oore_2019_IOP_Conf._Ser.__Earth_Environ._Sci._253_012021.pdf

by

IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Banggai cardinalfish and its microhabitats in a warming world: a preliminary study

To cite this article: A M Moore *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **253** 012021

Banggai cardinalfish and its microhabitats in a warming world: a preliminary study

A M Moore [1], S Ndobe[2], I Yasir [3], R Ambo-Rappe [3] and J Jompa [3]

1 Doctoral Program, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, Makassar 90245, Indonesia
2 Aquaculture Study Program, Faculty of Animal Husbandry and Fisheries, Tadulako University, Palu 94118, Indonesia
3 Marine Science Department, Faculty of Marine Science and Fisheries, Universitas Hasanuddin, Makassar 90245, Indonesia

Email: j.jompa@unhas.ac.id

Abstract. Global changes in the Anthropocene are affecting marine ecosystems in many ways, including alterations in long-established inter-species relationships. The Banggai cardinalfish *Pterapogon kauderni*, a species of global conservation concern, is highly dependent on benthic organisms serving as microhabitat. The objective of this study was to evaluate the effects of global change, in particular rising sea temperature, on *P. kauderni* and three key associated microhabitats: hard corals (Scleractinia), sea urchins (Diadematidae), and sea anemones (Actinia). Data collected before, during, and after the 2016 global coral bleaching event from *P. kauderni* habitat in the Banggai Archipelago, including coral bleaching (by genus) *and P. kauderni* (by life stage) microhabitat association (species or genus, coral life-form), were complemented by a literature review. While coral bleaching and mortality was less severe than in many other regions, hard coral genera and life-forms preferred by *P. kauderni* were disproportionately affected, and *P. kauderni* hosting sea anemones also bleached. Coral, sea urchin and sea anemone reproduction, larval development, and recruitment may be negatively affected. Likely post-settlement effects on sea urchin and sea anemone growth and survival are unclear. Direct impacts on *P. kauderni* are likely, including metabolic rate change with consequences for growth and longevity. Indirect impacts (e.g. changes in plankton composition and abundance, increased storm frequency/severity) will affect *P. kauderni* and all its microhabitats. This evaluation for *P. kauderni*, its key microhabitat groups, and their association, points towards increased need for both conservation action and research to fill identified knowledge gaps.

1. Introduction

Global change in the Anthropocene [1,2] is affecting marine ecosystems in many ways [3], including alterations to sea water physical and chemical properties [4] [5] and even shifts in ocean circulation. Such wide-ranging changes affect ocean productivity [6], species distributions [7,8], and can contribute to defaunation [9], in what has been dubbed the 6th great extinction event [10]. While by no means the only parameter of importance, temperature plays a major role in determining the distribution and health of species, communities, and ecosystems[8,11,12,13]. Furthermore, as observed in terrestrial ecosystem, changes in marine environments are likely to alter or disrupt long-established inter-species relationships [3,14].

One widespread phenomenon of particular concern in equatorial to sub-tropical coastal waters is the increased frequency, severity, and extent of coral bleaching events [15]. Bleaching occurs in Cnidarians, especially scleractinian corals [16], but also sea anemones [17,18,19] when the symbiosis between the host and symbiotic photosynthetic *Symbiodinium* dinoflagellates is disrupted [20,21], with potential negative impacts on associated fish species [17,22,23,24]. The mechanisms and factors affecting temperature-related bleaching are a focus of active research, not least because of the deleterious effect on associated organisms of bleaching-related mortality [13], and the potential for synergy with other impacts of global change [25].

The Banggai cardinalfish *Pterapogon kauderni* is a small marine fish with unusual life history traits [26,27]. Considered at risk of extinction within its extremely limited endemic range [28], *P. kauderni* is highly dependent on benthic organisms serving as microhabitat [29,30]. The objective of this study was to evaluate the effects of global change, in particular the increase in mean sea temperature and increasing frequency and severity of high temperature anomalies, on *P. kauderni* and the three key microhabitats with which this fish associates: hard corals (Scleractinia), sea urchins (Diadematidae), and sea anemones (Actinia).

2. Materials and Methods

2.1. Survey sites and data collection methods

We collected data on coral condition and diversity from 6 sites in the shallow-water (0-5m depth) habitat of *P. kauderni* in the Banggai Archipelago, Central Sulawesi, Indonesia before, during and after the 2016 global coral bleaching event (Table 1, Supplementary Data S1). Using a swim survey method [31], coral colony genus [32], life-form [33] and bleaching status [34], and water temperature were recorded. Data on *P. kauderni* population and microhabitat associations collected within belt transects (20 x 5 m, 100m^2) [31] comprised the number of *P. kauderni* by life stage (based on standard length (SL): recruit: < 18mm SL; juvenile: 18-35 mm SL; sub-adult/adult: > 35mm SL) associated with each microhabitat: hard corals (colony genus [32], life-form [33]); sea urchins and sea anemones (genus, where possible species); and other (lowest possible taxonomic level).

Table 1. Survey sites and scope of survey data

Site		Coordinates (WSG 84)		Swim Survey				Belt Transects	
No.	Name	Latitude S	Longitude E	2014[a]	2016[b]	2017	2018	2017	2018
1	Liang	1°33'03"	123°14'26"	Y	Y	Y		10	
2	Popisi	1°30'27"	123°31'20"	Y	Y	Y		10	
3	Bone Baru	1°31'56"	123°29'27"	Y	Y	Y	Y	10	35
4	Tinakin Laut	1°36'04"	123°29'14"	Y	Y	Y		10	
5	Tolokibit	1°42'48"	123°31'36"	Y	Y		Y	30	37
6	Kapela	1°42'52"	123°34'45"		Y	Y		10	

[a] Some data presented in [35]; [b] Some data presented in [30] and [36]

2.2. Data analysis

We tabulated both primary and secondary data and performed descriptive analyses. Quantitative and graphic analyses were conducted in Microsoft Excel 2010. Our results were compared with and discussed in the context of other research on the taxa and processes involved.

3. Results and Discussion

3.1. P. kauderni microhabitat associations

The microhabitat associations of *P. kauderni* by life stage class (Table 2) strengthen the ontogenetic shift hypothesis [37,38]. A high proportion (93.4%) of *P. kauderni* associated with sea anemones were

IOP Conf. Series: Earth and Environmental Science **253** (2019) 012021 doi:10.1088/1755-1315/253/1/012021

recruits or small juveniles, while 100% of fish associated with scleractinian corals other than *Heliofungia actiniformis* were adult, sub-adult, or large juveniles. All size classes (totalling 65% of all fish surveyed) were associated with Diadematid urchins, mainly of the genus *Diadema* (*D. setosum* and *D savignyi* [39]), as well as *Echinothrix* spp. (tentatively identified as *E calamares and E. diadema*) and *Astropyga* sp. The sea anemones most common as microhabitat for *P. kauderni* recruits and juveniles were *Actinodendron* spp., *Heteractis crispa*, and *Stychodactlya gigantea* (the latter two locally collected for human consumption), followed by *Entacmea quadricolor*. Apart from *Actinodendron* sp., clownfishes (genera *Amphiprion* and *Premnas*) were often observed co-habiting with *P. kauderni* in host anemones. With the exception of two large groups close to *Actinodendron* sp. and *E. quadricolor*, the majority (90%) of adult *P. kauderni* close to anemones (1-3 fish) included a brooding male. This might indicate preparation for release of recruits by the male [40] and possible readiness to prey on the recruits by other adult/sub-adult fish [41].

Table 2. Microhabitat associations of *P. kauderni* by life-stage class (belt transect data 2017-2018)

Microhabitat/Taxon	Life-Form	*P. kauderni* (n)	*P. kauderni* life-stage composition		
			Recruit	Juvenile	Adult
Hard coral (16.8% of total)		1438	4.7%	26.5%	68.8%
Acropora spp.	ACB	1047	0.0%	23.9%	76.1%
Goniopora spp.	CS	113	0.0%	15.9%	84.1%
Stylophora/Seriatopora spp.	CB	101	0.0%	57.4%	42.6%
Heliofungia actin	CMR	75	89.3%	5.3%	5.3%
Other hard corals[a]	CF/CB	102	0.0%	50.0%	50.0%
Diadematidae (65.0% of total)		5566	34.8%	28.7%	36.5%
Diadema spp.	DU	5379	34.4%	29.0%	36.5%
Echinothrix spp.	DU	176	43.2%	19.9%	36.9%
Astropyga sp.	DU	11	72.7%	18.2%	9.1%
Anemones (12.1% of total)		1036	46.3%	47.1%	6.6%
Heteractis crispa	AN	222	73.4%	24.8%	1.8%
Stichodactyla gigantea	AN	126	46.8%	50.0%	3.2%
Entacmea quadricolor	AN	120	59.2%	25.0%	15.8%
Actinodendron spp.	AN	509	34.0%	58.7%	7.3%
Other anemones [b]	AN	59	23.7%	69.5%	6.8%
Other microhabitat (6.1% of total)		522	1.7%	32.4%	65.9%
Dead coral	DC/RKC	73	0.0%	20.5%	79.5%
Other biotic	OT	206	0.0%	48.5%	51.5%
Other abiotic/none	OT/SD	243	3.7%	22.2%	74.1%
Total *P. kauderni* observed		8562	29.1%	30.8%	40.1%

[a] Genera and life-form: *Hydnophora* (CB); *Montipora* (CB/CF); *Porites* (CB); *Goniopora* (CS); *Echinopora horrida* (CB); *Lobophyllia* (CS); and *Millepora* (CME, branching form). [b] *H. magnifica, S. haddoni*

Observed microhabitat associations indicate significant plasticity in *P. kauderni* ontogenetic microhabitat associations, particularly for sub-adult and adult fish. Nonetheless, it is clear that hard corals are an important microhabitat for larger juveniles, sub-adult and adult *P. kauderni*. In 2018, we found strong indications confirming that the increased exploitation of *Diadema* sp., mostly for human consumption, is the main driver of declining urchin populations across much of the *P. kauderni* endemic range [29,30,41]. This decline is arguably increasing the importance of scleractinian corals, at least for larger *P. kauderni* size classes. In addition to impacts on *P. kauderni* populations, especially reproductive success [27,29,40], the decline of these important herbivores may have negative consequences for coral reef resilience [42,43].

3.2. Cnidarian bleaching impacts on P. kauderni habitat and microhabitat

Coral genera and life-forms most commonly used as *P. kauderni* microhabitat were among the taxa most visibly affected by the 2016 bleaching event (Table 3). At each site, some genera recorded in 2014 and or 2016 (mostly taxa severely bleached in 2016 [36]) were less abundant or not found in 2017 and/or 2018, indicating the 2016 bleaching event impacted both coral cover and biodiversity.

Table 3. CoralWatch hard coral colony condition data from *P. kauderni* population sites during the 2016 global coral bleaching event (4 sites)

Site 2016	Micro habitat	Sample (n)	CoralWatch Condition (% of colonies) CW1	CW2	CW3	CW4	CW5	CW6	Sea T° (°C) 2016	Past
Bone Baru	yes	43	18.60	32.56	23.26	16.28	4.65	4.65	31-32	27-30
	no	101	2.97	48.51	29.70	15.84	1.98	0.99		
Kapela	yes	62	14.52	33.87	38.71	9.68	3.23	0.00	31-32	27-31
	no	47	6.38	40.43	31.91	19.15	2.13	0.00		
Tolokibit	yes	65	20.00	44.62	9.23	13.85	12.31	0.00	32-33	28-30
	no	74	9.46	48.65	33.78	4.05	4.05	0.00		
Liang	yes	140	39.29	39.29	17.14	4.29	0.00	0.00	32-33	27-31
	no	150	20.00	46.67	20.67	12.00	0.67	0.00		
Overall (N=682)	yes	310	27.42	38.39	20.65	9.03	3.87	0.65	31-33	27-31
	no	372	12.03	46.52	27.01	12.30	1.87	0.27		

The Acroporidae have been considered especially vulnerable to temperature-related stress and bleaching [44]. While all observed genera within this family were affected, we observed higher bleaching and mortality in the genera *Stylophora* and *Seriatopora* than in *Acropora* and *Pocillopora*. An extreme case was the (possibly temporary) extirpation of *Stylophora* and *Seriatopora* at the Kapela site, where 100% of colonies bleached in 2016 and both genera were absent in 2017. *Porites* showed a life-form related response; in 2016, bleaching was more widespread and severe in colonies with large polyps and branching forms, and many did not survive to 2017 or 2018, while massive or semi-massive colonies seem more resistant and resilient. These results are similar to long term trends reported from the Great Barrier Reef [45]. The data in Table 3 show that the coral genera and life-forms serving as *P. kauderni* microhabitat were disproportionately affected by the 2016 global bleaching event. Furthermore, the possibly transient higher than normal seawater temperatures in 2018 at Tolokibit (32-34°C) affected more potential *P. kauderni* microhabitat than other corals. Bleaching was observed with ≈10% of colonies partly fully bleached (CW1) and around 25% very pale (predominantly CW2). *Acropora*, the surviving branching forms of *Porites*, and the few remaining *Stylophora* colonies were the most commonly affected.

Sea anemones totally or partially bleached inhabited by *P. kauderni*, with or without resident clownfishes, were observed at Bone Baru in 2016, and at Tolokibit in both 2016 and 2018, and at other sites in the Banggai Archipelago [36]. A growing body of research indicates that, while anemone bleaching may have adaptive benefits (through *Symbiodinium* clade shifts [18,46]) for the host anemone, there are negative effects on resident clownfishes [47], in particular in terms of increased metabolic rate [23] and possible disruption of settlement [22]. Such effects might also impact *P. kauderni*, in particular the vulnerable recruit and small juvenile size classes, especially if collection of either host anemones or resident fish occurs [48].

3.3. Observed and anticipated impacts of global change on *P. kauderni* and its microhabitats

Although very little research has been published on the species involved, empirical and experimental research on similar taxa indicates that various aspects of global climate change may have direct or indirect negative impacts on *P. kauderni* and key microhabitats (diadematid sea urchins, sea anemones and corals) at several life-stages (Table 4). Where inference has been drawn from research on other taxa, the substantial differences reported in responses of closely related, even congeneric sympatric species [50], indicate a need for further research at species level, as well as in the context of the symbiotic relations and wider ecosystem concerns relevant to *P. kauderni* conservation.

Table 4. Synopsis of some likely impacts of global change on *P. kauderni* and its microhabitats

Type of change	Type of impact	Likelihood of negative effects[a] BCF	DD	AN	HC	Selected references
Seawater temperature • higher averages, daily minima and maxima • more frequent and longer extremes	Metabolism/physiology/ risk of exceeding thermal tolerance/acclimation capacity/ disruption of symbioses	yes	yes	yes	yes	[3], [5], [8], [11], [17], [21], [22], [23], [49], [50]
	Lower O2 availability	yes	?	?	?	
	Disruption of food chains	yes	yes	yes	yes	
Weather patterns • more frequent/ severe storms • precipitation patterns	Physical damage/mortality	yes[c]	yes[c]	?	yes	[8], [25], [41], [51], [52]
	Elevated risk of predation on/mortality of recruits	yes				
	Water quality: salinity, pH, turbidity, pollution, etc. (direct/indirect on habitat)	yes	yes	yes	yes	
Ocean acidification • lower seawater pH • lower aragonite saturation/other chemical changes	Impaired calcification affecting skeleton growth and/or strength	?	yes	no	yes	[5], [8], [11], [49], [53]
	Lower larval survival/quality and/or settlement/competency	?	yes	?	yes	
Sea surface level rise • increased depth • changing coastlines	Reduction in habitat: seagrass meadows, coral reefs, mangroves[b] (drowning and coastal squeeze)	yes	yes	yes	likely	[8], [51], [52]

[a] BCF = *P. kauderni*; DD = Diadematidae; AN = sea anemones; HC = scleractinian corals
[b] Some large *P. kauderni* populations inhabit *Rhizophora* spp. prop roots on shallow sandbars [26], [27]
[c] Moore, unpublished data, 2018. *Diadema* and some *P. kauderni* thrown ashore during a storm in early 2018

Despite the observed bleaching and likelihood of growing impacts from global change, overexploitation and direct anthropogenic damage are currently the main immediate causes of *P. kauderni* habitat/microhabitat degradation [30]. The majority of observed coral degradation (dead and/or broken corals) between 2016 and 2017/2018 was not due to coral bleaching. At Bone Baru, widespread destruction was caused by an increase in destructive fishing, mainly overturning and other physical damage during collection of abalone (*Haliotis* sp.), gleaning and spearfishing. At Tolokibit, an *Acanthaster planci* outbreak (noted in 2017) was a major cause of coral death, along with damage from gleaning at spring low tides. The exploitation of *Diadema* and *Tripneustes* urchins at Tolokibit was no longer subsistence gleaning, but a commercial activity with truckloads collected once or twice a month and sold at IDR 15,000 (just over US$1) for ten urchins.

3.4. Outlook and future research directions

Our study indicates that, while local anthropogenic activities pose an immediate threat, the future will bring increasingly complex challenges for the holistic and sustainable management of *P. kauderni*, its habitat and microhabitats. Local and global drivers are likely to act synergistically, reducing the chances of *P. kauderni* habitat and population rehabilitation or recovery through natural microhabitat recruitment processes. Further research on the scale and synergies between stressors is required to better understand and mitigate or adapt to global change. Actions to reduce or eliminate major threats, in particular those related to unregulated, unreported and destructive (over) fishing of shallow-water marine invertebrates are both possible and potentially aligned with current government policy [54]. While such measures are vital, effective climate change mitigation at all levels, further identification and sound, science-based approaches to local mitigation of the already unavoidable impacts of global change on the Banggai cardinalfish and its microhabitats are likely necessary to ensure the long-term future of this iconic species in its native range.

Acknowledgments

The authors acknowledge support under an Indonesian Ministry of Research and Higher Education Pascadoktor grant awarded to S. Ndobe and J. Jompa in 2017 and 2018 (grants 703.b/UN28.2/PL/2017 and 285.a/UN28.2/PL/2018). The authors wish to thank all colleagues and stakeholders involved in the surveys and all who in any way helped in the processes enabling the writing, improvement, and publishing of this manuscript.

References

[1] Zalasiewicz J, Williams M, Haywood A and Ellis M 2011 The Anthropocene: a new epoch of geological time? *Philos. Trans. R. Soc. A: Math. Phys. Eng. Sci.* **369** 835–841

[2] Ellis E C 2011 Anthropogenic transformation of the terrestrial biosphere *Phil. Trans. R. Soc. A: Math. Phys. Eng. Sci.* **369** 1010–1035

[3] Doney S C, Ruckelshaus M, Duffy E J, Barry J P *et al* 2012 Climate change impacts on marine ecosystems *Ann. Rev. Mar. Sci.* **4** 11–37

[4] Tyrrell T 2011 Anthropogenic modification of the oceans *Philos. Trans. R. Soc. A: Math Phys. Eng. Sci.* **369** 887–908

[5] Doney S C, Fabry V J, Feely R A and Kleypas J A 2009 Ocean acidification: The other CO_2 Problem *Ann. Rev. Mar. Sci.* **1** 169–192

[6] [6] Riebesell U 2004 Effects of CO_2 enrichment on marine phytsplankton *J. Oceanogr.* **60** 719–729

[7] Molinos J G, Burrows M T and Poloczanska E S 2017 Ocean currents modify the coupling between climate change and biogeographical shifts *Sci. Rep.* **7** 1–9

[8] Przeslawski R, Ahyong S, Byrne M, Worheide G and Hutchings P 2008 Beyond corals and fish: The effects of climate change on noncoral benthic invertebrates of tropical reefs *Glob. Chang. Biol.* **14** 2773–2795

[9] Jackson J B C Ecological extinction and evolution in the brave new ocean 2008 *Proc. Natl. Acad. Sci.* **105** 11458–11465

[10] Braje T J and Erlandson J M 2013 Human acceleration of animal and plant extinctions: A late pleistocene, holocene, and anthropocene continuum *Anthropocene* **4** 14–23

[11] Byrne M 2011 Impact of ocean warming and ocean acidification on marine invertebrate life history stages: Vulnerabilities and potential for persistence in a changing ocean *Oceanogr. Mar. Biol. Annu. Rev.* **49** 1–42

[12] Cheung W W L, Watson R and Pauly D 2013 Signature of ocean warming in global fisheries catch *Nature* **497** 365–368

[13] Hoey A S, Howells E, Johansen J L, Hobbs Jean-Paul A *et al* 2016 Recent advances in understanding the effects of climate change on coral reefs *Diversity* **8** 1–22

[14] Cheung W W L, Lam V W Y, Sarmiento J L, Kearney K *et al* 2009 Projecting global marine

biodiversity impacts under climate change scenarios *Fish Fish.* **10** 235–251, 2009.
[15] Hughes T P, Anderson K D, Connolly S R, Heron S F *et al* 2018 Spatial and temporal patterns of mass bleaching of corals in the Anthropocene *Science* **359** 80–83
[16] Hughes T P and Kerry J T 2017 Global warming and recurrent mass bleaching of corals *Nature* **543** 373–378
[17] Steinberg R, van der Meer M, Walker E, Berumen M L *et al* 2016 Genetic connectivity and self-replenishment of inshore and offshore populations of the endemic anemonefish *Amphiprion latezonatus Coral Reefs* **35** 959–970
[18] Hill R, Fernance C, Wilkinson S P, Davy S K and Scott A 2014 Symbiont shuffling during thermal bleaching and recovery in the sea anemone *Entacmaea quadricolor Mar. Biol.* **161** 2931-2937
[19] Hobbs J A, Frisch A J, Ford B M, Thums M *et al* 2013 Taxonomic, spatial and temporal patterns of bleaching in anemones inhabited by anemonefishes *PLoS One* **8** e70966
[20] Weis V M Cellular mechanisms of Cnidarian bleaching: stress causes the collapse of symbiosis 2008 *J. Exp. Biol.* **211** 3059–3066
[21] Hillyer K E, Dias D A, Lutz A, Wilkinson S P *et al* 2017 Metabolite profiling of symbiont and host during thermal stress and bleaching in the coral *Acropora aspera Coral Reefs* **36** 105-118
[22] Scott A and Dixson D L 2016 Reef fishes can recognize bleached habitat during settlement: sea anemone bleaching alters anemonefish host selection *Proc. R. Soc. B: Biol. Sci.* **283** 1–7
[23] Norin T, Mills S C, Crespel A, Cortese D *et al* 2018 Anemone bleaching increases the metabolic demands of symbiont anemonefish *Proc. R. Soc. B: Biol. Sci.* **285** 1-6
[24] Pratchett M, Hoey A, Coker D and Gardiner N 2012 Interdependence between reef fishes and scleractinian corals in *Proceedings of the 12th International Coral Reef Symposium* 13C 1–5
[25] Hoegh-guldberg O, Poloczanska E S, Skirving W and Dove S 2017 Coral reef ecosystems under climate change and ocean acidification *Front. Mar. Sci.* **4** 1–20
[26] Ndobe S, Soemarno, Herawati E Y, Setyohadi D *et al* 2013 Life History of Banggai Cardinalfish, *Pterapogon Kauderni* (Actinopterygii: Perciformes: Apogonidae), from Banggai Islands and Palu Bay, Sulawesi, Indonesia *Acta Ichthyol. Piscat.* **43** 237–250
[27] Vagelli A A 2011 *The Banggai Cardinalfish: Natural History, Conservation, and Culture of Pterapogon kauderni* (Chichester UK: John Wiley & Sons, Ltd.)
[28] Allen G R and Donaldson T J 2007 *Pterapogon kauderni The IUCN Red List of Threatened Species* (http://dx.doi.org/10.2305/IUCN.UK.2007.RLTS.T63572A12692964.en.)
[29] Moore A, Ndobe S, Salanggon A-I, Ederyan and Rahman A 2012 Banggai cardinalfish ornamental fishery: the importance of microhabitat *Proc.12th Int. Coral Reef Symp. (Cairns, Australia* p. 13C)
[30] Ndobe S, Moore A M and Jompa J 2017 Status of and threats to microhabitats of the endangered endemic Banggai Cardinalfish *Pterapogon kauderni Coast. Ocean. J.* **1** 73–82
[31] Hill J and Wilkinson 2004 C *Methods for Ecological Monitoring of Coral Reefs* (Townsville: Australian Institute of Marine Science)
[32] [32] Kelley R 2011 *Indo-Pacific CoralFinder*, 2nd ed. (Townsville: BYOGUIDES)
[33] English S S, Wilkinson C C and Baker V V 1997 *Survey manual for tropical marine resources* (Townsville: Australian Institute of Marine Science)
[34] [34] Coral Watch 2011 *Coral Watch Do It Yourself Kit* (Brisbane: University of Queensland)
[35] Ndobe S and Moore A 2015 Penggunaan metode Indo-Pacific Coral Finder untuk mengetahui biodiversitas karang di Kepulauan Banggai *Prosiding Simposium Nasional Kelautan dan Perikanan Makassar* 95–103.
[36] Moore A M, Ndobe S and Jompa J 2017 Fingerprints of the Anthropocene: the 2016 Coral Bleaching Event in an Equatorial Archipelago *Proc. 4th Int. Mar. Fish. Symp.* 66–86
[37] Vagelli A A 2004 Ontogenetic shift in habitat preference by *Pterapogon kauderni* a shallow water coral reef apogonid with direct development *Copeia* **2004** 364–369

[38] Ndobe S, Madinawati and Moore A 2008 Pengkajian ontogenetic shift pada ikan endemik *Pterapogon kauderni J. Mitra Bahari* **2** 32–55
[39] Ndobe S, Moore A and Jompa J A 2018 Tale of two Urchins - Implications for *In-Situ* breeding of the endangered banggai cardinalfish (*Pterapogon kauderni*) *Aquacultura Indonesiana* **19** 65-75
[40] Ndobe S, Widiastuti I and Moore A 2013 Sex ratio dan pemangsaan terhadap rekrut pada ikan hias Banggai cardinalfish *Pterapogon kauderni* in *Prosiding Konferensi Akuakultur Indonesia* 9–20
[41] Moore A, Ndobe S and Zamrud M 2011 Monitoring the banggai cardinalfish, an endangered restricted range endemic species *J. Indonesia Coral Reefs* **1** 99–113
[42] Carpenter R C and Edmunds P J 2006 Local and regional scale recovery of *Diadema* promotes recruitment of scleractinian corals *Ecol. Lett.* **9** 268–277
[43] Mumby P J, Hedley J D, Zychaluk K, Harborne A R and Blackwell P G 2006 Revisiting the catastrophic die-off of the urchin *Diadema antillarum* on Caribbean coral reefs: Fresh insights on resilience from a simulation model *Ecol. Modell.* **196** 131–148
[44] Marshall P A and Baird A H 2000 Bleaching of corals on the Great Barrier Reef: Differential susceptibilities among taxa *Coral Reefs* **19** 155–163
[45] van Woesik R, Sakai K, Ganase A and Loya Y 2011 Revisiting the winners and the losers a decade after coral bleaching *Mar. Ecol. Prog. Ser.* **434** 67–76
[46] Venn A A, Loram J E, Trapido-Rosenthal H G, Joyce D A and Douglas A E 2008 Importance of time and place: Patterns in abundance of *Symbiodinium* clades A and B in the tropical sea anemone *Condylactis gigantea Biol. Bull.* **215** 243–252
[47] Jones A M, Gardner S and Sinclair W 2008 Losing 'Nemo': bleaching and collection appear to reduce inshore populations of anemonefishes *J. Fish. Biol.* **73** 753–761
[48] Jones A M 2012 Does collecting inhibit the recovery of anemone and anemonefish populations after bleaching? *Proc.12th Int. Coral Reef Symp.* **16A** 1-5
[49] Hardy N A and Byrne M 2014 Early development of congeneric sea urchins *Heliocidaris* with contrasting life history modes in a warming and high CO_2 ocean *Mar. Environ. Res.* **102** 78–87
[50] Eme J and Bennett W 2009 ACritical thermal tolerance polygons of tropical marine fishes from Sulawesi Indonesia *J. Therm. Biol.* **34** 220–225
[51] Hoegh-Guldberg O, Hoegh-Guldberg H, Veron J E N, Green A *et al* 2009 *The Coral Triangle and Climate Change: Ecosystems People and Societies at Risk* (Brisbane: Project Report WWF Australia)
[52] Waycott M 2011 *Vulnerability of Mangroves Seagrasses and Intertidal Flats in the Tropical Pacific to Climate Change* (Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change) eds J D Bell, J E Johnson and A J Hobday (Noumea: Secretariat of the Pacific Community 297–368)
[53] Munday P L, Dixson D L, Mccormick M I, Meekan M *et al* 2010 Replenishment of fish populations is threatened by ocean acidification *Proc. Natl. Acad. Sci. USA.* **107** 12930–12934
[54] Moore A M, Ndobe S and Jompa J 2017 A site-based conservation approach to promote the recovery of Banggai cardinalfish *Pterapogon kauderni* endemic populations *Coast. Ocean. J.* **1** 63-72

oore_2019_IOP_Conf._Ser.__Earth_Environ._Sci._253_01202..

ORIGINALITY REPORT

%11	%10	%8	%6
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	N Pompon, S Ndobe, K Mansyur, M Tis'in. " Growth and survival of juvenile Banggai cardinalfish ( ) reared under different salinities in recirculating aquaria equipped with protein skimmers ", IOP Conference Series: Earth and Environmental Science, 2019 Publication	%3
2	repository.tudelft.nl Internet Source	%2
3	A Moore, S Ndobe, R Ambo-Rappe, J Jompa, I Yasir. " Dietary preference of key microhabitat : a step towards holistic Banggai cardinalfish conservation ", IOP Conference Series: Earth and Environmental Science, 2019 Publication	%1
4	cites.org Internet Source	%1
5	scholarbank.nus.edu.sg Internet Source	%1

pertambangan.fst.uinjkt.ac.id

6	Internet Source	<%1
7	www.science.gov Internet Source	<%1
8	www.icrs2012.com Internet Source	<%1
9	Submitted to American Public University System Student Paper	<%1
10	heartland.org Internet Source	<%1
11	aquasiana.org Internet Source	<%1
12	onlinelibrary.wiley.com Internet Source	<%1
13	Bonin, Mary C., Hugo B. Harrison, David H. Williamson, Ashley J. Frisch, Pablo Saenz-Agudelo, Michael L. Berumen, and Geoffrey P. Jones. "The role of marine reserves in the replenishment of a locally-impacted population of anemonefish on the Great Barrier Reef", Molecular Ecology, 2015. Publication	<%1
14	Submitted to University of Exeter Student Paper	<%1

15	www.fao.org Internet Source	<%1
16	www.ianas.org Internet Source	<%1
17	vdocuments.site Internet Source	<%1
18	espace.library.uq.edu.au Internet Source	<%1
19	"Coral Bleaching", Springer Nature, 2018 Publication	<%1

EXCLUDE QUOTES ON

EXCLUDE BIBLIOGRAPHY ON

EXCLUDE MATCHES < 5 WORDS