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The introduced Banggai cardinal fish (*Pterapogon kauderni*) population in Ambon Island, Indonesia

To cite this article: K Wibowo *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **370** 012041

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The introduced Banggai cardinal fish (*Pterapogon kauderni*) population in Ambon Island, Indonesia

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Abstract. The Banggai cardinalfish *Pterapogon kauderni* (commonly referred to as BCF) is a fish endemic to the Banggai Islands, Central Sulawesi. Recently, Banggai cardinalfish have been introduced to several regions in Indonesia as a side effect of Banggai cardinalfish trading and mariculture. BCF juveniles cultured by the Balai Perikanan Budidaya Laut (BPBL) Ambon were released in several locations around Ambon Bay during 2014 - 2017. Around 20 - 500 BCF were released at each location. This study was carried out in April 2018 as a first monitoring of Banggai cardinalfish population status at all "restocking" locations in Ambon Bay. The data were collected by SCUBA diving using a Belt Transect method, with BCF size classes based on standard length (SL). The results found Banggai cardinalfish at three out of five monitoring locations. The first location was the Ferry Port, where 20 Banggai cardinalfish were released in 2014; the BCF density was 41 fish/100 m², dominated by adults (> 3.5 cm SL). The second location was behind the Natural Sciences Faculty of Pattimura University where 20 Banggai cardinalfish were also released in 2014; the density was 73 individuals/100 m² (with evenly distributed size). The third location was the bridge behind the SUPM campus, where 500 Banggai cardinalfish were released in 2016, but only 2 fish/100 m² (adults > 3.5 cm SL) were found during the study. No Banggai cardinalfish were found at the other two locations, namely the Port of Ambon and Suli Beach, although there were 500 individuals were released at each of those two locations in 2016 and 2017. These result shows that BCF have been able to adapt and breed rapidly in some coastal areas in Ambon Bay that provide suitable habitat for Banggai cardinalfish.

1. Introduction

The Banggai cardinalfish (*Pterapogon kauderni*) is known as one of the endemic species in Indonesian waters, with a native distribution around the Banggai Archipelago, Central Sulawesi [1,2]. Banggai cardinalfish has been exported as an ornamental fish since the 1980s in large numbers [3]. At least 50,000 fish were captured and traded abroad every month in the early 2000s, mainly through Bali and Manado [2]. This number continued to increase with the expanding network of ornamental fish trade through Palu, Kendari, Makassar, Surabaya and Jakarta. Transportation through this ornamental trade has enabled the introduction of these fish to several sites in Indonesia [4,5]. The introduced populations which have become established along the trade routes include Lembah Strait – North Sulawesi [1,2], Tumbak – North Sulawesi [1], Palu – Central Sulawesi [4], Bali [1,6] and Kendari – South East Sulawesi [5]. The high value of fish traded, ease of capture and increasing market demand have caused the intensity of fishing to increase rapidly in an uncontrolled fashion. This situation is exacerbated by the vulnerability of this fish to fishing as a result of some of the intrinsic characteristics



of the BCF such as low mobility, poor disguise, habitat located in shallow waters and very limited distribution.

Holistic data on individual densities and populations of Banggai cardinalfish in all Indonesian waters, especially the introduced populations which have been reported, is still lacking. Such data are important as a reference in determining recommendations to the government regarding the trade quota from the scientific authority to the management authority. The high ability of the Banggai cardinalfish to adapt to new environments spurs efforts to release and introduce the Banggai cardinalfish outside of its original habitat. Data on the dispersal of the Banggai cardinalfish as one of the impact of trading activities is important to understand the population status of this fish. Current information on various aspects is important and is needed as a reference in determining the recommendations for the trading quota to the management authority.

Ambon Bay is a semi-closed water body located on Ambon Island, Maluku. Information on the distribution of Banggai cardinalfish in Maluku waters, especially in Ambon Bay, was obtained from various parties, including the Marine Fisheries Seed Centre (Balai Perikanan Benih Laut = BPBL Ambon), ornamental fish collectors or entrepreneurs and fishermen. However, the BPBL Ambon has played a central role in the distribution of Banggai cardinalfish in Ambon waters. Starting in 2008, the BPBL Ambon obtained Banggai cardinalfish broodstock from the Banggai Islands and/or Manado for the hatchery. Over the period 2014 - 2017, the BPBL Ambon produced Banggai cardinalfish seed from the cultivation unit to be released (introduced) at several locations in Ambon Bay as an effort they called "restocking". However, no monitoring was conducted either by the BPBL Ambon or by other parties after the release of the Banggai cardinalfish, so that there was lack of data on these introduced Banggai cardinalfish populations. The purpose of this study was to evaluate the population of Banggai cardinalfish at the introduction sites in Ambon Bay. Furthermore, it is hoped that the data obtained will be the basis for ongoing monitoring efforts in order to evaluate the effect of the Banggai cardinalfish introductions on the ecosystems in these waters.

2. Materials and Methods

Research on Banggai cardinalfish populations was carried out in April 2018 at five locations that were used as Banggai cardinalfish "restocking" sites by the BPBL Ambon (Figure 1). Banggai cardinalfish observations were carried out using a modified Belt Transect method, with 20 x 5 m belt transects placed along the coastline at each station.

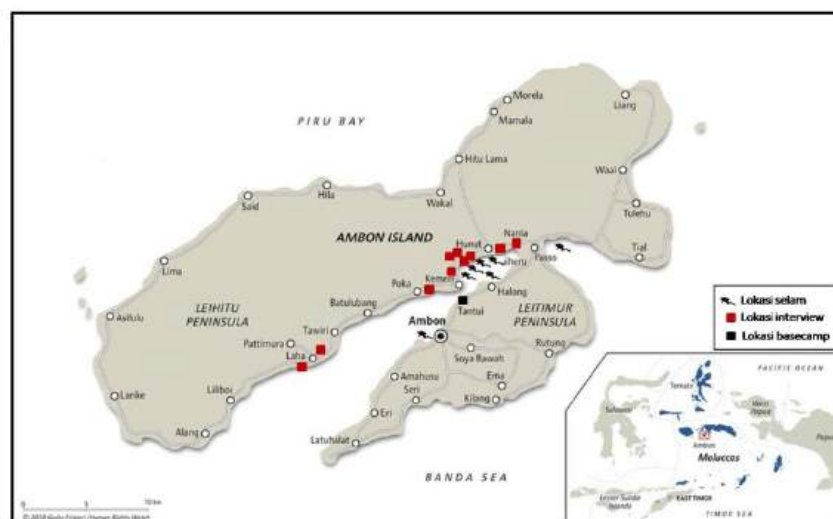


Figure 1. Banggai cardinalfish population survey stations in Ambon Bay, Maluku Province. Lokasi selam = Banggai cardinalfish belt survey site (using SCUBA); Lokasi interview = interview site; Lokasi basecamp = monitoring team basecamp site.

Banggai cardinalfish abundance, habitat (coral reefs, seagrass beds, etc.) and microhabitat (sea urchins, especially the species *Diadema* spp., corals, anemones, or others), were recorded 2.5 meters to the right and left of a transect line, giving an observation area of 100 m² at each station. Schematically, a description of Banggai cardinalfish in transect as presented in Figure 2. Banggai cardinalfish were recorded in 3 size classes based on standard length (SL): larvae (less than 1.8 cm SL), juveniles (1.8 - 3.5 cm SL), and adults (more than 3.5 cm SL).

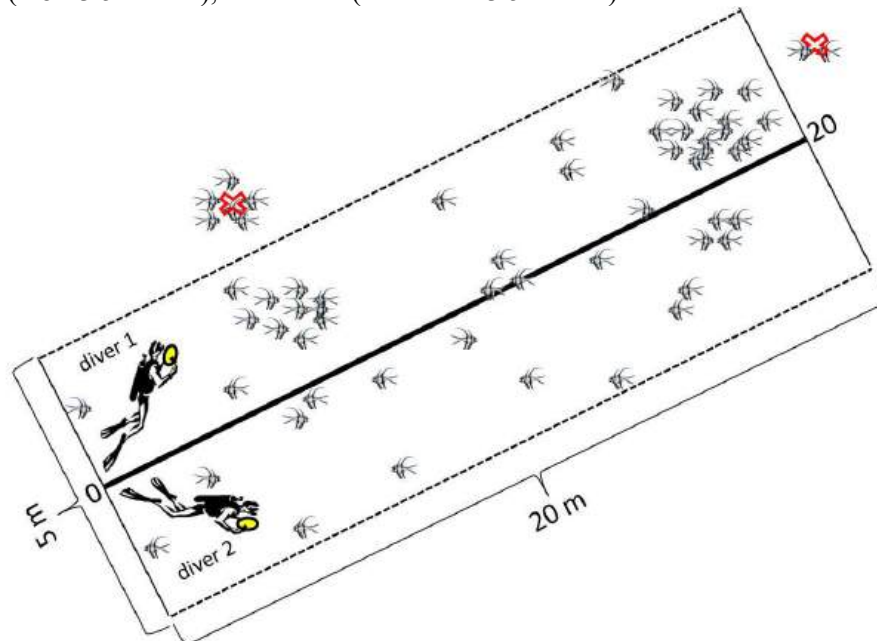


Figure 2. The modified belt transect method used for Banggai cardinalfish monitoring

3. Results

Information on the distribution of Banggai cardinalfish in Ambon was obtained mainly from the BPBL Ambon, as the party responsible for most of the dispersal of Banggai cardinalfish in the waters around Ambon. In 2008, BPBL Ambon brought in Banggai cardinalfish broodstock from the Banggai Islands and/or Manado for research on BCF culture (breeding). From then until now, various experiments have been carried out to seek the most suitable method for breeding Banggai cardinalfish. Nowadays, BPBL Ambon has four 3 x 3 m floating net cages with Banggai cardinalfish broodstock (Figure 3). Within a month, the BPBL can produce thousands of Banggai cardinalfish seed, a proportion of which are sent for export through ornamental fish export companies in Bali.

Over the period of 2014 - 2017, the BPBL Ambon released adult Banggai cardinalfish (4-5 cm SL) in several locations in the waters around Ambon (mainly in Inner Ambon Bay and Outer Ambon Bay) as an effort they called "restocking". The number of individuals deployed in each location varied between 20 - 500 individuals. Some of the locations where Banggai cardinalfish were introduced by the BPBL Ambon are summarized in Table 1.

Table 1. BPBL in Ambon Banggai Cardinalfish stocking locations and number of fish released

Location	Σ fish stocked (individual)	SL (cm)	Year	Observation result
Ferry Port	20	4-5	2014	Present
Behind Unpatti Natural Science Faculty	20	4-5	2014	Present
SUPM Bridge	500	4-5	2016	Present
Suli Beach	500	4-5	2016	Absent
Port of Ambon	500	4-5	2017	Absent

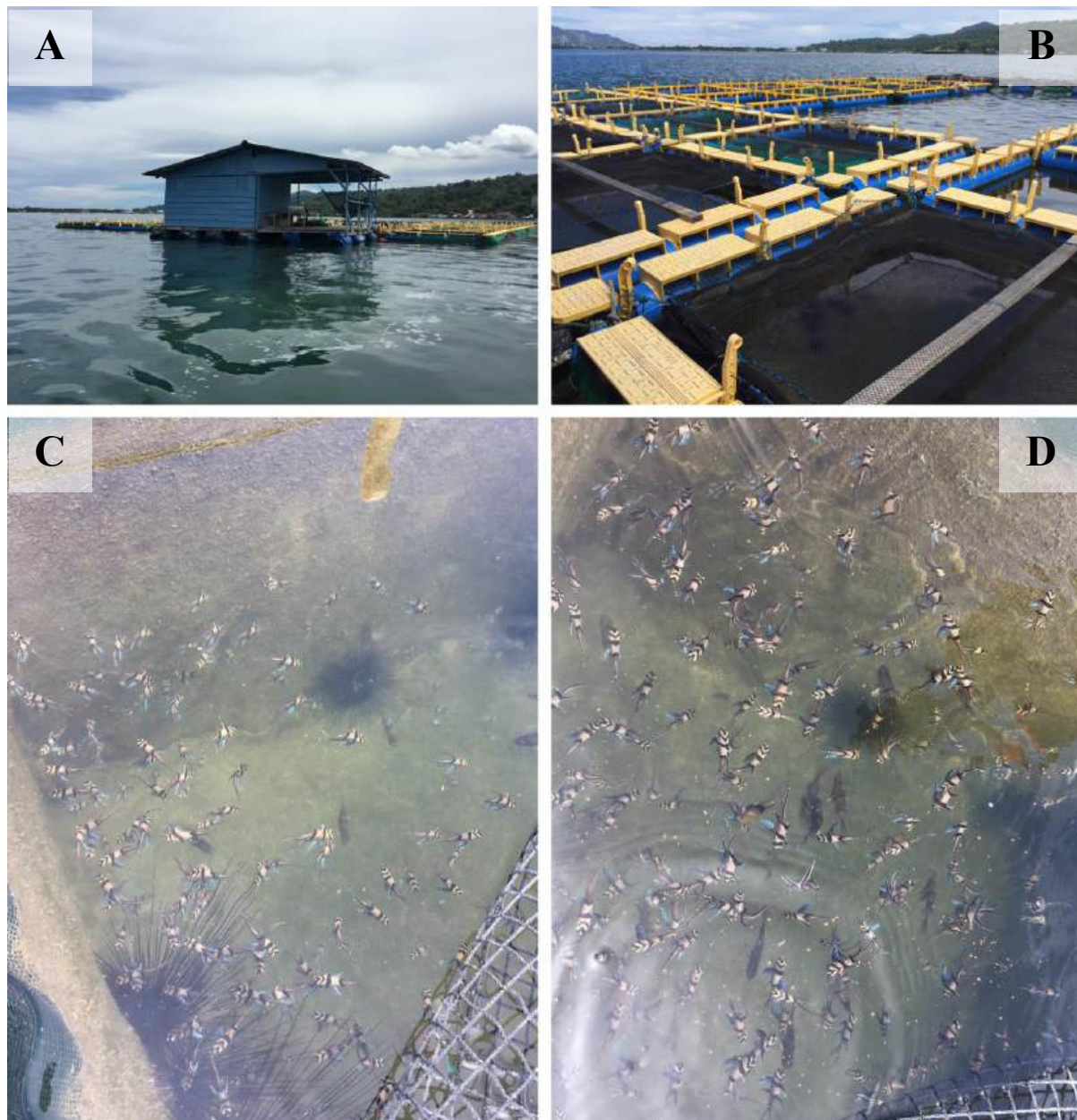


Figure 3. Floating net in the BPBL Ambon hatchery (A, B) and cultured Banggai cardinalfish measuring 3–4 cm SL at 4 months of age (C, D)

Data collected including Banggai cardinalfish abundance by size class (SL), habitat and micro-habitat, and depth are presented in Table 2. The former Ferry Port was the first stocking location, where 20 BCF were released in 2014. The Banggai cardinalfish abundance was high, with a density of 41 fish/100 m², dominated by large, mostly adult fish (> 3.5 cm SL). The sampling location had a depth of 1–3.3 m with habitat comprised of reef flats with sand and stone substrate. The seagrass *Enhalus accoroides* and sea urchin *Diadema setosum* were also found at this location in large quantities. All Banggai cardinalfish individuals observed in this location were symbiotic with *Diadema setosum* as their micro-habitat.

At the second stocking location, also in 2014, 20 individuals were released off the beach behind the campus of the Faculty of Natural Sciences, Pattimura University campus. The abundance of Banggai cardinalfish was also high, with 73 fish/100 m² (consisting of 28 fish/100 m² with SL < 2 cm; 21

fish/100 m² with SL 2-3.5 cm; 24 fish/100 m² with SL > 3 cm). This location had a depth of 1.5-2.2 m with habitat comprised of seagrass beds with sandy substrate. Seagrass vegetation found at this location was dominated by *Enhalus accoroides* and *Thalassia hemprichii*. The sea urchin *Diadema setosum* was abundant at this site, and all Banggai cardinalfish observed were associated with sea urchin micro-habitat.

Table 2. Data on Banggai cardinalfish abundance and habitat in Ambon Bay in 2018

Station ^a	Transect	Σ individuals by Size Class (Standard Length)			Depth (m)	Micro-habitat
		< 2 cm	2 - 3.5 cm	> 3.5 cm		
I	1	0	0	99	3.3	<i>Diadema setosum</i>
	2	0	0	61	2.5	<i>Diadema setosum</i>
	3	0	0	13	1.1	<i>Diadema setosum</i>
	4	6	4	13	1	<i>Diadema setosum</i>
	5	0	0	8	1.7	<i>Diadema setosum</i>
II	1	35	41	41	1.5	<i>Diadema setosum</i>
	2	57	54	67	2.4	<i>Diadema setosum</i>
	3	42	11	10	2	<i>Diadema setosum</i>
	4	2	0	0	2	<i>Diadema setosum</i>
	5	3	0	0	2.2	<i>Diadema setosum</i>
III	1	0	0	0	1.5	-
	2	0	0	0	1.5	-
	3	0	0	0	1.7	-
	4	0	0	0	1.7	-
	5	0	0	0	1.5	-
IV	1	0	0	2	1	Branching sponge
	2	0	0	0	1	-
	3	0	0	0	1.2	-
	4	0	0	0	1.2	-
	5	0	0	0	1	-
V	1	0	0	2	1.5	-
	2	0	0	0	1.3	-
	3	0	0	0	1	-
	4	0	0	0	1	-
	5	0	0	0	1.2	-
VI ^b	1	0	0	2	3	-
	2	0	0	0	3	-
	3	0	0	0	3	-
	4	0	0	0	2.7	-
	5	0	0	0	2.5	-
VII ^b	1	0	0	2	1.5	-
	2	0	0	0	1.3	-
	3	0	0	0	1.3	-
	4	0	0	0	1.5	-
	5	0	0	0	1.5	-

^a St. I: Ferry Port; St. II: beach behind the Faculty of Natural Sciences, Pattimura University; St. III: Port of Ambon; St. IV: bridge behind the SUPM campus; St. V: Suli beach; St. VI: dock of the Ambon Naval Base; St. VI: Biorock Project site

^b Additional study location (not part of the BPBL Ambon 'restocking' project)

At the third stocking location, 500 BCF were released under the bridge behind the SUPM campus in 2016. Only two adult Banggai cardinalfish (SL > 3.5 cm) were observed living in association with branching sponges as micro-habitat. The transect depth was 1–2 m in habitat comprising seagrass beds

and sandy mud substrate. The seagrass found at this location was *Enhalus accoroides* and no sea urchins were found. The waters in this location were relatively turbid because they were close to the mouth of a small river with mangroves growing around the estuary.

At the stocking fourth location, the Port of Ambon, 500 Banggai cardinalfish were released in 2016 location. The same number of fish (500 BCF) was also released at Suli Beach in 2017 as the fifth stocking location. Banggai cardinalfish were not found at either of those two stocking locations. The transects in those locations were in water 1.5-2.5 m deep with habitat comprised of seagrass beds with sandy substrate. Seagrass vegetation at these locations was dominated by *Enhalus accoroides* and *Thalassia hemprichii*. *Diadema setosum* was present in low abundance at Suli Beach but there were no Banggai cardinalfish associated with these urchins. Meanwhile, sea urchins were not found in the Port of Ambon. Both locations were fairly open, and periodically exposed to strong wave action, especially during the windy season.

In addition to the five locations above, information from residents and fishermen stated that Banggai cardinalfish had once been found around the dock of the Ambon Navy Base and at the location of a Biorock Project. Although appearing to offer suitable Banggai cardinalfish habitat, the surveys around the dock of the Ambon Navy Base and the nearby the Biorock Project location did not find any Banggai cardinalfish.

4. Discussion

The Banggai cardinalfish was originally known as an Indonesian endemic fish with a very limited native distribution, mostly in the waters of the Banggai Islands, Central Sulawesi Province [7–9]. Research on the endemic (native) range of the Banggai cardinalfish included surveys covering at least 159 locations on more than 50 islands over the period 1998 – 2004 [10], giving a Banggai cardinalfish distribution range of approximately 5,500 km². However, available habitat was found to be limited to approximately 300 km along the coast of 32 islands, with an area of around 30 km² [11].

Several years later, there have been many reports of the existence of Banggai cardinalfish outside the Banggai Islands, where the populations are the result of releases which occurred intentionally or unintentionally at several locations along the trade chain, resulting in several introduced populations. At the end of 2000, a number of adult and juvenile Banggai cardinalfish were found in the Lembeh Strait, North Sulawesi Province, approximately 400 km from their original habitat in the Banggai Islands. By 2001, the number of individuals had increased [2]. In 2006, a Banggai cardinalfish population was found in Mambo, Palu Bay, Central Sulawesi, around 440 km west of the Banggai Islands and separated by Sulawesi mainland [4]. The Palu Bay waters had a lower salinity, with few *Diadema setosum* sea urchins, a sandy mud substrate; there were seagrasses, some corals, sea anemones and sponges. The groups of Banggai cardinalfish ranged from 2 to 200 individuals, with each group generally consisting of a relatively homogenous size or age group. Adult Banggai cardinalfish were found swimming slowly close to the reef, between seagrass leaves and in open areas between sanctuaries (microhabitat) at depths between 0.5 and 3 m. Juvenile Banggai cardinalfish (SL < 2 cm) were found between tentacles or near anemones, with or without anemone fish [4]. The latest report on a Banggai cardinalfish population at an introduction site was from Gilimanuk Bay, Bali where the density was 0.76 fish/m² [12].

The results obtained from this study prove that Banggai cardinalfish is able to survive outside its native habitat in the Banggai Islands. In fact, Ambon Bay is a location that experiences relatively high environmental pressures due to human activities, such as household waste, household industrial waste, sea transportation (large ports) and so on. In general, the Banggai cardinalfish spread by BPBL Ambon were able to survive and reproduce rapidly in Ambon waters, especially in the semi-closed waters in the Inner Ambon Bay. The substrate in the locations where Banggai cardinalfish were found consisted of rock, sand and muddy sand. Banggai cardinalfish habitat was in shallow waters from 0.5 m to 2 m deep. This was similar to the previous studies where Banggai cardinalfish were generally found in protected waters in shallow areas [2,4,8]. Furthermore, a comprehensive survey on the spatial

distribution of Banggai cardinalfish mentioned that these fish usually occupy habitats at depths between 0.5–4.5 m with an average depth of 1.66 m [9].

Observations in Ambon waters showed that almost all Banggai cardinalfish individuals found to be associated with *Diadema setosum* sea urchins (99.65%), and the remainder associated with branching sponges (0.35%). This is unlike the results of previous studies in the Banggai Islands, where Banggai cardinalfish was found associated with microhabitat including various types of corals (*Acropora* spp., *Anacropora* spp., *Porites* spp., *Goniopora* spp., *Echinopora* spp., *Montipora* spp., *Seriotopora* spp., *Nephthea* spp.), mushroom corals (*Heliofungia actiniformis*), sea anemones (*Actinodendron* spp., *Heteractis* spp., *Entacmaea* spp., *Macroactyla* spp.), sea urchins (*Diadema setosum*, *Diadema savignyi*, *Tripneustes gratilla*), starfish (*Protoreaster nodosus*), hydrozoa (*Millepora* spp.), seagrass (*Enhalus accoroides*) and mangrove roots (*Rhizophora* spp.) [5,9,13–15].

Based on size class distribution (Figure 4), of the 569 Banggai cardinalfish individuals found in the belt transects, 25.48% were included in the larva category, and all were associated with *Diadema setosum* sea urchins; 19.33% were included in the juvenile category and all were also associated with sea urchins; while 55.18% were adult individuals of which 99.36% were associated with sea urchins and the remainder were associated with branching sponges. This result was different from several previous studies that showed the presence of ontogenetic shifts. The theory or hypothesis of ontogenetic shift in microhabitat refers to a tendency to shift between microhabitat/symbionts at different life stages [13]. After settlement, Banggai cardinalfish exhibits high site fidelity [16] despite an ontogenetic shift in microhabitat within a given site 1, 13, 15. In a habitat where sea urchins are abundant, Banggai cardinalfish of all size classes are generally observed associated with the sea urchins. Conversely, in habitats with low sea urchin abundance, Banggai cardinalfish will tend to choose another available microhabitat. The difference in age/size composition according to the type of microhabitat was very prominent visually and considered significant. Research in the Banggai Islands showed that juveniles prefer sea anemone as microhabitat (80%), and adults prefer hard corals (60%) [10]. Microhabitat shifts tend to occur slowly from sea anemones to hard corals. The difference in the percentage of juveniles that choose sea anemones rather other microhabitat was very real. Conversely, hard coral was only chosen by adult fish, with the exception of the anemone-like *Heliofungia actiniformis* [15]. The absence of sea anemones at some sites could account for this difference in results, which ultimately does not necessarily always indicate an ontogenetic shift. Nonetheless, sea anemones are a particularly important microhabitat for the survival of newly-released recruits and small juveniles, often shared with clown fish, and adult fish tend to dominate in hard coral microhabitat, though this was limited to coral life-forms which offer plenty of refuges, especially branching and foliose forms [15].

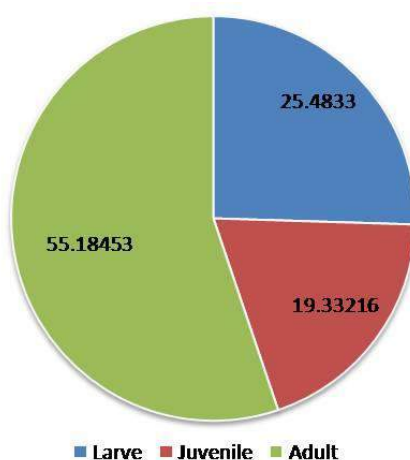


Figure 4. Percentage of Banggai cardinalfish in Ambon Bay by size class (Larva = < 2 cm SL, Juvenile = 2–3.5 cm SL, Adult > 3.5 cm SL)

The underwater visual census data show that Banggai cardinalfish were present at three out of five locations chosen as a 'restocking' areas: the Ferry Port, the beach behind the Faculty of Natural Sciences, Pattimura University and the bridge behind the SUPM campus. The BCF population at the Ferry Port (density 0.41 fish/m²) was dominated by adult fish (95.1%). At the second location, behind the Faculty of Natural Sciences, Pattimura University (density 0.73 fish/m²), size classes were fairly evenly distributed (larvae 38.29%, juveniles 29.2%, adults 32.51%). At the third location, the bridge behind SUPM campus, despite the release of 500 individuals in 2016, only 2 fish/100 m² (size < 2 cm SL) were found. Compared with the results of research in other locations, these results seemed to be characterized by relatively low abundance levels. Reported densities of Banggai cardinalfish in the Banggai Islands in 2012 [17] range from 0.5-3 individuals/m², indicating that the density of Banggai cardinalfish in Ambon Bay waters was lower than the native population in Banggai Islands. An introduced population of Banggai cardinalfish in Gilimanuk Bay, Bali had Banggai cardinalfish densities ranging from 0.1-1.4 fish/m², similar to the results of research in Palu Bay [4,12].

The establishment of Banggai cardinalfish populations in Ambon, as well as Banggai cardinalfish populations in Lembeh Strait and Tumbak (North Sulawesi), Palu Bay and Luwuk (Central Sulawesi), Gilimanuk Bay (Bali) and Kendari (Southeast Sulawesi) has been a side effect of trade activities that have begun since the early 90's. Most of these locations were transit sites on the Banggai cardinalfish trading routes before they were exported to various countries. The Banggai cardinalfish that did not meet the requirements of the marine ornamental trade standards were often deliberately released into the waters in these locations. The released Banggai cardinalfish eventually adapted to the new habitats and bred, although the breeding may not always be as fast as in the Banggai Islands due to differences in physical-chemical conditions of the sea water. Differences in the number and types of available microhabitat might also influence the difference in breeding rate or reproductive success of Banggai cardinalfish in new habitats compared to their original native distribution.

5. Conclusion

Introduced of endemic species to areas outside their native distribution is an interesting subject to study, particularly in relation to the species ability to adapt to the new habitats. Base on the information and data obtained during this research, it can be concluded that the Banggai cardinalfish is not native to Ambon waters. Its presence in these waters is as an introduced species, and is the result of a "restocking" program conducted by the government-run BPBL Ambon research station hatchery. Introduced Banggai cardinalfish populations in Ambon Bay waters showed some differences compared with the native populations in the Banggai Islands. At two study sites, the introduced Banggai cardinalfish populations were relatively abundant with size distributions ranging from juveniles to adults, and mostly fish were symbiotic with sea urchin micro-habitat. The study showed that, as an introduced fish species, the Banggai cardinalfish has been able to adapt and breed in Ambon Bay.

Acknowledgements

The authors gratefully acknowledge support for fully funding of this research from the Research Center for Oceanography – Indonesian Institute of Sciences (P2O – LIPI) under the Riset Prioritas P2O – LIPI Program COREMAP-CTI TA 2018 scheme (grant B-303/IPK.2/KP.06/I/2018). We also thank all colleagues and stakeholders who contributed to the survey and data collection on which this manuscript is based.

References

- [1] Vagelli A, Burford M and Bernardi G 2009 Fine scale dispersal in Banggai cardinalfish, *Pterapogon kauderni*, a coral reef species lacking a pelagic larval phase *Mar. Genomics* **1** 129–34
- [2] Erdmann M E and Vagelli A 2001 Banggai cardinalfish invade Lembeh Strait *Coral reef* **20** 252–3

- [3] Kolm N and Berglund A 2003 Wild populations of the Banggai cardinalfish (*Pterapogon kauderni*) suffer from “non-destructive” fishing for the aquarium trade *Conserv. Biol.* **17** 910–4
- [4] Moore A and Ndobe S 2007 Discovery of an introduced Banggai cardinalfish population in Palu Bay, Central Sulawesi, Indonesia *Coral Reefs* **26** 569.
- [5] Moore A, Ndobe S and Zamrud M 2011 Monitoring the Banggai cardinalfish, an endangered restricted range endemic species *J. Indones. Coral Reefs* **1** 99–113
- [6] Lilley R 2008 The Banggai cardinalfish: An overview of conservation challenges *SPC Live Reef Inf. Bull.* **18** 3–12
- [7] Allen G R and Steene R C 1995 Notes on the ecology and behaviour of the Indonesian cardinalfish (Apogonidae) *Pterapogon kauderni* Koumans *Rev. fr. Aquariol.* **22** 7–9
- [8] Allen G 2000 Threatened fishes of the world: *Pterapogon kauderni* Koumans, 1933 (Apogonidae) *Environ. Biol. Fishes* **57** 142
- [9] Vagelli A A and Erdmann M V 2002 First comprehensive ecological survey of the Banggai cardinalfish, *Pterapogon kauderni* *Environ. Biol. Fishes* **63** 1–8
- [10] Vagelli A A 2005 The Banggai conservation project: Working for the creation of a network of small marine sanctuaries in the Banggai Archipelago, Indonesia Communiqué. *Am. Zoo Aquarium Assoc.* 47–8
- [11] Vagelli A A 2008 The unfortunate journey of *Pterapogon kauderni*: A remarkable apogonid endangered by international ornamental fish trade, and its case in CITES. *SPC Live Reef Fish Inf. Bull.* **18** 17–28
- [12] Putra I N G and 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 *Indones. J. Mar. Sci.* **24** 15–22
- [13] Vagelli A 2004 Onthogenetic shift in habitat preference by *Pterapogon kauderni*, a shallow water coral reef apogonid with direct development *Copeia* **2** 364–9
- [14] Ndobe S, Madinawati and Moore A 2008 Onthogenetic shift assessment in endemic fish *Pterapogon kauderni* (in Bahasa Indonesia) *J. Mitra Bahari* **3** 32–55
- [15] Ndobe S, Moore A A and Jompa J 2018 Tale of two Urchins - Implications for in-situ breeding of the endangered Banggai cardinalfish (*Pterapogon kauderni*) *Indones. Aquac.* **19** 65–75
- [16] Kolm N, Hoffman E A, Olson J, Berglund A and Jones A G 2005 Group stability and homing behavior but no kin group structures in coral reef fish *Behav. Ecol.* **16** 521–7
- [17] Yahya Y, Mustain A, Artiawan N and Reksodihardjo-Lilley, G Tlusty M F 2012 Summary of results of population density surveys of the Banggai cardinalfish in the Banggai Archipelago, Sulawesi, Indonesia, from 2007–2012 *AACL Bioflux* **5** 303–308