Microhabitat preferences of endemic Banggai cardinalfish (*Pterapogon kauderni*) in the introduced habitat in Luwuk, Indonesia

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Abstract. Banggai cardinalfish (*Pterapogon kauderni*) is known as an endemic fish species in Banggai Islands, Central Sulawesi. Recently, Banggai cardinalfish has been found in several regions of Indonesia, including in the coastal area of Luwuk, Central Sulawesi. The discovery of the Banggai cardinalfish population in Luwuk is a side effect of ornamental fish trading activities. Observation of the population of Banggai cardinalfish in habitats in Luwuk was carried out from late April to early May 2019 to obtain up to date data on population status and the microhabitat preferences of each life stage. The data were collected by scuba diving using a modified Belt Transect method, with 3 replicate transects (20x5 m) at each location. Observations of Banggai cardinalfish abundance, habitats (coral reefs, seagrass beds, other) and microhabitats (*Diadema* spp., sea urchins, corals, sea anemones) were carried out in each belt transect. Banggai cardinalfish were classified into 3 sizes based on standard length (SL): post-larval stage (less than 1.8 cm), juvenile (1.8 - 3.5 cm), and adult (more than 3.5 cm). The observations showed that Banggai cardinalfish populations were found in all five locations at varying densities. The total number of fish observed during the survey was 2673 individuals, consisting of 11.34% recruits (303 individuals), 22.67% juveniles (606 individuals) and 65.99% adults (1764 individuals). The lowest density was 0.11 ind m^{-2} at Kilo 5, and the highest density was 4.167 ind m^{-2} in the Port of Luwuk. At the other three locations (traditional harbor, Maahas and Simpong), the density was around 0.5 to 1 ind m^{-2}. The majority (98.77%) of the Banggai cardinalfish were associated with sea urchins (*Diadema* spp.), while only 1.23% were found living in branching corals (*Acropora* spp.). The results show that the Banggai cardinalfish has been able to adapt and establish resident populations in several coastal areas of Luwuk that provide suitable habitat.

Key Words: Apogonidae, introduced species, microhabitat preference, *Pterapogon kauderni*, Sulawesi.

Introduction. The Banggai cardinalfish *Pterapogon kauderni* is a paternal mouthbrooder with an extremely small clutch size and no juvenile pelagic larval phase (Allen & Steene 1995; Vagelli 1999; Vagelli & Erdmann 2002; Ndobe et al 2013). *Pterapogon kauderni* has limited distribution in an area of less than 10000 km^2 and has been found naturally only in the Banggai Archipelago off the east coast of Sulawesi, Indonesia, because the species does not have a pelagic larval phase, which is the main dispersal method in most reef fish (Kolm & Berglund 2003). Also, a small population inhabits Luwuk harbour in Central Sulawesi, a very small embayment on the east coast of the Sulawesi mainland, separated from the Banggai Islands by the Peleng Strait (Vagelli & Erdmann 2002; Bernardi & Vagelli 2004; Vagelli et al 2008). Some introduced *P. kauderni* populations have become established at sites along the ornamental fish trade routes, such as Lembeh Strait, North Sulawesi (Erdmann & Vagelli 2001; Vagelli et al 2008; Carlos et al 2014), Tumbak, North Sulawesi (Ndobe et al 2008; Vagelli et al 2008; Peristiwady 2018), Palu, Central Sulawesi (Moore & Ndobe 2007a; Ndobe et al 2013; Syahril et al 2020), Bali (Lilley 2008; Vagelli et al 2008; Putra & Putra 2019; Arbi et al 2019), Kendari, Southeast

Sulawesi (Moore et al 2011; Kusumawardhani et al 2019; Kusumawardhani 2020), Ambon, Moluccas (Huwae et al 2019; Wibowo et al 2019), Ternate, North Moluccas (Arbi 2018), and Luwuk, Central Sulawesi (Vagelli & Erdmann 2002; Moore & Ndobe 2007b).

The Banggai cardinalfish live in shallow waters in a variety of habitats including coral reefs, seagrass beds and less frequently in more open habitats (low branching corals and rubble) (Vagelli & Volpedo 2004; Moore et al 2011), and is commonly found in calm and protected bays (Vagelli 2005; Ndobe et al 2005). *Pterapogon kauderni* is a site-attached species that stays associated with various benthic living substrates (Kolm et al. 2005; Vagelli 2011). The Banggai cardinalfish lives in groups mainly hovering within and above groups of long-spined sea urchins (*Diadema setosum*) (Allen & Steene 1995; Vagelli & Erdmann 2002; Vagelli 2002; Ndobe et al. 2008; Moore at al. 2011; Moore et al. 2012). They are also closely associated with other sea urchins (*Diadema savignyi*, *Tripneustes gratilla*, *Echinothrix* spp. and *Astropyga* spp.) (Vagelli & Volpedo 2004; Ndobe et al 2017), sea anemones (*Actinodendron* spp., *Entacmaea quadricolor*, *Heteractis crispa*, *Macrodactyla doreensis*, *Stichodactyla haddoni*) (Vagelli & Erdmann 2002; Vagelli 2002; Vagelli & Volpedo 2004; Ndobe et al 2008; Moore et al 2012), soft corals (*Nephthea* spp.) (Vagelli & Erdmann 2002; Vagelli 2002; Vagelli & Volpedo 2004; Ndobe et al 2008), branching coral stone corals (*Acropora* spp., *Anacropora* spp., *Porites* spp., *Goniopora* spp., etc.) (Allen 2000; Vagelli & Erdmann 2002; Vagelli 2002; Vagelli & Volpedo 2004), mushroom stone coral *Heliofungia* (Ndobe et al 2008), hydrozoans (*Millepora* spp.) (Vagelli & Volpedo 2004; Ndobe et al 2008), sponges (Ndobe et al 2008), and mangrove roots (*Rhizophora* spp.) (Vagelli & Volpedo 2004; Vagelli 2005; Ndobe et al 2005).

Microhabitat is important in its protection role and anemones seem to be a particularly important microhabitat for newly released Banggai cardinalfish recruits and small juveniles (Vagelli 2004; Ndobe et al 2008). Nearly all predators, including adult and sub-adult *Pterapogon kauderni*, seem to avoid the tentacles among which the smaller *P. kauderni* often hide, also benefiting from protection of the anemone (Moore et al 2012). If sea anemones are not present, Banggai cardinalfish will likely choose to associate with other biota that resemble anemones, for example the mushroom coral *Heliofungia* spp., soft corals or any other benthic organism that has many tentacles (Ndobe et al 2008), including the upside-down jellyfish *Cassiopea andromeda* that is physically similar to anemones (Vagelli 2011). There have been several studies on native (endemic) Banggai cardinalfish populations and their microhabitat preferences in the Banggai Islands and on some introduced populations, but not in Luwuk Bay. Therefore, this study was carried out to obtain up-to-date data on the Banggai cardinalfish population in Luwuk Bay, including an overview of the microhabitat preference patterns of this introduced Banggai cardinalfish population.

Material and Method

Time and study site. Research on the population and microhabitat preferences of Banggai cardinalfish was carried out from April to May 2019 in Luwuk Bay, Banggai District, Central Sulawesi Province, Indonesia. Various sources of information indicated that there were several small populations of Banggai cardinalfish inhabiting these waters. The study focused on five locations based on information regarding Banggai cardinalfish populations (Figure 1).

Density. Banggai cardinalfish observations were carried out using a modified belt transect method (Suwardi et al 2019), with 20 x 5 m belt transects placed along the coastline at each station. Banggai cardinalfish density, habitat (coral reefs, seagrass beds, etc.) and microhabitat (sea urchins, corals, anemones, or others), were recorded 2.5 meters to the right and left of a transect line, giving an observation area of 100 m^2 at each station (Figure 2). After completing the recording of the transect tape, it can be rolled back for 3 repetitions at each observation station (Labrosse et al 2002; Hill & Wilkinson 2004). Banggai cardinalfish were recorded in 3 size classes based on standard length (SL): recruits (less than 1.8 cm SL), juveniles (1.8 - 3.5 cm SL), and adults (more than 3.5 cm SL).

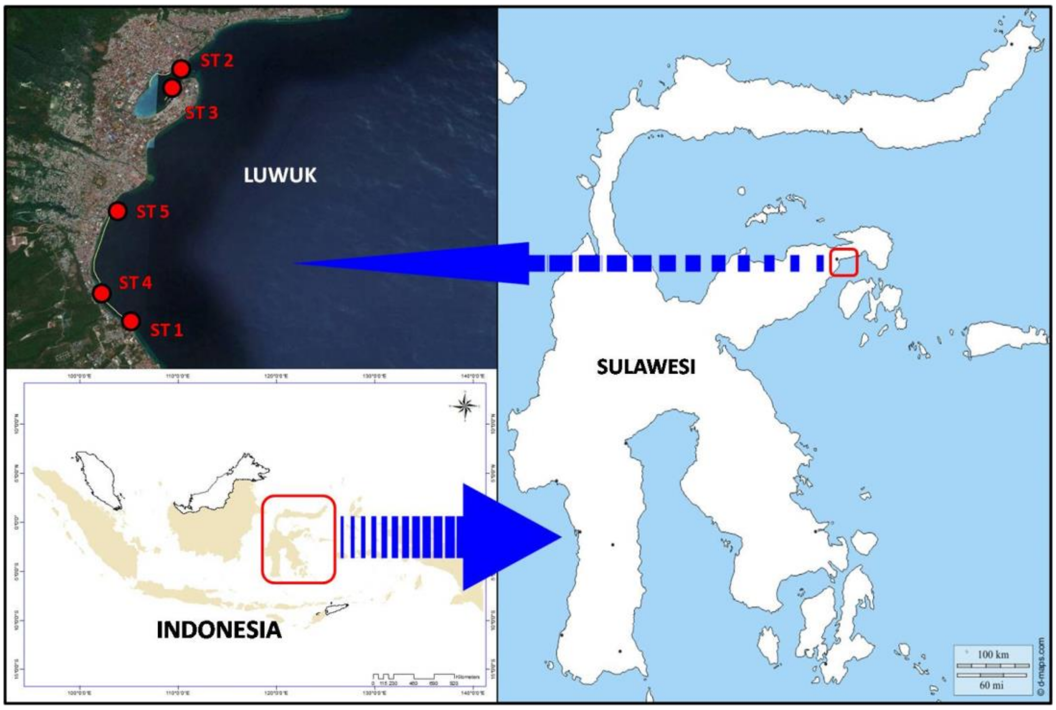

Figure 1. Banggai cardinalfish survey stations in Luwuk, Sulawesi, Indonesia.

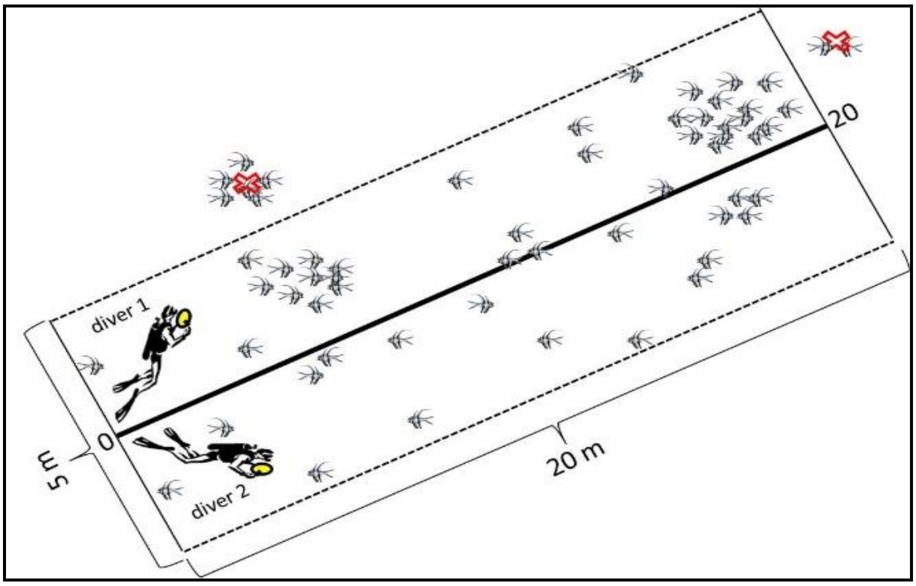

Figure 2. Modified Belt Transect method scheme used for Banggai cardinalfish population density observation (after Wibowo et al 2019).

The density of Banggai cardinalfish was calculated by the formula:

$$d = \frac{c}{A}$$

Where: d - density (ind m^{-2}); c - number of Banggai cardinalfish counted (ind); A - coverage of observation area (m^2).

The Friedman test was used to compare the densities of three stages of fish development at each station using SPSS 25 software with a confidence level of 95% ($p<0.05$).

Microhabitat preferences. The microhabitat of Banggai cardinalfish includes the existence of various marine organisms, such as black sea-urchins (*Diadema* spp.), hard corals, soft corals, anemones and other microhabitats. Observation of the Banggai cardinalfish microhabitat was carried out using the same modified belt transect used for assessing Banggai cardinalfish density. Data collected on Banggai cardinalfish microhabitat association included the type of organism, the number of individuals or colonies, and the number of individual Banggai cardinalfish inhabiting each type of microhabitat. Several Banggai cardinalfish habitat environmental parameters were also recorded: temperature (^oC, thermometer), depth (depth meter using dradloading method), salinity (‰, salino-refractometer), pH (digital pH meter, Methrom 826), silicate concentration (mg L^{-1}, spectrophotometry method), nitrate concentration (mg L^{-1}, spectrophotometry method), and orthophosphate concentration (mg L^{-1}, spectrophotometry method).

Data analysis. Neu's index analysis (preference index) was used to determine microhabitat preferences based on differences in density, following the formula:

$$wi = \frac{ui}{pi}$$

$$b = \frac{wi}{\sum wi}$$

Where: *wi* - microhabitat preference index at station i; *pi* - proportion of total area at observation station i (m^2); *ui* - proportion of individual fish counted at station i (ind); *b* - standardised index for station i.

Canonical analysis was used to determine the relationship between density and environmental parameters (biology, chemical, physic) using Canoco 4.5 software, and the result graphically drawn using CanoDraw (Leps & Smilauer 2003).

Results and Discussion

Description of the study site. Luwuk harbour is located in Luwuk Bay, with a surface of about 1.2 km by 0.5 km, with the narrow entrance passage of about 150 m wide. Small populations of Banggai cardinalfish are found in at least five locations around Luwuk Bay, mostly in or close to Luwuk harbour. Habitat type (Table 1) and the environmental parameters (Table 2) vary considerably between locations.

Table 1

Characteristics of type of habitat at each station

Station	*Description*	
	Location	*Banggai cardinalfish's habitat*
I	Kilo Lima beach 00.57058S, 122.47821E	Close to villages and tourist attractions. Habitat in the coral reef ecosystem. Sandy substrate.
II	Port of Luwuk 00.56930S, 122.47768E	Under the Luwuk Harbor pier. Habitat in the coral reef ecosystem. Muddy sand substrate.
III	Traditional Harbor 00.56932S, 122.47625E	Close to the traditional port of Lalong Bay. Habitat in seagrass ecosystem. Muddy sand substrate.
IV	Maahas village 00.58852S, 122.47256E	Close to the village. Habitat in seagrass and coral reefs ecosystems. Sandy substrate.
V	Simpong village 00.58206S, 122.47316E	Close to the village. Habitat in coral reef ecosystem. Sand substrate.

Table 2

Environmental parameters at each station

Station	*Salinity (‰)*	*Depth (m)*	*Temperature (°C)*	*pH*	*Silicate (mg L-1)*	*Nitrate (mg L-1)*	*Orthophosphate (mg L-1)*
I	32	3	31	8.14	0.1395	0.0072	0.0016
II	30	2	32	8.22	0.1654	0.0146	0.0036
III	31	3	30	8.22	0.4419	0.1595	0.0150
IV	30	2	30	8.26	0.1681	0.0053	0.0033
V	30	2	30	8.31	0.1250	0.0047	0.0027

Density. Banggai cardinalfish were found at five stations in the coastal waters of Luwuk, Central Sulawesi. All life stages of Banggai cardinalfish were found in this study, i.e. larvae, juveniles and adults (Figure 3). The life stage composition varied between sites, with all life stages found at three sites, while at Station I, post-larvae and juveniles were not found. At Station IV no juveniles were found. In addition, the density of Banggai cardinalfish at each stage of development also varied between observation stations.

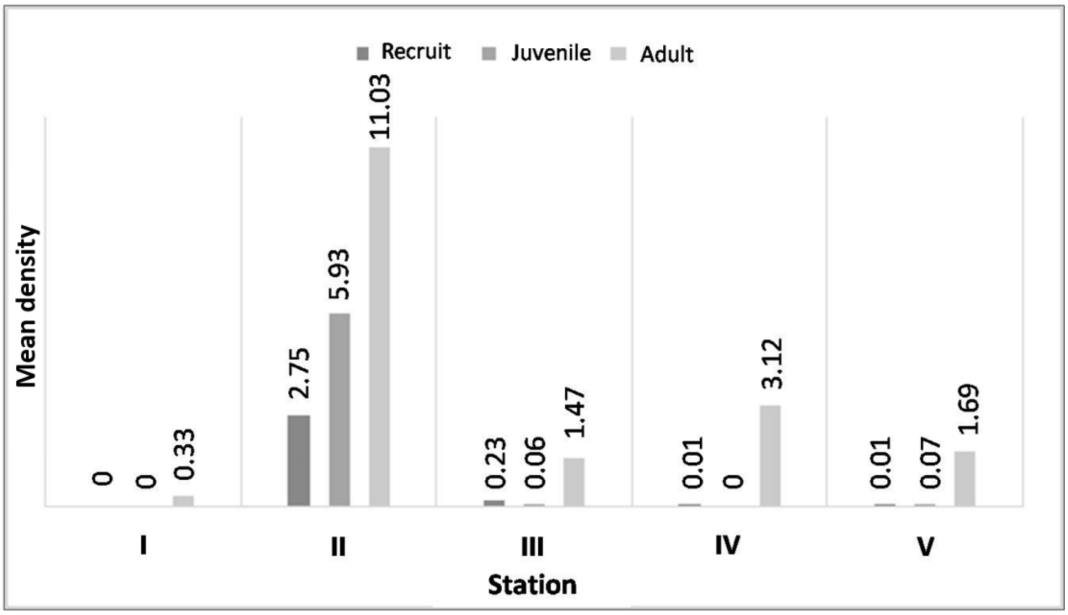

Figure 3. Density of Banggai cardinalfish by life stage at each station (100 m^2 transect, 3 replicates) in the coastal waters of Luwuk, Central Sulawesi, Indonesia.

Based on the results of the nonparametric test using the Friedman test method, all life stages of Banggai cardinalfish were found in the coastal waters of Luwuk, with statistically significant differences in average density between stations (asymp. sig. = 0.019, $p<0.05$). The minimum densities were 0 (not found) for recruits (Station I) and juveniles (Station I and IV), and 0.33 ind m^{-2} for adults (Station I). Meanwhile, the maximum densities for all three life stages were found at Station II (0.03 ind m^{-2}, 0.06 ind m^{-2} and 0.11 ind m^{-2}).

Based on the results of the ordination of redundancy analysis (RDA) of environmental parameters measured in this observation, they can be grouped into three main components with an eigenvalue of 1.0. The results illustrate that the three life stages of Banggai cardinalfish are distributed evenly with respect to the environmental parameters (Figure 4). Furthermore, depth and salinity affect the distribution of each Banggai cardinalfish life stage, with interset correlation values of 0.808 and 0.8035, respectively.

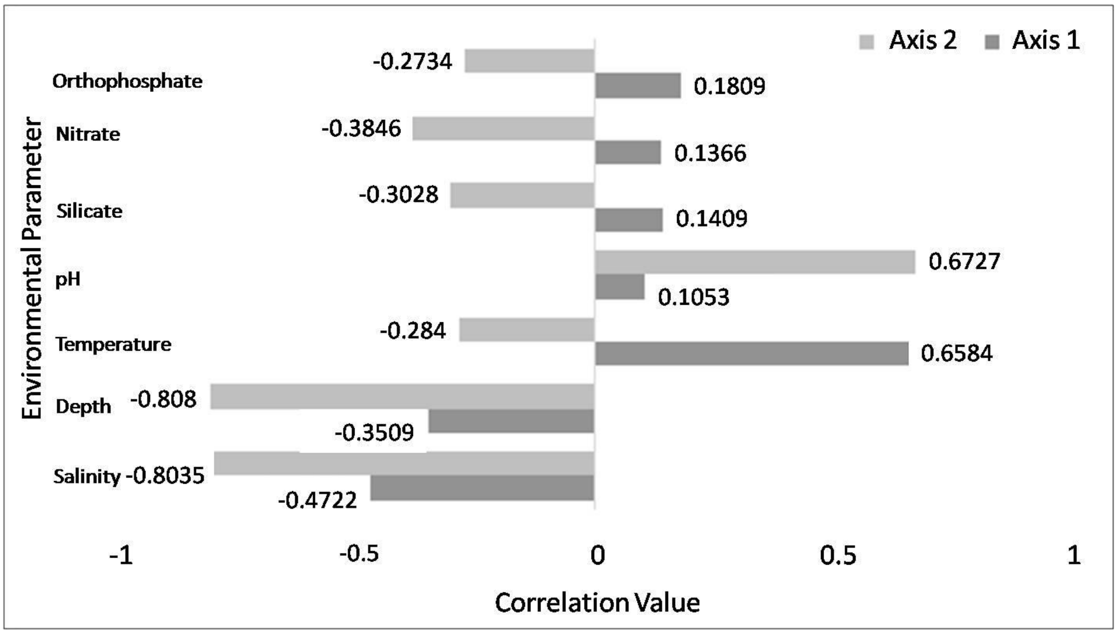

Figure 4. Interset correlation value showing the effect of environmental parameters on the distribution of life stages of the Banggai cardinalfish.

The ordination diagram shows Banggai cardinalfish life stages (blue arrows) and the environmental parameters (red arrows), and the observation stations shown as triangles (Figure 5). Based on Axis 1 the life stages tend to cluster at Station II. It was assumed that this is related to the higher density of each life stage at Station II. Based on the interset correlation values, depth and salinity are the factors that have the strongest influence on the distribution of Banggai cardinalfish life stages, as indicated by the longer arrows for depth and salinity.

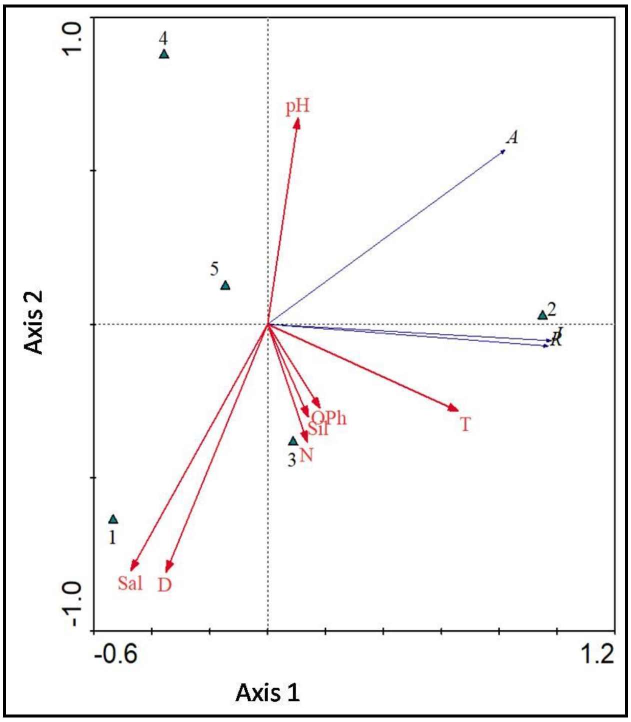

Figure 5. RDA triplot ordination diagram of the environmental parameters affecting Banggai cardinalfish density.

***Microhabitat preferences**.* Based on PCA ordination analysis of microhabitat, the eigenvalue value was 1.0. These results illustrate that the life stages are evenly distributed between microhabitats (Figure 6). The PCA ordination analysis results also indicate a similar distribution of Banggai cardinalfish life stages relative to the microhabitat. In addition, the data show that sea urchins were the microhabitat with the most influence on the distribution of Banggai cardinalfish life stages with a correlation factor of 0.6845 (R^2=0.6845).

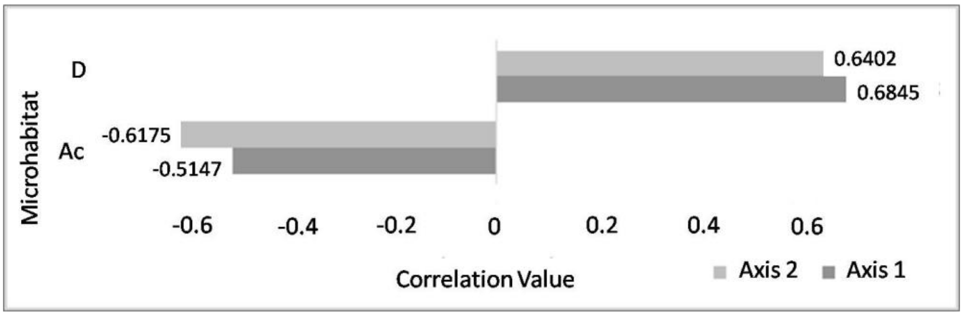

Figure 6. Interset correlation values showing the effect of microhabitat on the distribution of Banggai cardinalfish life stages.

The ordination diagram shows Banggai cardinalfish life stages and microhabitat types as arrows, while the observation stations are shown as triangles (Figure 7). Axis 2 in this ordination diagram shows that sea urchins were most abundant at Station II. The diagram also shows the Acropora coral microhabitat arrow in an opposite direction to that of sea urchin microhabitat; acroporid coral colonies were most abundant at Station I.

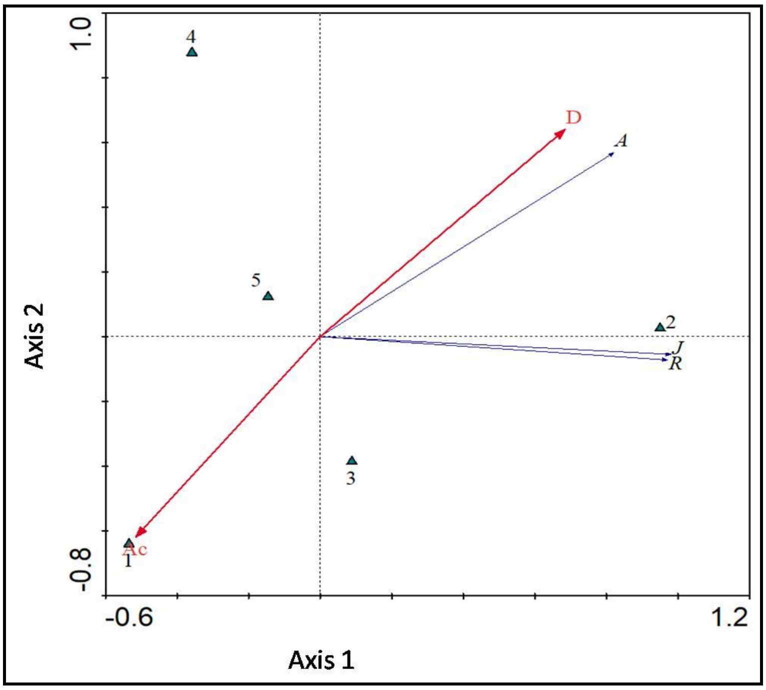

Figure 7. PCA biplot ordination diagram showing the effect of microhabitat types on Banggai cardinalish density.

Sea urchins of the genus *Diadema* were found at all five locations; despite variations in density, they hosted Banggai cardinalfish at all stations (Figure 8). The density was lowest at Station 1 (mean 0.26 ind m^{-2}) and highest at Station 2 (mean 3.4 ind m^{-2}).

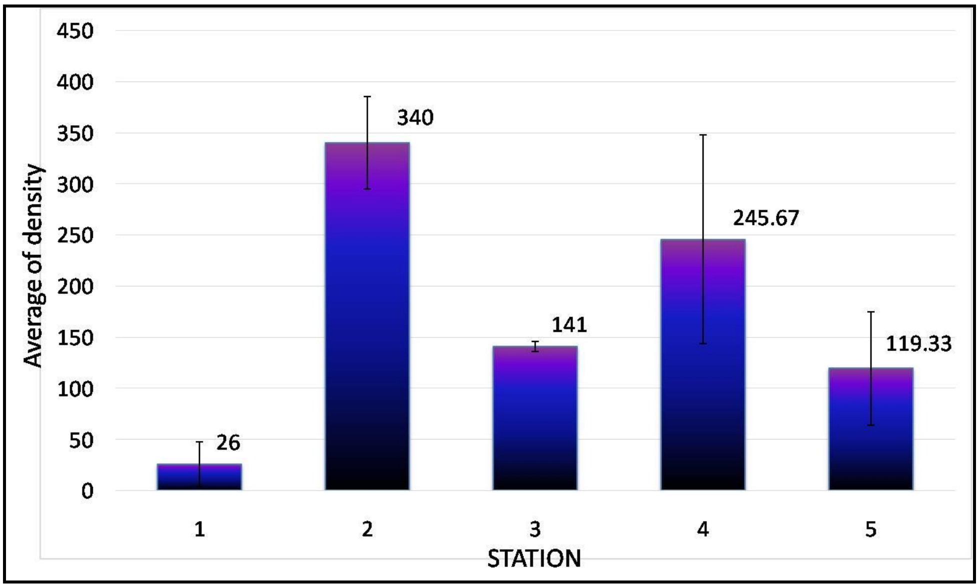

Figure 8. Density of long-spined sea urchins *Diadema* spp. (ind 100 m^{-2}) serving as Banggai cardinalfish microhabitat; the error bars indicate standard error.

Microhabitat preferences index. The preference index shows the microhabitat preference of each Banggai cardinalfish life stage in Luwuk Bay (Table 3). The highest recruit microhabitat preference index was 3.19, at Station III. The locations most preferred (w≥1) by the recruit stage were Stations III and II, while Stations V and IV were less favorable (w≤1) and no recruits were found at Station I (w=0). The juvenile stage preference index was highest (2.18) at Station II, while Stations III and V were less favorable (w≤1), and no juveniles were found at Stations I and IV (w=0). The highest adult stage preference index was 3.5 at Station III, while adults were present in all stations; Stations I, IV and V were less favorable (w≤1).

Luwuk waters were exposed to high levels of pollution, including regular fuel spills, freshwater run off and sewage discharges (Vagelli et al 2008). The closest native (endemic) Banggai cardinalfish population to Luwuk is at Tanjung Patikaman (a headland in Liang Sub-District on Peleng Island) about 120 km away and separated from Sulawesi by the Peleng Strait with strong currents and depths up to about 920 m (Vagelli 2005). It has been suggested that the Banggai cardinalfish in Luwuk Harbour are an introduced population (Bernardi & Vagelli 2004; Hoffman et al 2005). Introductions are known to have occurred in the Luwuk area from the late 1990's to 2019. The low density of Banggai cardinalfish at Station I was thought to be due to being in a coral reef ecosystem, which is a suitable zone for fish spawning. Thus, the development phase is dominated by adult fish. These results were similar to the findings of Vagelli (2011), who stated that most of the Banggai cardinalfish populations consist of several different stages of development, with juveniles being most abundant. The recruits are often found living in habitats inhabited by their parents (Ndobe & Moore 2007). According to Vagelli (2004), mating partners and incubating males can be found in all habitats inhabited by Banggai cardinalfish, suggesting that fish reproduction and recruitment can occur in all zones occupied by the species. However, the number of newly released recruits was higher in seagrass beds, although incubating males were more common in coral reef habitats. During the first two to three weeks after birth, recruits experience high predation rates (including cannibalism by adult conspecifics). After being released by the male parent, the recruits will tend to seek protection on a substrate that is isolated and separated from the parent's microhabitat (Vagelli 2011).

Table 3

Banggai cardinalfish microhabitat preference index in Luwuk coastal waters by life stage and site

Sta	*a*	*p*	*n*			*u*			*e*			*w*			*b*			*l*		
			R	J	A	R	J	A	R	J	A	R	J	A	R	J	A	R	J	A
I	6.04	0.08	0	0	33	0	0	0.02	23	45	132	0	0	0.25	0	0	0.04	5	4	5
II	36.17	0.45	278	593	1103	0.92	0.98	0.63	136	272	793	2.04	2.18	1.39	0.388	0.82	0.22	2	1	2
III	1.92	0.02	23	6	147	0.08	0.01	0.08	7	14	42	3.19	0.42	3.5	0.606	0.16	0.55	1	2	1
IV	23.78	0.3	1	0	312	0.003	0	0.18	90	179	521	0.01	0	0.6	0.002	0	0.09	4	4	4
V	12.59	0.16	1	7	169	0.003	0.01	0.1	47	95	276	0.02	0.07	0.61	0.004	0.03	0.1	3	3	3
∑	80.49	1	303	606	1764	1	1	1	303	606	1764	5.26	2.7	6.35	1	1	1			

Notes: *a* - coverage area of the microhabitat inhabited by the Banggai cardinalfish (m^{-2}); *p* - proportion of the microhabitat inhabited by the Banggai cardinalfish; *n* - number of individuals of Banggai cardinalfish; *u* - proportion of the number of individuals of Banggai cardinalfish observed; *e* - expected value of observed number of Banggai cardinalfish (individuals); *w* - selection index; *b* - standardized selection index; *l* - order of habitat preference of Banggai cardinalfish; R - post-larvae stage; J - juveniles; A - adults.

The theory of ontogenetic shift in microhabitat, namely the tendency to shift between microhabitats/symbionts with age and life-stage is well supported (Vagelli 2004; Ndobe et al 2008; Moore et al 2012; Ndobe et al 2018; Rahma & Safir 2018). After settlement, Banggai cardinalfish exhibits high site fidelity (Kolm et al 2005) despite an ontogenetic shift in microhabitat within a given site (Vagelli 2004; Vagelli et al 2005; Ndobe et al 2008; Moore et al 2012; Ndobe et al 2018; Rahman & Safir 2018). The difference in age/size composition of Banggai cardinalfish associated with different types of microhabitat is often very prominent visually and has been found to be statistically significant in several studies. Microhabitat shifts tend to occur slowly from sea anemones as recruits to hard corals, as adults, with all size classes often associated with *Diadema* sea urchins (Vagelli 2005; Ndobe et al 2008). If sea urchins are abundant, Banggai cardinalfish of various sizes are generally observed among the sea urchins. Conversely, in a habitat with a low sea urchin abundance, more Banggai cardinalfish will choose other available microhabitats.

Sea anemones are a particularly important microhabitat for the survival of newly-released larvae and small juveniles, often shared with clownfish. During observation, several predators of Banggai cardinal fish were seen, such as lionfish (*Pterois* spp.), stonefish (*Synanceia* spp.) and also moray eel (*Gymnothorax* spp.). Adult fish tend to dominate in hard coral microhabitats, although this is limited to coral life forms, which offer plenty of refuge, especially in branching and foliose forms (Ndobe et al 2008). An interesting phenomenon occurs in the relationship between clownfish *Amphiprion* spp. and juveniles of *P. kauderni*, which are symbiotic with sea anemones. Clownfish will usually expel all of fish that approach the sea anemones they occupy, including adult *P. kauderni*, but still tolerate the presence of juveniles (Ndobe et al 2013). There is increasing evidence that these three microhabitats (sea urchins, sea anemones and complex hard coral life-forms) are all important to maintain *P. kauderni* populations (Ndobe et al 2011; Kasim et al 2014; Ndobe et al 2018). The main cause of the decline in the abundance of Banggai cardinalfish populations is due to a decrease in the abundance of microhabitat populations, especially sea urchins and sea anemones (Ndobe et al 2017).

The strong influence of depth (Figures 4 and 5) indicates that the distribution of each Banggai cardinalfish life stage in these waters is divided based on depth. Banggai cardinalfish have been found at 0.5 to 6 m depth, generally at 1.5 to 5.5 m depth, in coral reef and seagrass bed ecosystems (Kasim et al 2012). This result is similar to the results of Carlos et al (2014), who observed that the distribution of the Banggai cardinalfish in the Lembeh Strait is also influenced by depth. The results show that the distribution in the Lembeh Strait tends to be influenced by depth, where fewer individual fish are found along with increasing depth. A higher salinity is not followed by an increase in Banggai cardinalfish density. This is possibly because osmotic pressure can affect the survival rate of the Banggai cardinalfish. Too high or too low osmotic pressure are both likely to reduce survival and/or growth of Banggai cardinalfish (Rahman et al 2017).

Banggai cardinalfish populations in the introduced habitat in Luwuk Bay were seen to choose several microhabitats, including long-spined sea urchins (*D. setosum* and *D. savignyi*), sea anemones, various life forms of hard coral, mushroom coral *Heliofungia* spp. and soft corals. Ontogenetic shift phenomenon in microhabitat also has been seen in this area, as results from previous studies. The distribution of each life stage of Banggai cardinalfish in Luwuk waters is influenced by the presence of sea urchins at the observation station. The reason is that Banggai cardinalfish does not have a defence mechanism; meanwhile, the fish must avoid predators by associating with other organisms for protection (Vagelli 2004). Thus, the existence of sea urchins as a microhabitat affects the ability of the Banggai cardinalfish to avoid predators. Based on the interset correlation value, sea urchins are the microhabitat with the strongest influence on the distribution of each life stage of the Banggai cardinalfish. The projection points are located in the direction of the projection points of each life stage. This illustrates the area with larger sea urchin colonies, followed by the higher density of each life stage of Banggai cardinalfish. According to Vagelli (2011), high density of recruitments was found in a population of 50 to 100 individuals in *D. setosum* in large colonies (about 5 to 10 m). Within this population, several small groups of recruitments consisting of 3 to 6 individuals were seen spread between juveniles and adults. Furthermore, there is an unknown mechanism behind selecting microhabitats of Banggai cardinalfish. Therefore, the actual role of the host in the fish population is unknown. Where it exists, interspecific competition may play an important role in microhabitat selection or lead to resource sharing. In addition, it is unknown whether factors such as differences in predator pressure between or in the same locations, and environmental characteristics are components of the microhabitat selection process, and the extent to which they can influence the level of association between the microhabitats and the Banggai cardinalfish (Vagelli 2011).

It can be assumed that these fish have specific microhabitat selection. Fish density data at each station shows that each life stage has a different average density, and this means that there is an imbalance in microhabitat use. The absence of a pelagic stage and its sedentary behaviour throughout life was the main factor causing it (Moore et al 2017). In addition, its passive movements and lack of self-defence mechanisms make this fish's life highly dependent on other organisms that provide protection (Vagelli 2017). After being released by the male parent, recruitment of Banggai cardinalfish will immediately conduct settlement and seek protection from predators in their microhabitat, such as sea urchins (*Diadema* spp.), sea anemones and hard coral (especially colonies of branching coral) (Vagelli 2004; Ndobe et al 2008).

Habitat requirements for different life stages (recruitments, juveniles, and adults), often show differences even in the same habitat, leading to changes in habitat preferences (Manangkalangi et al 2009; MacNeill 2010). The results assumed that the recruitment stage of Banggai cardinalfish was most favorable to Station III, because the usage of habitat is greater than the availability. Station III was located between seagrass beds and a coral reef ecosystem with sandy substrate. Sea urchin in abundance is the only microhabitat that can be found. However, if sea urchins move, Banggai cardinalfish will still have many other microhabitats available in both ecosystems to replace the role of sea urchins. If the recruitments remain associated with sea urchins for a long time, they will migrate passively along with the sea urchins to find more suitable microhabitats and switch to a different type of microhabitat; for example, if the sea urchin colony passes through the anemone, recruitment stage will move from the colony of sea urchins to anemone (Vagelli 2011). Fish and sea urchins were well associated because their spines and Banggai cardinal fish have the same color (Rahman & Safir 2018). When under threat from predatory attacks, juveniles can take shelter between the spines of sea urchins, or coral branches.

Conclusions. Based on the previous research and current data obtained during this study, it can be concluded that the Banggai cardinalfish is not native to Luwuk waters. It is an introduced species, and seemingly it is a result of releases by traders. The study showed that, as an introduced fish species, the Banggai cardinalfish has been able to adapt and breed in Luwuk waters. At two study sites, the introduced Banggai cardinalfish populations were relatively abundant, with size distributions ranging from recruitments to adults, mostly symbiotic with black sea urchins. The results showed that Banggai cardinalfish prefer semi-enclosed areas, such as harbors, compared to open areas.

Acknowledgements. The authors gratefully acknowledge support from the Research Center for Oceanography, Indonesian Institute of Sciences (RCO-LIPI). The research was fully funded by COREMAP-CTI 2019 Program through the Priority Research scheme (grant number B-5006/IPK.2/KP.06/I/2019). We also thank all colleagues and stakeholders who have contributed to the survey and collecting data, especially to the Marine and Fisheries Service (Local Government of District of Banggai) and Fish Quarantine and Inspection Agency of Luwuk (Ministry of Marine Affairs and Fisheries).

Conflict of Interest. The authors declare that there is no conflict of interest.

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Received: 24 February 2021. Accepted: 15 June 2021. Published online: 12 January 2022.
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How to cite this article:
Arbi U. Y., Kusumawardhani N. R., Vimono I. B., Anshari L., 2022 Microhabitat preferences of endemic Banggai cardinalfish (*Pterapogon kauderni*) in the introduced habitat in Luwuk, Indonesia. AACL Bioflux 15(1):54-67.