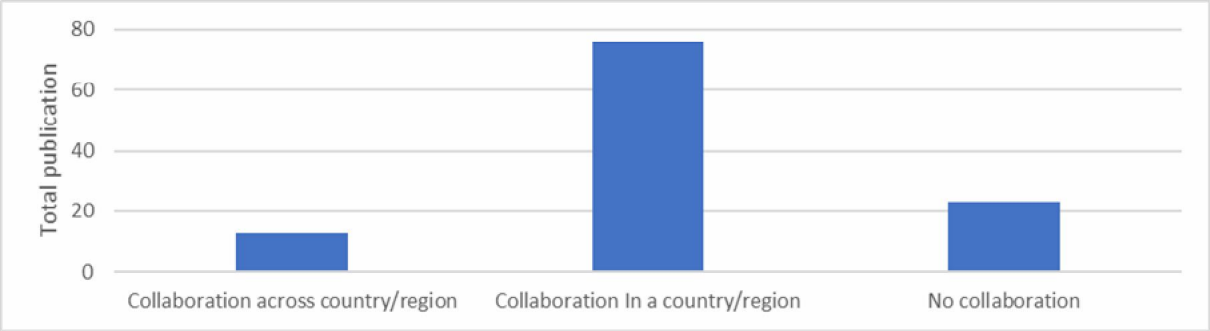

Figure 9. Publication distribution in terms of collaboration.

Figure 10 shows the collaboration trend across various categories. This distribution increases over time, specifically in a given country/region, where the author engages with local universities, government agencies, non-governmental organizations (NGOs). However, no significant change in trend was observed in single authorship. This condition appears similar to alliances across country/region, which peaked in the earlier era (2004) and has consistently ranged between 0-2 publications per year until 2009.

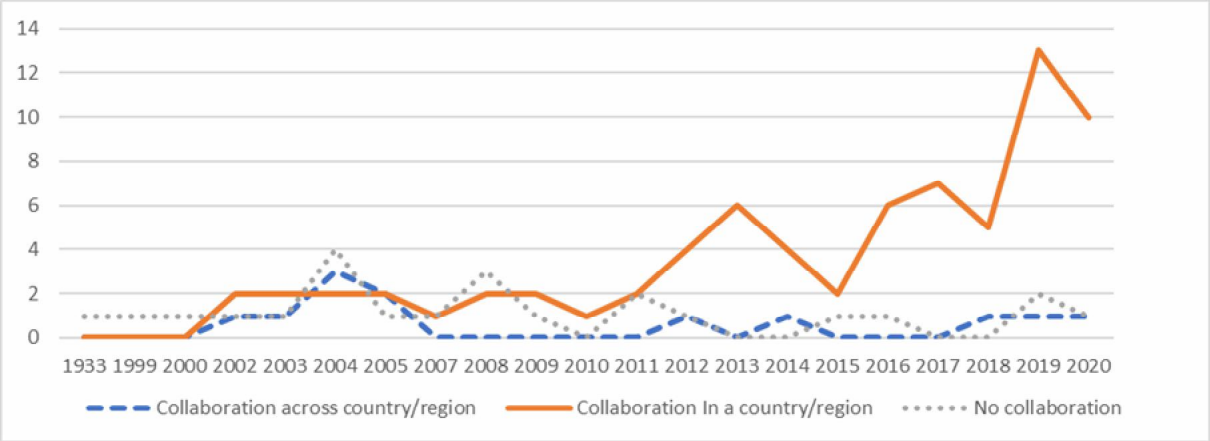

Figure 10. Publication distribution in authorship across different categories in terms of collaboration over the years.

Local research in Indonesia. In a total of 63 research publications on *P. kauderni* in Indonesia, about 50.8% (n = 32) were based in English. Meanwhile, the remaining 49.2% (n = 31) employed the native language, with the average covering practically every field. Several types of research focused on the population and habitat of the sample species across diverse locations in Banggai, since 2005 (Ndobe & Moore 2005). The earliest attempts on similar fish population within the regency started in 2001 by foreign researchers (Lunn & Moreau 2002; Vagelli & Erdmann 2002). Intensive analysis on population conditions was also conducted between 2006-2011 by various government organizations and local NGOs (Moore et al 2011; Ndobe et al 2013d). Routine monitoring was also carried out in 2012 and 2017/2018 (Wiadnyana et al 2020), as well as in 2019 (Ndobe et al 2020). However, the publications commenced in 2007 during the introduction of fish populations in several locations outside the endemic areas, including Lembeh Strait and Palu (Makatipu 2007; Moore & Ndobe 2007). Various related investigations led to the optimization of captive breeding and further researches on conservation management. Indonesia started focusing on the importance of conserving microhabitats since 2012, specifically diadema urchins and sea anemones, commonly

harvested by the surrounding community and fishermen from 2004 (Ndobe & Moore 2008; Moore et al 2012, 2020).

Since 2007, additional intensive research began to concentrate on the introduction sites of *P. kauderni*, both in population (Ndobe & Moore 2008; Carlos et al 2015; Arbi et al 2019; Huwae et al 2019; Kusumawardhani et al 2019; Putra & Putra 2019; Wibowo et al 2019), life history in terms of reproduction and growth (Ndobe et al 2013a; Mogontha et al 2020) and genetics (Rondonuwu et al 2020). Also, the research on captive breeding and conservation management obtained the majority of publication trends from 2005-2021. Meanwhile, the analysis for only conservation management occurred mostly in the form of species recommendations. Despite the predominant articles from Indonesia, the main obstacle was that almost half of the number were written in the local language (49.2%, n = 31) or 28% of the total world publications (Figure 11). This circumstance is believed to severely limit access to global research information.

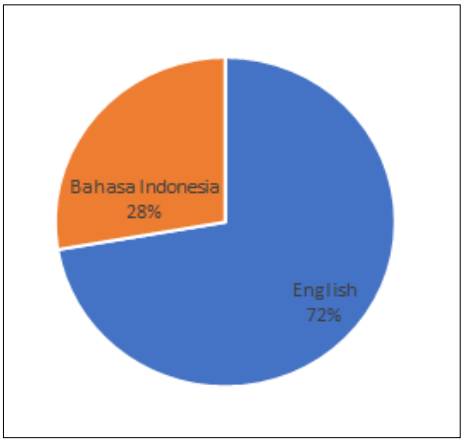

Figure 11. Publication distribution in terms of language.

Discussion

Geographical distribution. Regardless of the endemic nature of *P. kauderni*, several researches have been conducted outside Indonesia, including America, Europe, Australia and other Asian countries. The majority of research and pioneering publications also at the start of species rediscovery, emanated from USA (Vagelli 1999; Vagelli & Erdmann 2002; Bernardi & Vagelli 2004; Hoffman et al 2004, 2005; Vagelli 2004; Vagelli & Volpedo 2004), with Sweden (Kolm 2002a, 2002b, 2005; Kolm & Berglund 2003, 2004; Kolm et al 2005) covering the primary data, such as population, trade, genetics and life history. Meanwhile, the popular countries other than Indonesia with research focus on optimizing the captive breeding of *P. kauderni* were Australia (Moorhead & Zeng 2010), Iran (Roozbehfar et al 2012), India (Vishwas & Ajith 2014), France (Teletchea 2016) and Spain (Monticini 2019). Particular states only concentrated on the trade (Biondo & Burki 2019; Domínguez & Botella 2014; Rhyne et al 2017; Dee et al 2019; Pinnegar & Murray 2019) and disease aspects (Weber et al 2009; Johan & Zainathan 2020). Furthermore, the inability of a country to access *P. kauderni* in its natural habitat contributed to the majority of purchased samples. Also, trade publications employed commercial data from databases, management tools, surveys and direct field reports. Particular samples for laboratory experiments were acquired from Indonesia but the occurrence as wild species or the result of captive breeds was unclear (Vishwas & Ajith 2014). However, a certain proportion used the original captive-breeding materials (Roozbehfar et al 2012; Kasiroek et al 2017) with the assumption that cultured individuals are easier to adapt to a new environment and are also cheaper in the long run, compared to wild-caught stock. Based on geographical area, Indonesia produced the most research on population monitoring from *P. kauderni*, due to the convenience in conducting field investigations. The United States is also among the countries that investigate extensively about the species population, with a monitoring area covering virtually the entire population in Banggai (Vagelli & Biondo 2017).

Research focus and methods. Various aspects were observed in the research of *P. kauderni* with initial focus on the life history, particularly the reproductive and growth parameters. The research specimens were obtained from aquarium trade and preserved under optimized captive conditions. This environment was subsequently observed by examining and collecting eggs to measure the mating behaviors. The results were preliminary data showing the reproductive pattern, both from fecundity, mating features, spawning and early ontogeny (Vagelli 1999), which represents an earlier research that examines the entire sample. Subsequent researches on the species behavior also applied similar method, involving specimen collection from trade marine fish and maintained under captive conditions, where the reproductive behavioral patterns are observed in an experimental set-up (Kolm 2002; Kolm & Berglund 2003). The results also showed that the body size of the male *P. kauderni* influencing the number of clutches were potentially incubated and the female was able to adjust the egg size to suit her partner. In addition to the laboratory and experimental analyses, direct observations help to ascertain the natural behavior (Kolm & Berglund 2003). However, different opinions on the reproductive characteristics, both in terms of methods and data analysis appeared visible (Vagelli & Volpedo 2004; Kolm 2005). The research on the ecology and initial population commenced in 2002 (Lunn & Moreau 2002; Vagelli & Erdmann 2002; Ndobe & Moore 2005), and the trade impact was analyzed using surveys and direct field interviews (Kolm & Berglund 2003; Lunn & Moreau 2004). A number of these early research examined almost all aspects of *P. kauderni* and serve as pioneers and foundations for further investigations.

Particular research related to the potentials (Gopakumar 2005; Ndobe & Moore 2005) and captive breed optimization of the sample were published, after determining the initial data (Vagelli 2004). The manuals for the species cultivation in captive conditions were also published simultaneously (Hopkins et al 2005), in an effort to reduce its wild exploitation. Previous research examined the potentials of *P. kauderni* to reside under low salinity conditions with a high survival rate and salinity of 26 ppt (Madinawati et al 2009; Ndobe 2011). The juvenile samples showed a survival rate up to 68% with salinity between 22 and 24 ppt (Vishwas & Ajith 2014). A major limitation in the species cultivation is the availability of males to incubate eggs. As a consequence, the use of certain methods appears necessary, such as masculinization that involves increasing the male percentage with hormones at the larval stage (Safir et al 2020). Since the introduction of cultivation techniques in captive breed conditions, various similar attempts have been conducted by several organizations, including Ambon (Balai Besar Seed Ambon), Bali (Bali Aquarich, Yayasan Alam Indonesia Lestari), and Banggai Laut (BCF Lestari Community Group) (Soehartono & Mardiastuti 2020). No publications on the contribution of *P. kauderni* cultivation from Indonesia to the export market have been recorded. Thailand has been able to export at least 120,000 individuals/year with captive breed status since 2013 (Rhyne et al 2017). Also, the species exports from Sri Lanka were probably the result of captive breeds (Rhyne et al 2017). This indicates the success of the fish cultivation efforts in relatively large quantities.

Further research related to *P. kauderni* is required to comprehend its unique philopatry properties that rarely occur in other marine species, specifically fish with basic data for obtaining genetic information, using mitochondrial sequences (Bernardi & Vagelli 2004). The results showed that *P. kauderni* has a different genetic structure based on location, particularly the population distributed in the North and East region of Banggai. However, the constraints of minimal samples and markers have not been able to explain conclusive data regarding the effects of reduced gene flow and bottleneck events. This situation is possibly overcome by the development of 11 microsatellites specific to *P. kauderni* (Hoffman et al 2004). In 2005, research on the genetic structure of *P. kauderni* was published using these markers with sufficient samples to detect the genetic diversity (Hoffman et al 2005). The results successfully showed the high genetic structure of *P. kauderni* even within a large distance apart from 2-5 km.

The publication trend has been increasing on the topic of conservation since 2008. This is probably related to the withdrawn proposal for *P. kauderni* inclusion in CITES Appendix II submitted by the USA (Vagelli 2008) and also its involvement in IUCN

endangered category (Allen & Donalson 2007). Indonesia is committed to sustainably manage the *P. kauderni* fishery. The majority of potential assessments and conservation recommendations utilize the compiled data from literatures and forum group discussion (FGD). Conservation activities commenced since 2006 by conducting population and trade surveys until the establishment of Marine Protected Areas (MPAs) in local communities and research related to in situ cultivation (Ndobe & Moore 2008). The Banggai Cardinalfish Action Plan is a multi-year initiative and the first step to establishing Decree Number 168/2007 of the Banggai Islands Regency Head, in addition to BCF Centre. Early publications on disease/parasite types that attack *P. kauderni* were initially reported to be trematodes, nematodes, and encysted isopods (Vagelli & Erdmann 2002). Systemic diseases of an iridovirus from the *Megalocytivirus* genus of the Iridoviridae family were originally published in 2009. Specimens that showed abnormal behavior died at a mortality rate of 100% after the early 2000s. The research uses PCR-based molecular testing and in situ hybridization (ISH) as an add-on. Meanwhile, the failure of CITES proposal for *P. kauderni* pose a major concern, due to its high collection pressure and drastic population decline (Vagelli 2008). The results of the analysis of several regions in the Marine Protected Area (MPA) were considered ineffective, due to the cover areas with no *P. kauderni* (Togong Lantang) populations. Therefore, several experts proposed the design of MPA zones based on genetic structure and sub-population data (Ndobe et al 2012; Ndobe et al 2018a). This circumstance led to diverse management recommendations, including catch quotas per year, size and application period for 3 years, microhabitat conservation, fishing restrictions in the breeding period, as well as management through the concept of an ecosystem-based approach by considering ecological conditions, such as microhabitat degradation and community involvement (socio-economic aspects) (Hartati et al 2012; Ndobe et al 2013c). Another conservation policy involves training fishermen on sustainable fishing methods and marketing skills. The NGO LINI and BCF Center facilitated the development of a more effective air-based trade route (Jakarta via Luwuk) by forming a fishing group called “BCF Lestari”. Intensifying the trade monitoring system for the sample species entails partnering with government to create community groups to supervise illegal fishing activities, despite poor facilities (Babo & Rompas 2017). Also, the establishment of aquaculture research in Bali and Ambon further increased public awareness (Moore & Ndobe 2013). One of the conservation concepts based on the analysis of various literatures on *P. kauderni* is “BCF gardens”. This idea refers to a restoration pattern and sustainable use of populations through microhabitat renewal on a small scale, community-based and supported by a gradual scientific research program (Moore et al 2017). Furthermore, the National Action Plan for 2007-2012 has not realized the potential targets, but has been programmed through the Ministry of Maritime Affairs and Fisheries (Ndobe 2018a). The initiative involves a number of priorities, including the protection of *P. kauderni* in its sub-populations and threatened microhabitat (sea urchins and anemones), archives and records of illegal trade (especially the Kendari route), as well as reducing the release of the species that are not from the sub-population. In other species, institutionalization at multiple levels in a holistic socio-ecological context is necessary to provide robust and resilient conservation management and researches for assessing the potential for climate change and its mitigation. However, several constraints and risks are observed in the realization process, such as limited funds, human resources for supervision, less regulations, socialization among local fishermen, and most importantly, the socio-economic factors (Ndobe et al 2019).

In 2019, the ministerial regulation number 49/KepMen-KKP/2019 was formed regarding insufficient restrictions on *P. kauderni* in Central Sulawesi, particularly the Banggai Islands and Banggai Laut Regencies. These regions regulate restrictions on the fish collection during mating season between February-March and October-November as well as in its harvesting (Soehartono & Mardiastuti 2020). Following the international community’s decision at CITES, COP 17, the US government on January 20, 2016 registered *P. kauderni* in the Endangered Species Act by prohibiting its importation. Meanwhile, the EU has listed the species in a strict domestic measure and suspension is possibly prescribed in the Commission implementing Regulation (EU) Number 792/2012.

Previously demands on the species conservation involve extending its restrictions under the protective regulation section 4(d) of the endangered species act, as well as the limitations on imports, exports, and various commercial activities (Dubois et al 2021). Several special conservation efforts include protecting microhabitats, periodically observing population trends, and monitoring illegal trade routes that do not report their catch to supervisory authorities.

Furthermore, a traditional molecular diagnostic technique for confirming diseases from infected fish was discovered (Weber et al 2009). Table 3 shows that in addition to viruses, ectoparasites were also found at the fish quarantine site in Luwuk (Rahman 2014). Based on the isolation and identification results, bacterial infections occurred in all levels of the *P. kauderni* trade chain, particularly *Vibrio alginolyticus*. Also, a fairly large percentage of iridoviridae virus infections were found in the collection points of Luwuk, Bali, and Manado (Adriany & Koesharyani 2018). The number of disease threats, particularly at the trading stage and fish collection under uncontrolled conditions showed the susceptibility of *P. kauderni* to infections, specifically viruses. These diseases and their rapid spread did not exist in the wild catch, but the threat of transmission from areas with very high infection risk, specifically for iridovirus, poses the tendency for high species mortality. Therefore, caution is needed in planning, particularly related to the restocking of captive breeding results into their wild natural areas.

Table 3

List of diseases that infected *P. kauderni*

Infection/ parasite	*Types*	*Reference*
Digenetic Trematoda	Worm	Vagelli & Erdmann (2002)
Nematoda	Worm	Vagelli & Erdmann (2002)
Encysted isopods	Lice	Vagelli & Erdmann (2002)
Iridovirus (*Megalocytivirus*)	Virus	Weber et al (2009)
Alcaligenes faecalis	Bacteria	Adriany & Koesharyani (2018)
Micrococcus luteus	Bacteria	Adriany & Koesharyani (2018)
Acinetobacter spp.	Bacteria	Adriany & Koesharyani (2018)
Plesiomonas shigelloides	Bacteria	Adriany & Koesharyani (2018)
Yersinia enterolitica	Bacteria	Adriany & Koesharyani (2018)
Vibrio alginolyticus	Bacteria	Zamrud et al (2017)
Vibrio pelagius	Bacteria	Zamrud et al (2017)
V. damsela	Bacteria	Zamrud et al (2017)
V. carchariae	Bacteria	Zamrud et al (2017)
V. anguillarum	Bacteria	Zamrud et al (2017)
V. ordalii	Bacteria	Zamrud et al (2017)
V. parahaemolyticus	Bacteria	Zamrud et al (2017)
V. aerogenes	Bacteria	Zamrud et al (2017)
Chilodonella	Protozoa	Zamrud & Laapo (2014)
Trichodina	Protozoa	Zamrud & Laapo (2014)
Amyloodinium	Protozoa	Zamrud & Laapo (2014)
Vorticella	Protozoa	Zamrud & Laapo (2014)
Zoothamnium	Protozoa	Zamrud & Laapo (2014)
Ichthyophthirius	Protozoa	Zamrud & Laapo (2014)

The introduction of *P. kauderni* initiated significant trade outcome in several areas of the commercial route, including Lembeh Strait, Tumbak Luwuk, Palu, Kendari, Bali, Ambon (Moore & Ndobe 2007; Ndobe et al 2018b; Ndobe et al 2019). These actions were unintentional, such as the destruction of cages, but were deliberately distributed in certain locations, due to the inability to fulfill the trade standards (Arbi et al 2019) or were stocked for cultivation/conservation purposes (Wibowo et al 2019). Early publications on the species inclusion outside its natural habitat occurred in Lembeh Strait (Vagelli & Erdmann 2002) and was reported in 2017 at Palu region (Moore & Ndobe 2007). Meanwhile, in 2019, publications commenced in other supplementary areas, such as Kendari, Bali and Ambon (Arbi et al 2019; Huwae et al 2019; Kusumawardhani et al

2019; Putra & Putra 2019; Wibowo et al 2019). The average method in the population survey involves cruising technique and the belt transect process was employed in Banggai cardinalfish (Suwardi et al 2019). Also, the research that discuss the current life history and reproduction of *P. kauderni* in the introduction section have been recorded in Palu (Ndobe et al 2013a) and Lembeh Strait (Mogontha et al 2020). This shows the species capacity in surviving outside its endemic areas, but not entirely on a large scale (Ndobe et al 2019; Ndobe et al 2018b). The existence was only in patchy conditions or uneven distribution, such as in Ambon, Bali, Kendari and Palu. This circumstance appeared relatively different for *P. kauderni* in the Lembeh Strait (Vagelli 2011) since its introduction in late 1999 (Makatipu 2018). However, 50 individuals were discovered in early 2000, and expanded significantly to 644, with a distribution area of 18.75 ha in 2001 (Vagelli & Erdmann 2002). Recent data showed the widely spread species in the Lembeh Strait area with an average of 1.48 individuals/m^2 (Carlos et al 2015; Makatipu 2018; Rondonuwu 2020). This result is relatively high compared to the population in other locations and also in the endemic region with an average abundance below 0.5 m^2. However, its distribution in Lembeh Strait was estimated at 2,670.74 Ha in 2020 (Rondonuwu 2020), with an increased rate of 142.44 times from the 2001 rate. The high population density of *P. kauderni* is believed to the local population in the Lembeh Strait, particularly in anemonefish that are exclusive symbionts of anemones. As a consequence, there is a stiff competition for limited resources and the abundance of rival species (Albins & Hixon 2008). This high population density and other factors also influence the species' demographics, such as intensity, by disrupting the interactions of regular predators and prey (Vagelli 2011). The research on the bio-ecological impact of *P. kauderni* in Lembeh Strait has not been conducted, despite several interests and assumptions that the inherent species is classified as invasive (Vagelli 2011; Ndobe et al 2018b).

There is need to regularly observe the species population and trade for existing trends and successful conservation assessment. However, the difficulty in comparing populations poses a major challenge since the population survey in 2001, specifically inconsistent survey methods and locations (Table 4).

Table 4

P. kauderni population sampling method

Sampling year	*Total sites*	*Method*	*Reference*
		Endemic	
2000	8	Hover based on area covered by sea urchin	Kolm & Berglund (2003)
2001	3		Vagelli & Erdmann (2002); Vagelli (2011)
2004	9	Hover based on area covered by sea urchin	Ndobe & Moore (2005)
2007	34		Vagelli (2008)
2007-2012	28	Belt transect 100x5 (2), 1000 m^2/site	Yahya et al (2012)
2010	18	Belt transect (10x20 m) 500 m^2/site	Kasim (2012)
2011-2012	24	Belt transect 20x5m = 100 m^2) and swim survey	Ndobe et al (2013d)
2015	52	Transect 8m wide (4800 m^2)/site, from mangrove shore to depth of 4 m	Vagelli & Biondo (2017)
2017	24	Belt transect 20x5 (6), total: 600 m^2/site	Ndobe et al (2018b)
2017	24	Belt transect 20x5 (6), total: 600 m^2/site	Wiadnyana et al (2020)
2018	24	Belt transect 20x5 (6), total: 600 m^2/site	Wiadnyana et al (2020)
2019	8	Belt transect 20x5 (6), total: 600 m^2/site	Ndobe et al (2020)

Introduction				
Sampling year	*Location*	*Total sites*	*Method*	*Reference*
2015	Lembeh	3	No data	Carlos et al (2015)
2018	Ambon	5	Belt transect (10x20 m) (5) total: 500 m^2/site	Wibowo et al (2019)
2018	Bali	2	Belt transect (50x5 m) total: 250 m^2/site	Putra & Putra (2019)
2018	Bali	9	Belt transect (10x20 m) (5) total: 500 m^2/site	Wibowo et al (2019)
2019	Kendari	5	Belt transect (20x5 m) (4) total: 400 m^2/site	Kusumawardhani et al (2019)

Problems, including the criticism of the sampling method for population data with a limited transect length of 20 x 5 m were considered unsuitable. This was due to the species' patchy nature and distributional displacement following the movement of its microhabitat such as sea urchins (*Diadema setosum*) (Conant 2015; Ndobe et al 2018b). Furthermore, the inconsistent sampling process at several locations resulted in certain population areas being under-studied or not having potential data for benchmark purposes.

Conclusions and research gap. Researches on *P. kauderni* has been widely conducted since the late 90s, while experiencing trend analysis and research composition. This indicates a positive trend where the number of the species' publications continues to increase every year. The increment was also reflected on the topics on conservation of captive breeding and populations of *P. kauderni* outside its endemic areas. Research with more than one author showed an increasing trend but was dominated by collaborating authors from similar country while counterparts from different countries tend to be unchanged and less frequent, compared to the beginning of the research in the late 90s and early 2000s. In addition, the large number of publications about this species in Indonesia was possibly responsible for the limited access by international community. However, it is undeniable that the existing research has produced a number of recommendations and policies for the sample's conservation.

Furthermore, researches on life history and behavior has proven that *P. kauderni* has high tendency for maintenance and propagation under captive conditions. Also, the research on captive optimization is used to maximize the species' cultivation. Thailand for instance, has been able to produce *P. kauderni* from captive breeding to the aquarium market with an average of 120,000 specimens per year. There is no published information on the number of results or the presence of exports produced by these facilities in Indonesia, despite the reports on several captive breed locations. However, it is not certain whether this country has the capacity to generate this species under captive breed conditions. In terms of population size, differences between separate methods and locations were observed, but population trends of this species in nature are difficult to analyze. The results showed a decline in the population of *P. kauderni* in nature, hence, a need to investgate the effectiveness of conservation efforts appears necessary, since the National Action Plan movement was conducted in 2007. Furthermore, the total number of several publications was different, in terms of the species trade in recent years that relied on KKP and quarantine data. This is because not all traders and fishermen collect these specimens in the registered nature, and also illegal catches and harvests were not reported accordingly. In addition, certain research which considered insufficient, were the effects of the introduction of *P. kauderni* species in non-native area and also on the local ecology or inclusion in the invasive category.

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References

Adriany D. T., Koesharyani I., 2018 [Diseases infection in Banggai cardinal (*Pterapogon kauderni*) in trade chain]. Jurnal Riset Akuakultur 12(3):283-294. [in Indonesian].

Albins M. A., Hixon M. A., 2008 Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes. Marine Ecology Progress Series 367:233-238.

Allen G. R., Steene R. C., 1995 Notes on the ecology and behaviour of the Indonesian cardinalfish (Apogonidae) *Pterapogon kauderni* Koumans. Revues Francaise d' Aquariologie 22(1-2):7-9.

Allen G. R., Donalson T. J., 2007 The IUCN red list of threatened species. Banggai cardinalfish (*Pterapogon kauderni*). Available at: http://www/iucnredlist/org/. Accessed: May, 2021.

Arbi U. Y., Suharti S. R., Huwae R., Rizqi M. P., Suratno, 2019 [Population of endemic fish (*Pterapogon kauderni*) in introductory habitat in Gilimanuk Bay, Bali]. Seminar Nasional Tahunan XVI Hasil Penelitian Perikanan Dan Kelautan 3, pp. 167-178. [in Indonesian].

Babo J., Rompas W., 2017 [Marine and fishery department supervision on activity of illegal fishing in Banggai Laut Regency]. Jurnal Administrasi Publik 4(48):1-8. [in Indonesian]

Bernardi G., Vagelli A., 2004 Population structure in Banggai cardinalfish *Pterapogon kauderni*, a coral reef species lacking a pelagic larval phase. Marine Biology 145(4): 803-810.

Biondo M. V., Burki R. P., 2019 Monitoring the trade in marine ornamental fishes through the European Trade Control and Expert System TRACES: challenges and possibilities. Marine Policy 108:103620.

Carlos N. S. T., Rondonuwu A. B., Watung V. N. R., 2015 [Distribution and abundance of *Pterapogon kauderni* Koumans, 1933 (Apogonidae) in the Eastern Lembeh Strait, Bitung City]. Jurnal Ilmiah Platax 2(3):121-126. [in Indonesian]

Conant T. A., 2015 Endangered species act, status review report: Banggai cardinalfish, *Pterapogon kauderni*. NOAA, 40 pp.

Conant T. A., 2021 Banggai cardinalfish, *Pterapogon kauderni*. Available at: https://repository.library.noaa.gov/view/noaa/29974/noaa_29974_DS1.pdf/ Accessed: July, 2021.

Dee L. E., Karr K. A., Landesberg C. J., Thornhill D. J., 2019 Assessing vulnerability of fish in the U.S. marine aquarium trade. Frontiers in Marine Science 5:527.

Direktorat Konservasi Dan Keanekaragaman Hayati Laut., 2016 [National Action Plan (RAN) for Conservation of Banggai Cardinalfish]. Available at: https://kkp.go.id/an-component/media/upload-gambar-pendukung/KKHL/BUKU/RANKonservasi BCF.pdf. Accessed: May, 2021. [in Indonesian]

Domínguez L. M., Botella A. S., 2014 An overview of marine ornamental fish breeding as a potential support to the aquarium trade and to the conservation of natural fish populations. International Journal of Sustainable Development and Planning 9(4): 608-632.

Dubois D., Schubert D. J., Davenport J. P., 2021 Petition for Protective Regulations Under Section 4(d) of the Endangered Species Act for the Banggai Cardinalfish 4 (April). Available at: https://www.biologicaldiversity.org/campaigns/reef_fish_in_peril/pdfs/Banggai-cardinalfish-4D-petition-04-22-2021.pdf. Accessed: July, 2021.

Gopakumar G., 2005 Marine ornamental fish culture status, constraints and potential. Proceeding of Ocean Life Food and Medicine Expo, Chennai, pp. 347-359.

Hartati S. T., Wudianto, Sadiyah L., 2012 [Management for Banggai cardinal fish (BCF) (*Pterapogon kauderni*) in Banggai Islands waters]. Jurnal Kebijakan Perikanan Indonesia 4(1):1-7. [in Indonesian]

Hoffman E. A., Arguello J. R., Kolm N., Berglund A., Jones A. G., 2004 Eleven polymorphic microsatellite loci in a coral reef fish, *Pterapogon kauderni*. Molecular Ecology Notes 4(3):342-344.
Hoffman E. A., Kolm N., Berglund A., Arguello J. R., Jones A. G., 2005 Genetic structure in the coral-reef-associated Banggai cardinalfish, *Pterapogon kauderni*. Molecular Ecology 14(5):1367-1375.
Hopkins S., Ako H., Tamaru C. S., 2005 Manual for the production of the Banggai cardinalfish, *Pterapogon kauderni*, in Hawai'i. Rain Garden Ornamentals, 28 pp.
Huwae R., Patty S. I., Arbi U. Y., Hehuwar J., 2019 [Preliminary study on Banggai cardinal fish square population (*Pterapogon kauderni*, Koumans, 1933) in inner Ambon Bay]. Jurnal Ilmu Kelautan Kepulauan 2(1):22-31. [in Indonesian]
Johan C. A. C., Zainathan S. C., 2020 Megalocytiviruses in ornamental fish: a review. Veterinary World 13(11):2565-2577.
Kasim K., 2012 Impacts of fishing and habitat on the density of Banggai cardinal fish (*Pterapogon kauderni*, Koumans 1933) in Banggai Archipelago, Indonesia. United Nations University Fisheries Training Programme, Iceland [final project], 50 pp
Kasiroek W., Indananda C., Pinthong K., Supiwong W., Pengseng P., Tanomtong A., 2017 NOR polymorphism and chromosome analysis of banggai cardinalfish, *Pterapogon kauderni* (Perciformes, Apogonidae). Cytologia 82(1):17-23.
Kolm N., 2002 Male size determines reproductive output in a paternal mouthbrooding fish. Animal Behaviour 63(4):727-733.
Kolm N., 2005 Differential allocation in the Banggai cardinalfish, *Pterapogon kauderni*: a reply to Vagelli and Volpedo. Environmental Biology of Fishes 72(2):223-225.
Kolm N., Berglund A., 2003 Wild populations of a reef fish suffer from the "nondestructive" aquarium trade fishery. Conservation Biology 17(3):910-914.
Kolm N., Berglund A., 2004 Sex-specific territorial behaviour in the Banggai cardinalfish, *Pterapogon kaunderni*. Environmental Biology of Fishes 70(4):375-379.
Kolm N., Hoffman E. A., Olsson J., Berglund A., Jones A. G., 2005 Group stability and homing behavior but no kin group structures in a coral reef fish. Behavioral Ecology 16(3):521-527.
Koumans F. P., 1933 On a new genus and species of Apogonidae. Zoologische Mededelingen 16(10):78.
Kuiter R. H., Kozawa T., 2019 Cardinalfishes of the world. New edition. Seaford, Victoria, 198 pp.
Kusumawardhani N. R., Arbi U. Y., Aunurohim, 2019 [Analysis of habitat preference of the Banggai cardinalfish (*Pterapogon kauderni*) at the introductory location of Kendari waters, Southeast Sulawesi]. Seminar Nasional Kelautan XIV, Fakultas Teknik Dan Ilmu Kelautan Implementasi Hasil Riset Sumber Daya Laut Dan Pesisir Dalam Rangka Peningkatan Daya Saing Indonesia B2, pp. 47-59. [in Indonesian]
Lunn K. E., Moreau M. A., 2002 Conservation of Banggai cardinalfish populations in Sulawesi, Indonesia: an integrated research and education project. SPC Live Reef Fish Information Bulletin 10:33-34.
Lunn K. E, Moreau M. A., 2004 Unmonitored trade in marine ornamental fishes: the case of Indonesia's Banggai cardinalfish (*Pterapogon kauderni*). Coral Reefs 23(3):344-351.
Mabuchi K., Fraser T. H., Song H., Azuma Y., Nishida M., 2014 Revision of the systematics of the cardinalfishes (Percomorpha: Apogonidae) based on molecular analyses and comparative reevaluation of morphological characters. Zootaxa 3846(2):151-203.
Madinawati, Ndobe S., Gamgulu A., 2009 [Growth of Banggai cardinalfish (*Pterapogon kauderni*) reared at different salinity in a controlled system]. Jurnal Akuakultur Indonesia 8(2):193-198. [in Indonesian]
Makatipu P. C., 2007 [Get to know the ornamental fish Banggai cardinal (*Pterapogon kauderni*)]. Oseana 32(3):1-7. [in Indonesian]

Makatipu P. C., 2018 [Status of the Banggai cardinalfish (*Pterapogon kauderni*) in Lembeh Strait, Bitung City, North Sulawesi]. Prosiding Seminar Ilmiah Pengelolaan Berkelanjutan Sumberdaya Pesisit Dan Laut Sulawesi Utara: Arah Dan Tantangan, pp. 110-121. [in Indonesian]
Mogontha L., Bataragoa N. E., Rondonuwu A. B., 2020 [Biology reproduction of Banggai cardinal fish *Pterapogon kauderni* Koumans, 1933 in Lembeh Strait]. Jurnal Perikanan dan Kelautan Tropis 11(1):33-40. [in Indonesian]
Moher D., Liberati A., Tetzlaff J., Altman D. G., 2009 Preferred reporting items for systematic review and meta-analyses: the PRISMA statement. BMJ 339:b2535.
Monticini P., 2019 Breeding marine aquarium fishes: opportunity or threat for the local fishing community? INFOFISH International 2019:32-36.
Moore A., Ndobe S., 2007 Discovery of an introduced Banggai cardinalfish population in Palu Bay, Central Sulawesi, Indonesia. Coral Reefs 26(3):569.
Moore A., Ndobe S., 2013 The Banggai cardinalfish: an overview of management and conservation initiatives. Galaxea, Journal of Coral Reef Studies 15:238-242.
Moore A., Ndobe S., Zamrud M., 2011 Monitoring the Banggai cardinalfish, an endangered restricted range endemic species. Journal of Indonesian Coral Reefs 1(2):99-113.
Moore A., Ndobe S., Salanggon A. I., Ederyan R. A., 2012 Banggai cardinalfish ornamental fishery: the importance of microhabitat. Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, 9-13 July, 13C.
Moore A. M., Ndobe S., Jompa J., 2017 [A site-based conservation approach to promote the recovery of Banggai cardinalfish (*Pterapogon kauderni*) endemic populations]. Coastal and Ocean Journal 1(2):63-72. [in Indonesian]
Moore A. M., Yasir I., Ambo-Rappe R., Ndobe S., Jompa J., 2020 Microhabitat preference of the Banggai cardinalfish (*Pterapogon kauderni*): a behavioural experimental approach. IOP Conference Series: Earth and Environmental Science 564(1):012019.
Moore A. M., Ndobe S., Yasir I., 2021 Importance of monitoring an endangered endemic species - intra-species biodiversity perspectives on the Banggai cardinalfish conservation and trade. IOP Conference Series: Earth and Environmental Science 681(1):012120.
Moorhead J. A., Zeng C., 2010 Development of captive breeding techniques for marine ornamental fish: a review. Reviews in Fisheries Science 18(4):315-343.
Ndobe S., 2011 [Growth of Banggai cardinalfish (*Pterapogon kauderni*) an ornamental fish on a different salinity]. Media Litbang Sulteng 4(1):52-56. [in Indonesian]
Ndobe S., Moore A., 2005 [The potential and importance of developing in-situ breeding of *Pterapogon kauderni*]. InfoMAI 4(2):9-14. [in Indonesian]
Ndobe S., Moore A., 2008 Banggai cardinalfish: towards a sustainable ornamental fishery. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July, pp. 1026-1029.
Ndobe S., Moore A., 2013 Banggai cardinalfish (*Pterapogon kauderni*) populations (stocks) around Banggai Island, a geometric and classical morphometric approach. Preprint 2013(12):1-31.
Ndobe S., Setyohadi D., Herawat E. Y., Soemarno, Moore A., 2012 An ecological and social approach to Banggai cardinalfish conservation management. Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, 9-13 July, 6 pp.
Ndobe S., Soemarno, Herawati E. Y., Setyohadi D., Moore A., Palomares M. L. D., Pauly D., 2013a Life history of Banggai cardinalfish, *Pterapogon kauderni* (Actinopterygii: Perciformes: Apogonidae) from Banggai Islands and Palu Bay, Sulawesi, Indonesia. Acta Ichthyologica et Piscatoria 43(3):237-250.
Ndobe S., Widiastuti I., Moore A., 2013b [Sex ratio and predation on recruits in the marine ornamental Banggai cardinalfish (*Pterapogon kauderni*)]. Prosiding Konferensi Akuakultur Indonesia, Sulawesi Tengah, pp. 9-20. [in Indonesian]
Ndobe S., Moore A., Nasmia, Madinawati, Serdiati N., 2013c The Banggai cardinalfish: an overview of local research (2007-2009). Galaxea, Journal of Coral Reef Studies 15: 243-252.

Ndobe S., Moore A., Salanggon A. I. M., Muslihudin., Setyohadi D., Herawati E. Y., Soemarno, 2013d [Banggai cardinalfish (*Pterapogon kauderni*) management: an ecosystem-based approach]. Marine Fisheries 4(2):115-126. [in Indonesian]
Ndobe S., Moore A., Ya'la Z. R., 2018a [Banggai cardinalfish (*Pterapogon kauderni*) sustainable management plan concept]. Simposium Nasional Pengelolaan Perikanan Karang Berkelanjutan Indonesia, pp. 317-334. [in Indonesian]
Ndobe S., Yasir I., Moore A. M., Biondo M. V., Foster S. J., 2018b A study to assess the impact of international trade on the conservation status of *Pterapogon kauderni* (Banggai cardinalfish). Available at: https://cites.org/sites/default/files/eng/com/ac/30/Inf/E-AC30-Inf-16.pdf. Accessed: July, 2021.
Ndobe S., Moore A., Yasir I., Jompa J., 2019 Banggai cardinalfish conservation: priorities, opportunities, and risks. IOP Conference Series: Earth and Environmental Science 253(1):012033.
Ndobe S., Handoko K., Wahyudi D., Yasir M., Irawati Y., Tanod W. A., Moore A. M., 2020 Monitoring the endemic ornamental fish *Pterapogon kauderni* in Bokan Kepulauan, Banggai marine protected area, Indonesia. Depik: Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan 9(1):18-31.
Pickering C., Bryne J., 2014 The benefits of publishing systematic quantitative literature reviews for PhD candidates and other early-career researchers. Higher Education Research and Development 33(3):534-548.
Pinnegar J. K., Murray J. M., 2019 Understanding the United Kingdom marine aquarium trade – a mystery shopper study of species on sale. Journal of Fish Biology 94(6): 917-924.
Putra I. N. G., Putra I. D. N. N., 2019 Recent invasion of the endemic Banggai cardinalfish, *Pterapogon kauderni* at the Strait of Bali: assessment of the habitat type and population structure. ILMU KELAUTAN: Indonesian Journal of Marine Sciences 24(1):15-22.
Rahman S. A., 2014 [Identification and intensity of parasites in Banggai cardinalfish (*Pterapogon kauderni*)]. Pengembangan Teknologi Terapan Untuk Meningkatkan Produksi Perikanan 11:352-360. [in Indonesian]
Rhyne A. L., Tlusty M. F., Szczebak J. T., Holmberg R. J., 2017 Expanding our understanding of the trade in marine aquarium animals. PeerJ 5:e2949.
Rondonuwu A. B., 2020 Characteristic of Banggai cardinalfish *P. kauderni* Koumans, 1933 in Lembeh Strait, Tumbak, North Sulawesi Province, and Banggai Group Island, Central Sulawesi Province. Universitas Sam Ratulangi, Dissertation.
Rondonuwu A. B., Lumingas L. J. L., Bataragoa N. E., Pratasik S. B., Tilaar F. F., Salaki M. S., 2020 Mitochondrial CO1 sequences of banggai cardinal fish (BCF) from Lembeh Strait, North Sulawesi, Indonesia. AACL Bioflux 13(2):760-767.
Roozbehfar R., Biria M., Kiani F., Sedaghat M., 2012 Captive breeding of Banggai cardinalfish, *Pterapogon kauderni* (Koumans, 1933) for exit of IUCN Red List. World Journal of Zoology 7(4):273-278.
Safir M., Tobigo D. T., Mangitung S. F., Madinawati M., Zainab Z., 2020 Masculinization of Banggai cardinalfish (*Pterapogon kauderni*) using 17α-methyltestosterone-enriched *Artemia* sp. Omni-Akuatika 16(2):135-140.
Soehartono T. R., Mardiastuti, 2020 Banggai cardinalfish (*Pterapogon kauderni*) and the attempt for the inclusion of CITES Appendix II. Jurnal Ilmu dan Teknologi Kelautan Tropis 12(2):595-606.
Suwardi., Arbi U. Y., Wiadnyana N. N., Ndobe S., Reksodihardjo G., Lestari Y. T., Nelly E., Suharti S. R., 2019 [Banggai cardinalfish monitoring guidelines]. Agung F. M. (ed), Kementerian Kelautan dan Perikanan, 64 pp. [in Indonesian]
Teletchea F., 2016 Domestication level of the most popular aquarium fish species: is the aquarium trade dependent on wild populations? Cybium 40(1):21-29.
Vagelli A., 1999 The reproductive biology and early ontogeny of the mouthbrooding Banggai cardinalfish, *Pterapogon kauderni* (Perciformes, Apogonidae). Environmental Biology of Fishes 56:79-92.

Vagelli A. A., 2004 Significant increase in survival of captive-bred juvenile Banggai cardinalfish *Pterapogon kauderni* with an essential fatty acid-enriched diet. Journal of the World Aquaculture Society 35(1):61-69.
Vagelli A. A., 2008 The unfortunate journey of *Pterapogon kauderni*: a remarkable apogonid endangered by the international ornamental fish trade, and its case in CITES. SPC Live Reef Fish Information Bulletin 18:17-28.
Vagelli A. A., 2011 The Banggai cardinalfish: natural history, conservation, and culture of *Pterapogon kauderni*. John Willey & Sons Ltd., 203 pp.
Vagelli A. A., Erdmann M. V., 2002 First comprehensive ecological survey of the Banggai cardinalfish, *Pterapogon kauderni*. Environmental Biology of Fishes 63(1):1-8.
Vagelli A. A., Volpedo A. V., 2004 Reproductive ecology of *Pterapogon kauderni*, an endemic apogonid from Indonesia with direct development. Environmental Biology of Fishes 70(3):235-245.
Vagelli A. A., Biondo M. V., 2017 The distribution, population condition and conservation status of *Pterapogon kauderni* in 2015. Report for the 29th Animals Committee Meeting, Convention on International Trade of Endangered Species, CITES, 18-22 July, 15 pp.
Vishwas R. M., Ajith K. T. T., 2014 Captive breeding and hatchery production of mouth brooding jewel cardinal perch, *Pterapogon kauderni*, (Koumanns, 1933) using brackish water: the role of live prey and green water enrichment in juvenile production. Journal of Aquaculture Research and Development 5(7):1000277.
Weber E. S., Waltzek T. B., Young D. A., Twitchell E. L., Gates A. E., Vagelli A. A., Risatti G. R., Hedrick R. P., Salvatore F., 2009 Systemic iridovirus infection in the Banggai cardinalfish (*Pterapogon kauderni* Koumans, 1933). Journal of Veterinary Diagnostic Investigation 21(3):306-320.
Wiadnyana N. N., Suharti S. R., Ndobe S., Triharyuni S., Lilley G. R., Risuana S., Wahyudi D., Moore A. M., 2020 Population trends of Banggai cardinalfish in the Banggai Islands, Central Sulawesi, Indonesia. IOP Conference Series: Earth and Environmental Science 420(1):012033.
Wibowo K., Arbi U. Y., Vimono I. B., 2019 The introduced Banggai cardinal fish (*Pterapogon kauderni*) population in Ambon Island, Indonesia. IOP Conference Series: Earth and Environmental Science 370:012041.
Yahya Y., Mustain A., Artiawan N., Reksodihardjo-Lilley G., Tlusty M., 2012 Summary of results of population density surveys of the Banggai cardinalfish in the Banggai Archipelago, Sulawesi, Indonesia, from 2007-2012. AACL Bioflux 5(5):303-308.
Zamrud M., Laapo A., 2014 [Frequency by ectoparasites that infect Banggai cardinalfish (*Pterapogon kauderni*) trafficked in the Banggai Islands]. Prosiding Forum Inovasi Teknologi Akuakultur 1083:7. [in Indonesian]
Zamrud M., Ndobe S., Laapo A., 2017 [Diagnosis and bacterial infection pathology of *Vibrio* sp.]. E-Jurnal Mitra Sains 5(3):38-48. [in Indonesian]

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Authors:
Fione Yukita Yalindua, Bitung Station-Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: yukitayalindua@gmail.com
Putri Sapira Ibrahim, Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: putrisaphiraibrahim@gmail,com
Sugeng Purwo Saputro, Research Center for Geotechnology-BRIN, Jl. Sangkuriang, Bandung, 40135, Jawa Barat, Indonesia, e-mail: sugeng.p.saputro@gmail.com
Teguh Peristiwady, Bitung Station-Research Center for Oceanography-BRIN, Jl. Pasir Putih I Ancol Timur, Jakarta Utara, 14430, DKI Jakarta, Indonesia, e-mail: ikan_teguh@yahoo.com
Helen Joan Lawalata, Department of Biology, Faculty of Mathematics and Natural Science, Manado State University, Jl. Koya, Tondano Selatan, 95618, Sulawesi Utara, Indonesia, email: lawalata_helen@yahoo.com

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