

Population density, size structure and microhabitat use of the endangered *Pterapogon kauderni* in its native range (Banggai Islands) and introduced population (Lembeh Strait), Sulawesi, Indonesia

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<https://doi.org/10.67784/1003>

Abstract. Banggai cardinalfish (*Pterapogon kauderni*) is an endangered, range-restricted apogonid endemic to the Banggai Archipelago (Banggai Islands), Indonesia, and a flagship species of the marine ornamental fish trade. Aquarium-mediated releases have established non-native populations, including in Lembeh Strait, North Sulawesi. This study compared population density, size structure, and microhabitat use of *P. kauderni* between introduced and native ranges using underwater visual census along 50-m x 5-m belt transects in Lembeh Strait (March 2021) and in the Banggai Islands (October 2021). Individuals were counted, assigned to three size classes (recruit, 1.8 cm, SL; juvenile, 1.8–3.5 cm, SL; adult, > 3.5 cm, SL), and recorded with associated protective microhabitats: branching coral, *Diadema* sea urchins, sea anemones, and seagrass. A total of 3,997 individuals from 45 colonies were recorded (42 with recorded microhabitat). Mean density was 2.00 ± 0.62 ind m⁻², with no significant difference between introduced and native ranges (Mann–Whitney U = 10.0, $p = 0.69$). Populations were adult-dominated overall (73.7%), while pooled descriptive proportions showed more juveniles in Lembeh and more adults in Banggai; however, station-level comparisons detected no significant regional differences. Coral and *Diadema* were the most frequent colony microhabitats, and 88.2% of individuals were associated with *Diadema*. Colonies with *Diadema* contained significantly more individuals ($p = 0.005$), and abundance increased with the number of protective microhabitats present (Spearman $\rho = 0.34$, $p = 0.028$). An exploratory colony-level comparison showed higher median abundance in colonies with *Diadema* rather than in colonies with none, but this result was interpreted cautiously because multiple colonies occurred within the same stations. These findings provide evidence for habitat-based monitoring and management of native and introduced populations in Indonesian waters.

Keywords: Apogonidae, aquarium trade, belt transect, Coral Triangle, *Diadema setosum*, ontogenetic shift, reef fish conservation, underwater visual census.

Introduction. The Banggai cardinalfish, *Pterapogon kauderni* Koumans, 1933 (Apogonidae), is among the most distinctive and conservation-relevant coral-reef fishes of the Coral Triangle. The species is naturally restricted to the shallow waters of the Banggai Archipelago off eastern Central Sulawesi, Indonesia, where it occupies one of the smallest geographic ranges of any marine fish (an endemic range of approximately 5,000

km² and an estimated area of occupancy of only ~20 km² (Vagelli & Erdmann, 2002; Ndobe et al., 2018). *P. kauderni* is a paternal mouthbrooder with direct development: it lacks a dispersive pelagic larval phase, produces small clutches of large, well-developed offspring, and releases fully formed juveniles that settle immediately into the microhabitat. This combination of low fecundity, extreme site fidelity, and negligible larval dispersal produces a naturally fragmented population of small, demographically isolated groups, and renders the species exceptionally vulnerable to localized depletion (Vagelli, 1999; Bernardi & Vagelli, 2004; Hoffman et al., 2005).

These life-history traits, together with intense and largely unregulated harvesting for the international marine aquarium trade, led to the species being assessed as Endangered on the IUCN Red List (Allen, 2000; Allen & Donaldson, 2007). Hundreds of thousands to millions of individuals have been extracted annually since the 1990s (an estimated 600,000-900,000 fish year⁻¹ in the early 2000s (Lunn & Moreau, 2004; Ndobe et al., 2018)), and proposals to regulate the trade under CITES have been repeatedly debated. Because the species is so attractive to aquarists and is readily transported, escaped or deliberately released individuals have founded a number of non-native populations well outside the natural range, including in Lembeh Strait (North Sulawesi), Palu Bay, Tomini Bay, Luwuk, and Bali (Erdmann & Vagelli, 2001; Ndobe et al., 2018; Yalindua et al., 2022). The Lembeh Strait population, first reported in 2000-2001 (Erdmann & Vagelli, 2001), has since persisted and expanded, and is now a regular feature of one of Indonesia's most heavily dived muck-diving destinations. Such introduced populations present a conservation paradox: they may act as inadvertent ex-situ refuges, yet they also raise concerns about ecological impacts on recipient communities and the translocation of pathogens such as the Banggai cardinalfish iridovirus (Weber et al., 2009; Ndobe et al., 2018).

Throughout its range *P. kauderni* is obligately associated with a small set of structurally complex, protective microhabitats that provide refuge from predators, particularly for newly settled recruits. The most important of these are the long-spined sea urchin *Diadema setosum*, sea anemones, branching corals (notably *Acropora*), and seagrass beds (Vagelli & Erdmann, 2002; Vagelli, 2011; Ndobe et al., 2013). The species exhibits a well-documented ontogenetic shift in microhabitat use, with the smallest individuals sheltering deep within urchin spines and anemone tentacles before associating more loosely with branching coral and other structure as adults (Vagelli, 2004). Because the persistence of local groups depends directly on the availability and condition of these microhabitats, quantifying microhabitat use is central both to understanding the species ecology and to designing effective conservation measures.

Despite considerable attention to the species, directly comparable, transect-based demographic data for native and introduced populations remain limited, and few studies report population density, size structure, and microhabitat use together within a single standardized sampling framework (Ndobe et al., 2013). Here we provide such data for eight stations spanning the native range (Banggai Islands) and an established introduced population (Lembeh Strait). Our objectives were to (i) estimate the density of *P. kauderni* (individuals m⁻²) and its size-class composition at each station; (ii) characterize the protective microhabitats used by the species and test whether abundance is associated with the presence of *Diadema* urchins and with the number of protective microhabitats available; and (iii) compare density, size structure, and microhabitat use between the native and introduced ranges. This study aims to compare the population characteristics of *P. kauderni* between its native range in the Banggai Islands and its introduced range in Lembeh Strait, while providing a quantitative baseline for monitoring and managing both endemic and introduced populations.

Material and Method

Description of the study sites. Surveys were conducted at eight shallow, near-shore stations in two regions of Sulawesi, Indonesia (Figure 1). Four stations were located in Lembeh Strait, North Sulawesi part of the introduced range of *P. kauderni*, and were surveyed on 30-31 March 2021: Abadi Island (western side), Papusungan kecil (western

side), Serena Besar Island, and Tandurusa (LIPI beach). Four stations were located in the Banggai Islands, the species' native range (Table 1) and were surveyed on 20-22 October 2021: Bone Baru, Bone-Bone (beneath a stilt settlement), Bontosi (near the village jetty and breakwater), and Tinakin Laut (Banggai Island). All stations were characterized by shallow (≤ 2.5 m) sheltered habitat comprising mixtures of branching and massive coral, coral rubble, sand, seagrass, sea anemones and *Diadema* urchins. Depth, substrate, microhabitat, and geographic coordinates were recorded at each station.

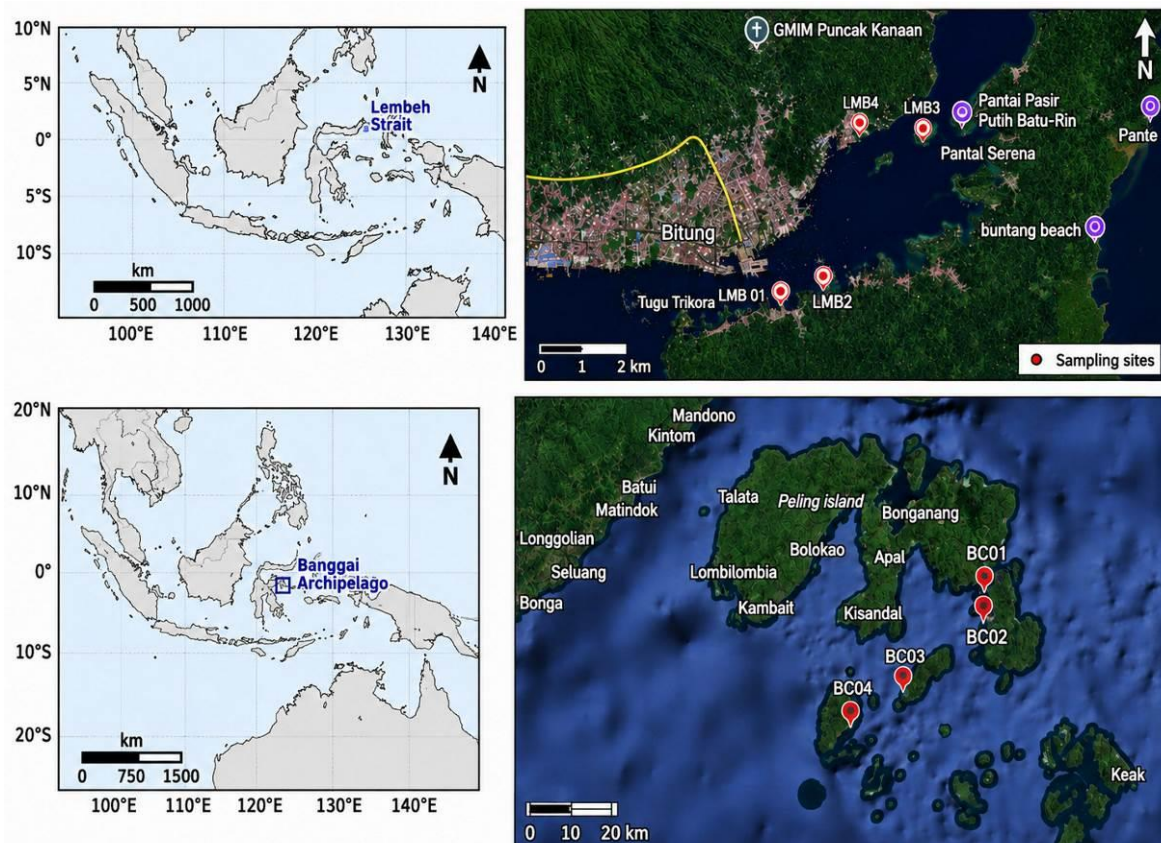


Figure 1. The location area of Sampling *P. kauderni* in Banggai Island and Lembeh Strait, Sulawesi, Indonesia.

Table 1

Survey area of sampling *P. kauderni* in its native range and introduction area

Station code	Survey area	Locality / region	Latitude (°)	Longitude (°)
BC01	Banggai	Bone Baru	-1.537508	123.482596
BC02	Banggai	Tinakin Laut	-1.608951	123.485084
BC03	Banggai	Bontosi	-1.780692	123.272133
BC04	Banggai	Bone-Bone	-1.869074	123.134143
LMB01	Lembeh	Abadi Island	1.432991	125.205271
LMB02	Lembeh	Papusungan kecil	1.436231	125.213429
LMB03	Lembeh	Serena Besar Island	1.459369	125.233080
LMB04	Lembeh	Tandurusa	1.460255	125.221668

Underwater visual census belt transect. Population sampling of *P. kauderni* followed the underwater visual census (UVC) method using a belt-transect approach (English et al., 1997). At each station a 50-m transect line was deployed by SCUBA/snorkel parallel to the shoreline or following the habitat contour at the depth at which *P. kauderni* occurred. The observation area extended 2.5 m to either side of the transect line, giving a total surveyed area of 250 m² per station (50 m × 5 m) per repetition (Figure 2). After completing the recording of the transect tape, it rolled back for 3 repetitions at each

observation station (Labrosse et al., 2002; Hill & Wilkinson, 2004). All *P. kauderni* within the belt were counted and classified into three size classes based on standard length (SL). Body length was estimated visually in situ to the nearest 0.5 cm by trained observers against a scale bar marked on the underwater slat. Individuals were assigned to recruit (1.8 cm, SL), juvenile (1.8–3.5 cm, SL), and adult (> 3.5 cm, SL) (Arbi et al., 2022; Ndobe et al., 2023). Fish occurred in discrete groups (“colonies”) associated with particular patches of structure. For each colony, size-class, habitat type and the protective microhabitat present were recorded, together with depth, substrate, position along the transect, time of day and associated fish taxa. Protective microhabitats were classified as *Diadema* sea urchins, sea anemones, coral and seagrass; coral growth forms were not distinguished in the analyses.

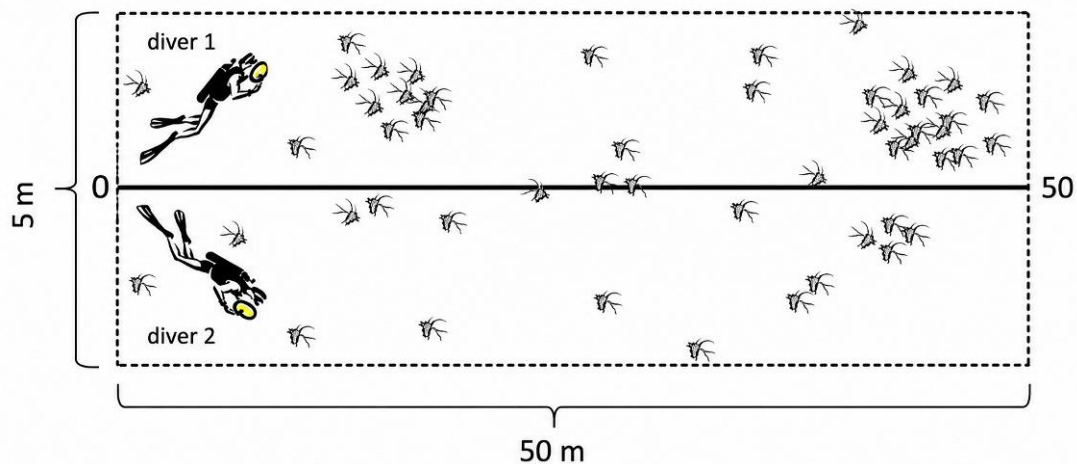


Figure 2. Modified belt transect method scheme used for Banggai cardinalfish population density observation.

Data analysis. Station-level abundances were obtained by summing the size-class counts of all colonies within each station, and the reconstructed totals were cross-checked against the original field tally sheets. Population density was expressed as individuals per square metre (ind m^{-2}) by dividing the station total, and each size-class total, by the fixed surveyed area of 250 m^2 . This calculation follows the logic of fixed-area UVC and belt-transect surveys, in which fish abundance is estimated from counts made within a known transect length and belt width (Labrosse et al., 2002; Hill & Wilkinson, 2004). Densities are reported as mean $\pm$ standard error (SE) overall and by region. Because each region was represented by only four stations, differences between the introduced range in Lembeh Strait and the native range in the Banggai Islands were tested using the non-parametric Mann–Whitney U test (Quinn & Keough, 2002; Zar, 2010). A nonsignificant result was interpreted as no detected difference in these sampled stations, not evidence of equivalence.

Size structure was summarized as counts and percentages of recruits, juveniles and adults at each station and in pooled regional totals. Pooled composition was used only descriptively because fish within a station are not independent replicates. Regional comparisons used Mann–Whitney U tests on station-level proportions of each size class, with four stations per region (Hurlbert, 1984; Quinn & Keough, 2002). The pooled region $\times$ size-class χ^2 test was not used for inference. Differences in survey month between the regions were considered when interpreting the station-level comparisons.

Microhabitat use was analysed at the colony level for the 42 colonies with recorded microhabitat information: 28 of 30 colonies in Lembeh Strait and 14 of 15 in the Banggai Islands. For each protective microhabitat, frequency of occurrence was calculated as the percentage of colonies in which that microhabitat was present. Because a colony could be associated with more than one protective structure, frequencies for *Diadema* sea urchins, sea anemones, corals, and seagrass were not mutually exclusive. The number of associated *P. kauderni* was also calculated for each microhabitat category. Regional differences in the occurrence of each microhabitat were tested using Fisher’s exact test

on 2×2 region $\times$ presence/absence tables, which is appropriate for categorical comparisons with small sample sizes or low expected frequencies (Quinn & Keough, 2002; Zar, 2010). The relationship between the number of protective microhabitats present in a colony and colony abundance was assessed using Spearman's rank correlation, and colony abundance was compared between colonies with and without *Diadema* using the Mann–Whitney U test (Zar, 2010).

Colony-level Fisher's exact tests, Spearman's rank correlation and a Mann–Whitney U comparison of colony abundance with and without *Diadema* were retained only as exploratory summaries (Quinn & Keough, 2002; Zar, 2010). Multiple colonies came from the same station, and these calculations did not account for station clustering. Their unadjusted p-values therefore do not establish independent habitat effects or general regional differences. Microhabitat availability was not quantified independently, so results describe use or association rather than selection or preference, which require comparison of use with availability (Johnson, 1980; Manly et al., 2002). Analyses were performed in R version 4.5.0 (R Core Team, 2025), with $\alpha = 0.05$ for the station-level comparisons.

Results. Across the eight stations we counted 3,997 *P. kauderni* in 45 colonies (Lembeh: 2,401 individuals in 30 colonies; Banggai: 1,596 individuals in 15 colonies). Station totals ranged from 83 (Tinakin Laut) to 1,143 (Bone-Bone). Mean density across all stations was 2.00 ± 0.62 ind m^{-2} (median 1.55; range 0.33–4.57). Density was highly variable among stations within both regions (Figure 3). The introduced Lembeh stations averaged 2.40 ± 0.83 ind m^{-2} and the native Banggai stations 1.60 ± 1.00 ind m^{-2} ; this difference was not statistically significant (Mann–Whitney U = 10.0, $p = 0.69$). The two highest densities were recorded at Bone-Bone (native; 4.57 ind m^{-2}) and Tandurusa (introduced; 4.49 ind m^{-2}), and the two lowest at Tinakin Laut (native; 0.33 ind m^{-2}) and and Serena Besar Island (introduced; 0.42 ind m^{-2}), indicating that the patchy, colonial distribution of the species - rather than region per se - drove most of the variation in density. Adults dominated density in both regions (overall mean 1.47 ind m^{-2}), followed by juveniles (0.31 ind m^{-2}) and recruits (0.21 ind m^{-2}).

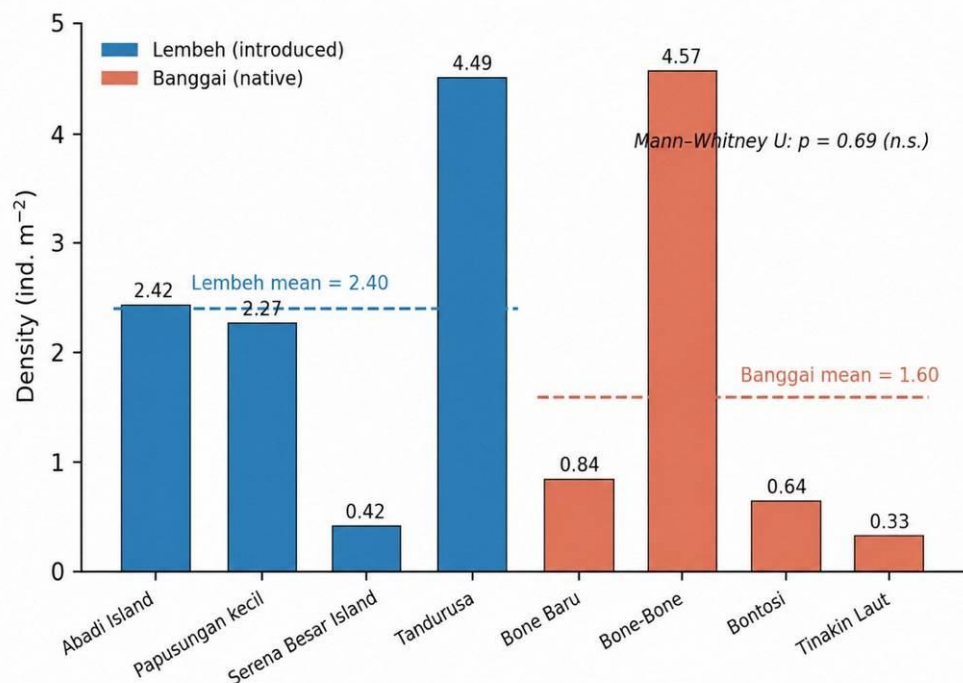


Figure 3. Density of *P. kauderni* (individuals m^{-2}) at each station. Dashed lines show regional means. Bar values are station densities. Density did not differ significantly between the introduced and native ranges (Mann–Whitney U = 10.0, $p = 0.69$).

Size structure. Both populations were strongly adult-dominated. Overall, adults comprised 73.7% of individuals ($n = 2,946$), juveniles 15.7% ($n = 626$) and recruits

10.6% ($n = 425$) (Figure 4). Adults were the most abundant class at all eight stations, the exception being Papusungan kecil, where juveniles and adults were similar. The pooled size composition was descriptively different between regions, juveniles formed a larger share of the introduced Lembeh population (21.1%) than of the native Banggai population (7.5%), whereas adults formed a larger share in Banggai (81.1%) than in Lembeh (68.8%); recruit proportions were similar (10.1% vs 11.4%). However, these pooled comparisons were not tested inferentially because individual fish within stations are not independent replicates. Station-level tests detected no regional differences in adult proportions (Mann–Whitney $U = 6.0$, $p = 0.69$), juvenile proportions ($U = 12.0$, $p = 0.34$) or recruit proportions ($U = 8.0$, $p = 1.00$). Each comparison used four stations per region. Because sampling occurred in March in Lembeh and October in Banggai, the observed composition also cannot be attributed to range status alone.

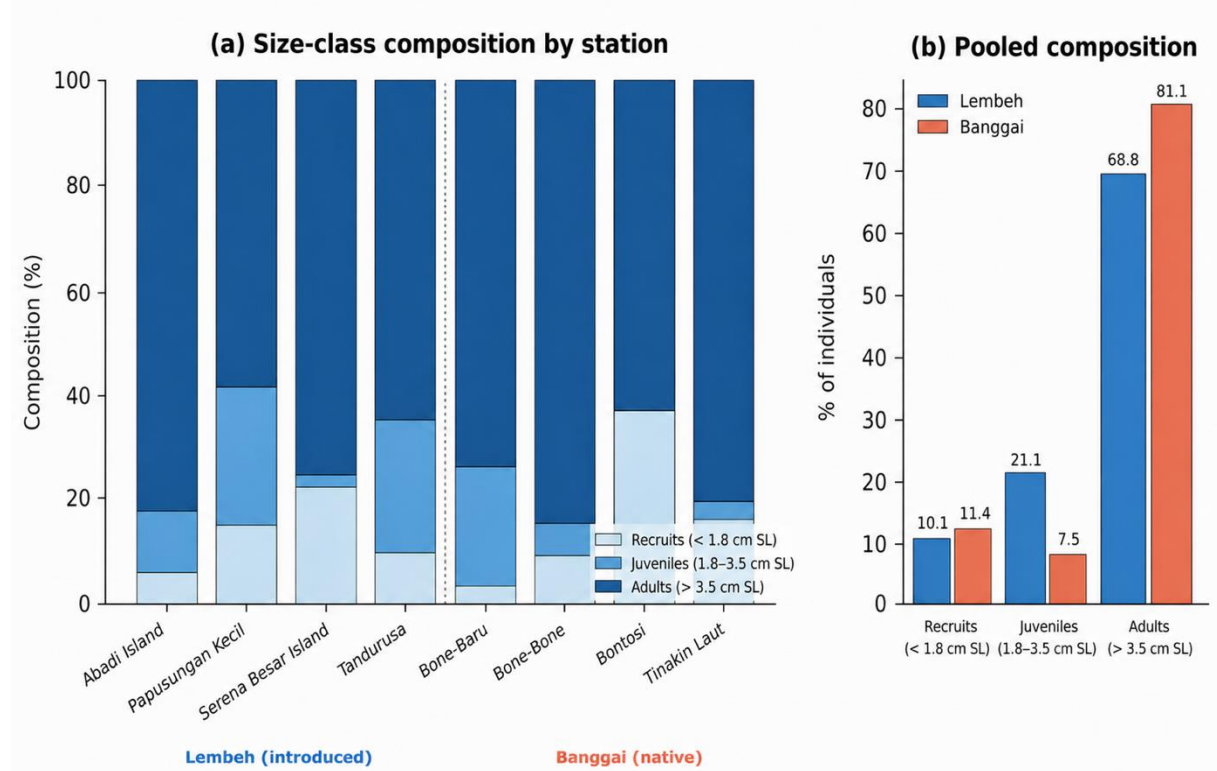


Figure 4. Size structure of *P. kauderni*. (a) Percentage composition of recruits (< 1.8 cm, SL), juveniles (1.8–3.5 cm, SL) and adults (> 3.5 cm, SL) at each station. (b) Descriptive pooled composition in the introduced (Lembeh) and native (Banggai) ranges. Both populations were dominated by adults. Pooled composition is shown for descriptive purposes only and was not used for statistical inference.

Microhabitat use. From the total of 45 colonies, 42 had a recorded microhabitat information (Lembeh, $n = 28$; Banggai, $n = 14$). Coral was the most frequently used microhabitat (present in 61.9% of colonies), closely followed by *Diadema* sea urchins (54.8%), sea anemones (38.1%) and seagrass (14.3%) (Figure 5a). Documented associations involved 3,389 fish with *Diadema* (88.2% of all 3,997 fish), 2,528 with coral (63.2%), 724 with seagrass (18.1%) and 358 with anemones (9.0%). These fish counts overlap across habitats; the percentages use the full survey count, rather than a complete-case fish denominator. Seagrass occurred with 5/14 Banggai colonies (35.7%) and 1/28 Lembeh colonies (3.6%). The exploratory Fisher's exact result for this contrast was $p = 0.011$, but it did not account for colonies being clustered within stations and is not treated as evidence of a general regional effect.

Microhabitat structure was positively related to local abundance. Colony abundance increased with the number of protective microhabitats present (Spearman $\rho = 0.34$, $p = 0.028$), and colonies associated with *Diadema* urchins held significantly more fish

(median 49 individuals) than colonies without urchins (median 12; Mann–Whitney $U = 330.0$, $p = 0.005$; Figure 5b). Recruits, however, made up a larger fraction of fish in colonies without *Diadema* (28.4%) than in colonies with *Diadema* (8.3%): the large urchin and coral-associated aggregations were overwhelmingly adult, whereas anemone and seagrass-associated patches contained proportionally more small individuals, consistent with the species known ontogenetic shift in microhabitat use (though differential detectability of small recruits among microhabitats cannot be excluded).

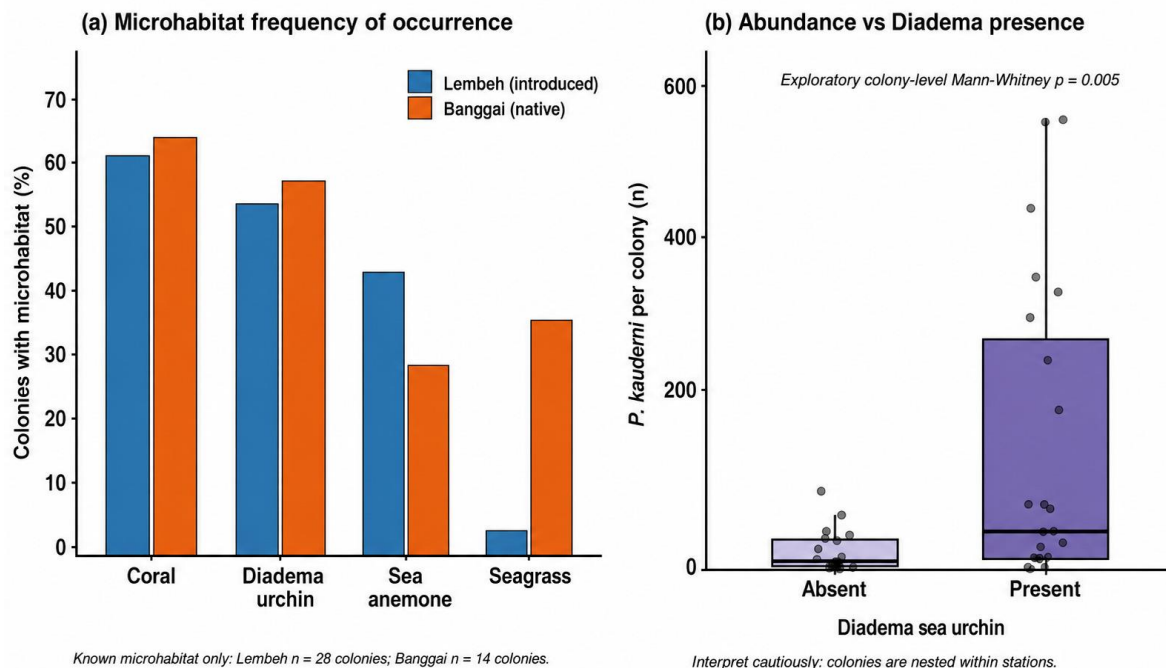


Figure 5. Exploratory microhabitat summaries for *P. kauderni*. (a) Frequency of occurrence (percentage of colonies in which each protective microhabitat was present) in the introduced and native ranges; colonies could use more than one microhabitat). (b) Number of *P. kauderni* per colony in relation to the presence of *Diadema* sea urchins (box = interquartile range, line = median, points = colonies). Colonies with *Diadema* held significantly more fish (Mann–Whitney $p = 0.005$).

Discussion. Based on this study three results stand out: (i) station-scale densities were high but extremely patchy, and did not differ between the native and introduced ranges; (ii) both populations were strongly adult-dominated; and (iii) abundance was tightly coupled to a small set of structural microhabitats, with *Diadema* urchins and branching coral hosting the largest aggregations. The mean density we recorded (2.0 ind m^{-2}) and the wide among-station range ($0.33\text{--}4.57 \text{ ind m}^{-2}$) are consistent with the strongly aggregated, colonial dispersion that characterizes this direct-developing species. Because our transects deliberately targeted shallow microhabitat where the species occurs and integrated several dense colonies along each 50-m belt, station-scale densities are expected to exceed habitat or reef-wide averages reported in broader surveys; reported densities for *P. kauderni* vary over more than two orders of magnitude among sites and studies (from ≈ 0.03 to $> 4 \text{ ind m}^{-2}$; Vagelli & Erdmann, 2002; Ndobe et al., 2013), and our values fall within the upper part of that published range. The absence of a significant density difference between regions despite the very different histories of the two populations indicates that, where suitable microhabitat exists, the introduced Lembeh population attains local densities comparable to those in the native range, underscoring the species capacity to establish and persist outside its natural distribution.

Our density estimates sit within the broader literature once scale is accounted for. Using essentially the same belt-transect design (50-m transects, 2.5 m to either side), Ndobe et al. (2013) reported station densities of $0.31\text{--}2.41 \text{ ind m}^{-2}$ in the Banggai Islands and Palu Bay, almost exactly the range we recorded ($0.33\text{--}4.57 \text{ ind m}^{-2}$), with

our values extending only slightly higher. By contrast, the broad-scale visual censuses of Vagelli & Erdmann (2002) returned a habitat-wide mean of only ≈ 0.03 ind m^{-2} , some two orders of magnitude below our station figures. This gap is expected rather than contradictory: because we deliberately centred transects on occupied microhabitat and integrated several dense colonies per belt, our values index local, colony-scale density rather than reef-wide density, and the two measures should not be equated. Consistent with a colony-based view, the mean group size implied by our data (≈ 80 – 106 fish colony $^{-1}$; overall ≈ 89) exceeds the 21.3 ± 57.2 individuals colony $^{-1}$ reported by Erdmann & Vagelli (2001) but falls well within their observed range (groups of up to 450).

The stronger claim that the introduced Lembeh population now matches native-range densities warrants more caution, because published estimates for this population vary enormously with method and site. In the years just after its discovery, Lembeh was reported at only 0.04 ind m^{-2} (surveyed 2004) and 0.05 ind m^{-2} (surveyed 2007), leading Vagelli (2008) to conclude that it had failed to expand and remained far below the densities of unexploited native populations. Later transect work spans a wide band - ≈ 1.48 ind m^{-2} with 72% adults across 13 Lembeh stations in 2013 (Makatipu et al., 2013), as low as 0.04 ind m^{-2} at some eastern sites (Carlos et al., 2014), and 0.07 – 0.90 ind m^{-2} in 2022 (Huwae et al., 2023), all below our Lembeh mean of 2.40 ind m^{-2} . Much of this scatter is methodological, but the rise from ≈ 0.04 ind m^{-2} in the mid-2000s to ≈ 1.48 ind m^{-2} by 2013 is consistent with real growth of the population, and the high densities we record, mirrored at the introduced Gilimanuk Bay population in Bali up to 2.87 ind m^{-2} (Tambunan et al., 2022), show that established introductions can reach native-range values where microhabitat is suitable. Not every introduction succeeds, however: several restocked sites in Ambon Bay held under 0.5 ind m^{-2} , or had vanished within a few years of release (Wibowo et al., 2019). We therefore endorse the qualitative conclusion that the Lembeh population has persisted and increased, while regarding any strict density equivalence between the two ranges as provisional until both are sampled under an identical design.

The pronounced adult dominance in both regions (73.7% adults) merits careful interpretation. It may reflect genuine demographic structure at the time of sampling, the aggregation of adults around prominent structure, and/or the lower detectability of small recruits that shelter cryptically among urchin spines and anemone tentacles. The proportionally higher representation of juveniles in Lembeh (21.1%) than in Banggai (7.5%) was evident in the pooled data but was not statistically robust at the station level, and the two regions were surveyed in different months (March vs October). Because reproduction and recruitment in *P. kauderni* are continuous but seasonally variable, this seasonal mismatch is a likely contributor to the apparent compositional difference and precludes attributing it to range status. Seasonally matched, repeated surveys would be required to test for genuine demographic differences between native and introduced populations.

The adult-dominated structure is itself corroborated independently: Makatipu et al. (2013) likewise found Lembeh fish to be 72% adults (≥ 3.5 cm), closely matching our Lembeh figure (68.8%). The seasonal reading of the native–introduced contrast, however, is less straightforward than a simple March-versus-October mismatch suggests. Although recruitment is continuous, it peaks in the inter-monsoon lulls, with recruits most often observed between September and December (Vagelli & Volpedo, 2004; Ndobe et al., 2013, 2018). Our Banggai stations were sampled in October, inside this peak, yet held proportionally fewer juveniles than the March-sampled Lembeh stations, the opposite of what a recruitment pulse alone would predict. The lower juvenile fraction in Banggai is therefore unlikely to be a pure sampling-season artefact, and differential detectability of cryptic recruits, density-dependent effects, and true among-region demographic differences all remain plausible. Indeed, post-release survival is reported to fall as adult density rises, through cannibalism (Vagelli & Volpedo, 2004; Ndobe et al., 2018), so the very large, adult-dominated colonies we recorded around *Diadema* and coral may themselves suppress local recruit retention, consistent with our finding that recruits formed a larger share of fish in colonies without *Diadema* (28.4%) than in those with it (8.3%).

The microhabitat results reinforce the well-established dependence of *P. kauderni* on structurally protective biota. Coral and *Diadema* urchins were the most frequently used microhabitats, and the great majority of individuals were associated with urchins. The significantly greater abundance of fish in urchin-associated colonies, and the positive relationship between abundance and the number of protective microhabitats present, are consistent with the hypothesis that structural microhabitats provide important refuge conditions associated with larger local groups. At the same time, recruits were proportionally more frequent in anemone- and seagrass-associated patches than in the large, adult-dominated urchin and coral aggregations, a pattern consistent with the documented ontogenetic shift in which the smallest individuals settle into anemones and urchins before associating more broadly with branching coral and other structure as they grow.

Quantitatively, the dominance of *Diadema* accords closely with prior work. Ndobe et al. (2013) found 71.8% of individuals associated with *Diadema*, then seagrass (11.7%), branching coral (9.5%) and anemones (5.4%), and the IUCN-commissioned review reported that roughly two-thirds of all individuals occur on Diadematidae (Ndobe et al., 2018); our 88.2% of individuals on urchins sits at the high end of this spectrum. An apparent discrepancy, our ranking of coral as the most frequent microhabitat by colony (61.9%) against its small share of individuals in Ndobe et al. (2013) resolves once the two metrics are separated: coral was often present in colonies, but the largest aggregations centred on urchins, so coral ranks high by colony occurrence yet lower by associated abundance, exactly as our parallel reporting of both quantities shows. The recruit-anemone/seagrass association we detected reproduces the ontogenetic shift first quantified by Vagelli (2004), in which recruits occupy seagrass and anemones or anemone-like substrata such as *Heliofungia*, soft corals, and even the jellyfish *Cassiopea* where anemones are scarce (Ndobe et al., 2018), before moving onto coral and urchins as adults. The positive link we found between colony abundance and microhabitat number likewise echoes repeated reports that abundance and age structure track the local availability of *Diadema* and sea anemones (Ndobe et al., 2018). The greater seagrass use in our native range is best read as site-specific variation in habitat configuration rather than a range effect, and reinforces the need to measure microhabitat availability, not merely use, in future work.

From a conservation perspective, our data have several implications. First, they confirm that the persistence of local *P. kauderni* groups is contingent on the availability and condition of a narrow set of microhabitats; degradation or removal of *Diadema* urchins, anemones, branching coral or seagrass would be expected to reduce local carrying capacity directly. Habitat-focused management, protecting these microhabitats and the shallow areas that support them is therefore as important as controlling extraction. Second, the high, native-range-comparable densities of the introduced Lembeh population highlight the dual nature of such populations: they may constitute inadvertent demographic refuges for an endangered species, but they also pose ecological and biosecurity risks (including potential competition, alteration of recipient communities, and translocation of pathogens such as the Banggai cardinalfish iridovirus) and complicate the species' conservation narrative. Decisions about whether to tolerate, manage or remove introduced populations should be informed by monitoring of both their dynamics and their impacts.

Two clarifications sharpen this conservation message. First, the native-range declines that frame concern for the species are well documented: surveys since 2000 report reductions of 36-90% at most sites, and the local extirpation of as many as six populations, against an area of occupancy of only ≈ 20 km² (Kolm & Berglund, 2003; Ndobe et al., 2018). Our standardized density and microhabitat data add a baseline against which such trends can continue to be tracked. Second, the biosecurity risk attributed to introduced populations should be stated precisely. The Banggai cardinalfish iridovirus (a megalocytivirus; Weber et al., 2009) has been detected throughout the ornamental trade chain but, to date, in no wild population, and is thought to be of captive origin (Ndobe et al., 2018). Translocation of this pathogen to wild fish therefore remains a plausible but as-yet-undemonstrated risk rather than a documented impact, a

distinction that matters when weighing whether to tolerate, manage, or remove introduced populations such as that in Lembeh.

Several limitations temper these conclusions. Each region was sampled on a single occasion, with only four stations per region, so statistical power for regional comparisons was low and the seasonal confound is unresolved. Small recruits are likely undercounted. Microhabitat availability was not quantified, so we describe microhabitat use rather than selection. Finally, the demographic and microhabitat records were reconstructed from field tally sheets. We therefore present these results as a robust first baseline rather than a definitive demographic comparison, and recommend that they be extended through seasonally replicated surveys, quantification of microhabitat availability, and georeferenced mapping of colonies.

Conclusions. Belt-transect surveys at eight shallow stations show that *P. kauderni* occurs at high but highly patchy densities (overall mean 2.0 ind m⁻²) in both its native Banggai range and an introduced population in Lembeh Strait, with no significant density difference between them. Both populations were strongly adult-dominated, and local abundance was closely tied to the presence of protective microhabitats, especially *Diadema* sea urchins and branching coral while recruits were relatively more frequent in anemone and seagrass patches. This study emphasizes that conserving *P. kauderni* requires protecting the structural microhabitats on which it depends, and provide a quantitative reference point for monitoring both wild and introduced populations of this endangered, range-restricted species.

Acknowledgements. The authors would like to express their sincere gratitude to Mochtar Djabar, Simon Patti, and Dr. Aser Yalindua for their valuable technical assistance during field data collection. The authors also acknowledge the support of the Government of Banggai Laut, especially the Deputy of Banggai Laut regency, Hablit H. Ilyas, for facilitating the sampling activities of *P. kauderni* within the regency. Their assistance and institutional support were essential to the implementation of the field survey.

Author Contributions. Conceptualization: AI, FYY and PSI; Investigation and field data collection: AI, FYY, PSI, PM and RH; Data curation and analysis: FYY and AI; Original draft and preparation: FYY, AI, PSI, AF and NIU; Writing, review and editing: FYY, AI, PSI, AF, LOA, NIU, WK, JGNN and PKM.

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

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Funding. This research was funded by COREMAP-CTI in 2021 and by the Research Program of the Research Organization for Life Science and Environment (RP-ORHL), National Research and Innovation Agency (BRIN).

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Received: 07 July 2026. Accepted: 24 August 2026. Published online: 07 October 2026.

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How to cite this article:

Yalindua, F. Y., Indrawati, A., Ibrahim, P. S., Makatipu, P., Huwae, R., Faricha, A., Anshari, L. O., Undap, N. I., Koagouw, W., Nusa, J. G. N., & Mantiri, P. K. (2026). Population density, size structure and microhabitat use of the endangered *Pterapogon kauderni* in its native range (Banggai Islands) and introduced population (Lembeh Strait), Sulawesi, Indonesia. *Aquaculture, Aquarium, Conservation & Legislation*, 19(5), 2350-2362.
<https://doi.org/10.67784/1003>