Banggai cardinalfish conservation: priorities, opportunities, and risks

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Abstract. Human actions are undoubtedly the major factor affecting the biosphere in this Anthropocene era, making it vital to involve all levels of society in the stewardship of natural resources, in particular marine ecosystems and biodiversity. The Banggai cardinalfish *Pterapogon kauderni* is a unique species at risk of extinction and an object of global conservation concern. The endemic range of *P. kauderni* is limited to around 500km2, mostly in the Banggai Archipelago, Central Sulawesi, Indonesia. The objective of this study was to evaluate the priorities for *P. kauderni* conservation, with a focus on the recently declared Banggai Dalaka MPA, the National Plan of Action (NPOA-BCF) and the decisions taken at CITES CoP 17 in 2016. Risks identified include the loss of genetic diversity and structure, serial depletion of populations/stocks, loss of identity ("branding" issues), local threats to habitat/microhabitat, and the impacts of global change. Opportunities include local, national and international awareness, the CITES Animal Commission processes, iconic status, and stakeholder capacity. Key priorities identified included: (i) prioritise endemic (not introduced) *P. kauderni* populations; (ii) protect genetic diversity through site/stock-based management (conservation, ornamental fishery, monitoring), initiated using existing genetic population structure data, while seeking to develop a database of genetically unique (reproductively isolated) stocks; (iii) protect and rehabilitate *P. kauderni* habitat and microhabitat (especially *Diadema* urchins and sea anemones) within the Banggai Dalaka MPA; (iv) investigate, record (and where necessary restrict) in-country movements of *P. kauderni*, especially removal from the endemic range (e.g. currently unrecorded shipping to Kendari), as well as export and international movements; (v) regulate and restrict the release of *P. kauderni* to the wild from captivity and/or between known/suspected genetic stocks; (vi) institutionalisation at multiple levels in a holistic socio-ecological context to provide robust and resilient conservation management and capitalise on the "flagship species" potential of the Banggai cardinalfish.

1. Introduction

Human actions are undoubtedly the major factor affecting the biosphere in this Anthropocene Epoch [1,2] threatening the life-support system on which we, as a species, depend [2,3]. In addition to the many direct impacts often clearly visible to stakeholders at the local level, the so-called indirect impacts generated by the cumulative actions of people around the world are increasingly evident at all scales from the molecular level to the planetary scale, from the deepest ocean trenches to the outer

reaches of our atmosphere, and we are now facing multiple crises at local to global levels. Of the nine "planetary boundaries", within which it is proposed that a "safe operating space for humanity" might be found, "biosphere integrity" is in the "red" (high risk) zone [4], and many consider that the sixth mass extinction is now underway, in both terrestrial and marine biomes [5]. Indeed In view of the complexity and pervasiveness of the problems faced, it is vital to involve all levels of society in the stewardship of natural resources, in particular marine ecosystems and biodiversity.

The seas around Sulawesi and its satellite archipelagos are recognised for their high biodiversity, resulting from the complex interweaving of tectonic history and biological evolutionary processes; however the species and ecosystems of this unique region are under threat from increasing local pressures as well as global trends [6]. The Banggai Archipelago east of Sulawesi is a case in point. Home to the endemic Banggai cardinalfish (*Pterapogon kauderni* Koumans 1933), much of the archipelago is now within the recently declared Banggai Dalaka provincial level MPA, spanning three districts (Banggai, Banggai Kepulauan and Banggai Laut). Encompassing at least 90% of the *P. kauderni* endemic (native) distribution and populations [7], this MPA has four main conservation targets: tropical coastal ecosystems (coral reefs, seagrass beds, mangrove forests); *P. kauderni* populations and habitat; other protected/priority conservation species; and fisheries resources (finfish and invertebrates).

Considered at risk of extinction [8], *P. kauderni* has become an object of local, national, and global conservation concern [9,10]. In 2016, the second proposal for listing *P. kauderni* in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix II resulted in several decisions (17_259 to 17_263) at the 17th CITES Conference of Parties (CoP 17) (https://www.cites.org/eng/dec/valid17/81887). In brief, the decisions task Indonesia with implementing conservation and management measures to ensure the sustainability of international trade in *Pterapogon kauderni*. Progress should be reported to the Animals Committee at specific intervals, and all CITES parties and other relevant organisations are encouraged to assist Indonesia.

Indonesia has taken several actions including the compilation of a National Plan of Action (NPOA-BCF), the implementation of which relies heavily on appropriate and effective management of the Banggai Dalaka MPA, which is still in the planning stage. One outcome of the decisions was the commissioning of a study by the CITES Secretariat through the IUCN in May-July 2018, prior to the 30th CITES Animal Commission meeting in 2018. The objective of this study [11] was to evaluate the priorities for *P. kauderni* conservation, with a focus on the recently declared Banggai Dalaka MPA, the National Plan of Action (NPOA-BCF) and the decisions taken at CITES CoP 17 in 2016.

Conservation of the Banggai cardinalfish should be grounded in sound science, taking into account existing conditions; in particular, the current status of *P. kauderni* populations and trade as well as knowledge regarding the biology and ecology of this species, its symbionts and habitat. Furthermore in this Anthropocene Epoch, it is vital to consider the likely short and long-term impacts of global change on this species. In this context it is considered important to evaluate the priorities for effective conservation of the Banggai cardinalfish and its habitat, from local, national and global perspectives. Opportunities and risks need to be identified, including those which may be time-bound, for example due to national governance cycles as well as the CITES processes.

2. Methods

This study was based largely on secondary data (published as well as so-called "grey literature") on the current condition of endemic *P. kauderni* populations and habitat, past and current management initiatives for this species and it's habitat in the Banggai Archipelago, Central Sulawesi, Indonesia. Data on the movement (trade) of *P. kauderni* were sourced from the Indonesian Fish Health and Quarantine Service on-line database (http://bkipm.kkp.go.id/bkipmnew/?r=stats/). Also included in the analysis were unpublished (primary) data collected during field surveys in the Banggai Archipelago and during a study commissioned by the IUCN to support implementation of CITES CoP 17 Decisions 17.259-17.263, as well as preliminary (qualitative) results from an experimental study on the effects of rising sea temperatures on *P. kauderni* and *Diadema* urchins. Data were analysed descriptively to

identify key priorities, opportunities and risks in the context of *P. kauderni* conservation.

3. Results and Discussion

3.1. Current status of Pterapogon kauderni population and ESUs

There is overwhelming evidence that *Pterapogon kauderni* populations have declined substantially since the species was "rediscovered" in the mid-1990's [7,11,12]. Furthermore, there is evidence for at least two cases where populations have been extirpated [7,11,13]. The most recent survey in 2017 found extremely low *P. kauderni* densities at four sites, with at least one (Mandel) considered at risk of extirpation; furthermore, there was a low percentage of juvenile fish at 14 out of 24 sites [11]. The fine scale genetic population structure of *P. kauderni* [14,15] makes the Evolutionarily Significant Unit concept [16] especially relevant at a sub-species level for this species. Existing genetic and morphometric data [14,15,17,18,19] indicate that each small island with a *P. kauderni* population is a separate ESU; meanwhile the larger islands appear to host several *P. kauderni* ESUs, as several apparently reproductively isolated populations (stocks) have been identified, separated by as little as 2 km. At least 21 ESU's are supported by existing genetic data, while a similar or greater number of unidentified ESUs are suspected. Of these 21 ESUs, 18 are within the Banggai Archipelago, although one is just outside the Banggai Dalaka MPA (Figure 1), and 3 are on small islands further east, off the coast of Taliabu Island.

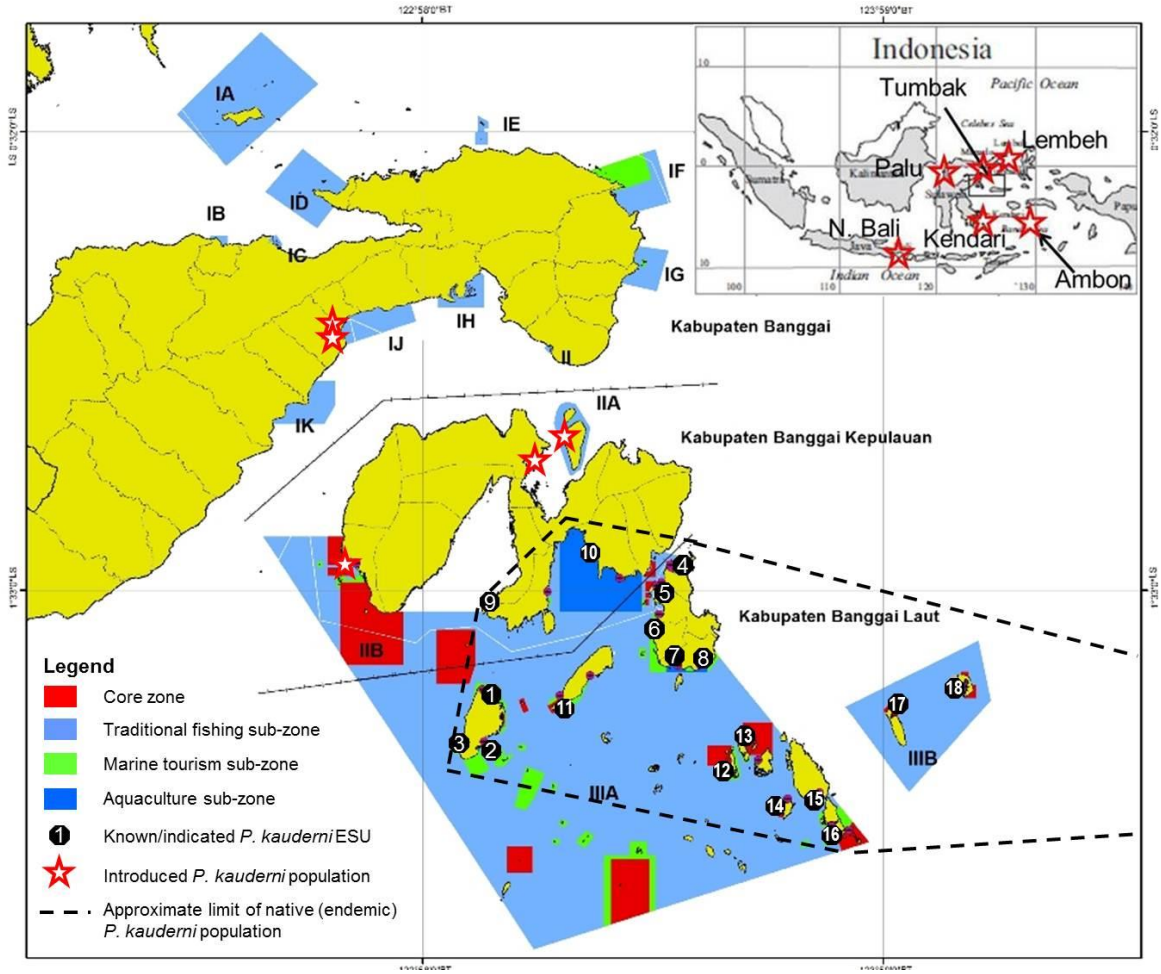

Figure 1. *Pterapogon kauderni* endemic distribution and introduced populations within the Banggai Dalaka MPA, showing ESUs supported by existing genetic population structure data

The situation with respect to the genetic diversity and structure of *P. kauderni* has been further complicated by the capture and subsequent release of *P. kauderni* both within and outside of the endemic (native) distribution. The former has resulted in the mixing of genetic strains, some thought to have been isolated reproductively for around 100,000 years or more [15], while the latter has led to the establishment of introduced populations (Figure 1) within the Banggai region at other sites in Sulawesi, and across the Indonesian Archipelago [11,13,14,20,21,22,23,24]. While early introductions were mostly in connection with the *P. kauderni* ornamental fishery and trade, more recent introductions have occurred under Government programs, including the intentional release of *P. kauderni* at a second site in Luwuk (called Kilo 5) in 2017 and 2018.

3.1.1. Pterapogon kauderni habitat and microhabitat. Pterapogon kauderni habitat within the native distribution (Figure 1) is limited to shallow waters (mostly 0.5-5m depth) including coral reefs/reef flats, seagrass beds, some mangrove (*Rhizophora* sp.) stands, and lagoons [7,8,11,12,20], with an estimated total extent of less than 30 km2 [7]. Within these habitats, *P. kauderni* is highly dependent on symbiotic relationships with a range of protective microhabitats, especially for reproductive success [7,25,26]. The shallow-water habitat of *P. kauderni* is typically subject to threats from intensive human activity, resulting in environmental degradation [14,27]. Key *P. kauderni* microhabitats are also under increasing pressure, with declining population trends observed in Diadematid sea urchins (primarily the genus *Diadema*) and sea anemones as well as suitable hard coral life-forms at a majority of sites surveyed since 2004 [12,13, 25,27,28]. While the main cause of *Diadema* and sea anemone population decline is a sharp increase in harvesting since around 2007, the drivers of hard coral degradation include all the commonly reported threats to corals in this region. The harvest of a wide variety of shallow-water marine invertebrates (mostly through gleaning) is pervasive throughout the region, but is rarely (if ever) reported in any statistics and has received very little attention compared to fin-fish fisheries. In the past, such activities were generally for subsistence, limited in terms of the number of people involved, and often seasonal [20]. The increase in scale and shift towards commercial exploitation (e.g. large-scale bi-monthly collection and sale of *Diadema* at Tolokibit) now appear to pose a real threat to *P. kauderni* populations and indeed to the integrity of coastal ecosystems. An overview of trends at 10 *P. kauderni* sites monitored in 2011/2012 [13] and in 2017/2018 (this study) is shown in Table 1. In the case of *Diadema* microhabitat, declining trends were observed in both abundance and average size (test diameter), with predominantly juvenile individuals remaining at several sites in 2017 and 2018.

Table 1. Trends in *P. kauderni* habitat (ecosystem) and microhabitat at 10 sites

No.	Survey Site: Name	Typology	Exposure	Ecosystem: Main type[a]	Ecosystem: Extent (trend)	Habitat Condition 2011/2012: State	Habitat Condition 2011/2012: Trend[b]	Habitat Condition 2017/2018: Trend[c]	Micro-habitat trend
1	Popisi	bay	protected	RF/SG	stable	poor-average	decline	decline	decline
				CR	decline	average	unknown	phase shift to seagrass	sharp decline
2	Bone Baru	bay	semi-open	RF/SG	decline	average	decline[d]		decline
3	Tinakin Laut	strait	protected	RF/SG	decline	poor	decline	stable	fluctuating [d]
4	Monsongan	bay	semi-open	CR/RF	decline	average	stable	decline	decline [d]
5	Tolokibit	bay	protected	RF/SG	stable	poor-average	decline	decline	sharp decline [d]
6	Toropot	bay/lagoon	protected	SG/RF	decline	poor-average	decline	stable	some recovery
7	Kombongan	bay	protected	RF	stable	poor-good	unknown	stable	no clear trend
8	Tanjung Nggasuang	lagoon	protected	CR/RF/ SG	decline	severely degraded	sharp decline	some recovery	some recovery
9	Toado	shoal	protected	MG	stable	good	unknown	stable	no clear trend
10	Liang	bay	protected	CR/SG	stable	poor	decline	decline	sharp decline [d]

[a] CR – coral reef (crest/upper slope); RF = reef flat; SG = seagrass; MG = mangroves (dominated by *Rhizophora* sp.)
[b] Comparison with 2004-2007 data, adapted from [13]; [c] Primary data 2017-2018, compared to 2011/2012 data
[d] *Diadema* populations dominated by small (presumed mostly juvenile) individuals of less than 3 m test diameter

3.1.2. Pterapogon kauderni trade. There is a broad consensus that the trade in P. kauderni has not been managed sustainably [7,11]. A study on the population dynamics of P. kauderni estimated an exploitation rate E of 0.5 [12], well above the range recommended for such species. After the first proposal for listing P. kauderni under CITES Appendix II in 2007, a number of measures were implemented which had some success in reducing the volume and the impacts of the trade [29]. However at the end of the first NPOA (2007-2012) there was no statutory protection or other regulation in place [10,13]. The shift in jurisdiction over waters 0-4 nm from the coastline (from District to Provincial level) under the new regional autonomy law in 2014 (UU 23/2014) has been a major factor driving an increase in many illegal and often destructive practices over the past four years [10,11,27]. By 2017, both informal instruments (e.g. the community MPA in Bone Baru) as well as formal fisheries management (e.g. routine patrols) in place before 2014 had, to all practical intents and purposes, ceased to function. Meanwhile, as of the time of writing, the Banggai Dalaka MPA is not yet operational.

One regulatory instrument currently functioning is the statutory obligation to report inter-regional movement of fish and fisheries products to the Fish Health and Quarantine Service. There has been a marked and sustained improvement in reporting of ornamental fish consignments to the Luwuk Fish Quarantine, which has a branch office in the town of Banggai. The volume of consignments from Luwuk represents the legal trade volume in *P. kauderni* from the Banggai Archipelago (i.e. from the native/endemic distribution). However, these data do not represent all, or even the majority, of fish leaving the Archipelago. Analysis of data from the national Fish Health and Quarantine database on the (reported) movement of commodities between jurisdictions within Indonesia for the period from 2008 (when records began) to May 2018 (Figure 2) has revealed a major and hitherto unsuspected shift in the *P. kauderni* trade since 2014. It also shows a mismatch between recorded dispatches and arrivals, with no record of the arrival of the majority (50-90%) of fish dispatched between 2015 and May 2018.

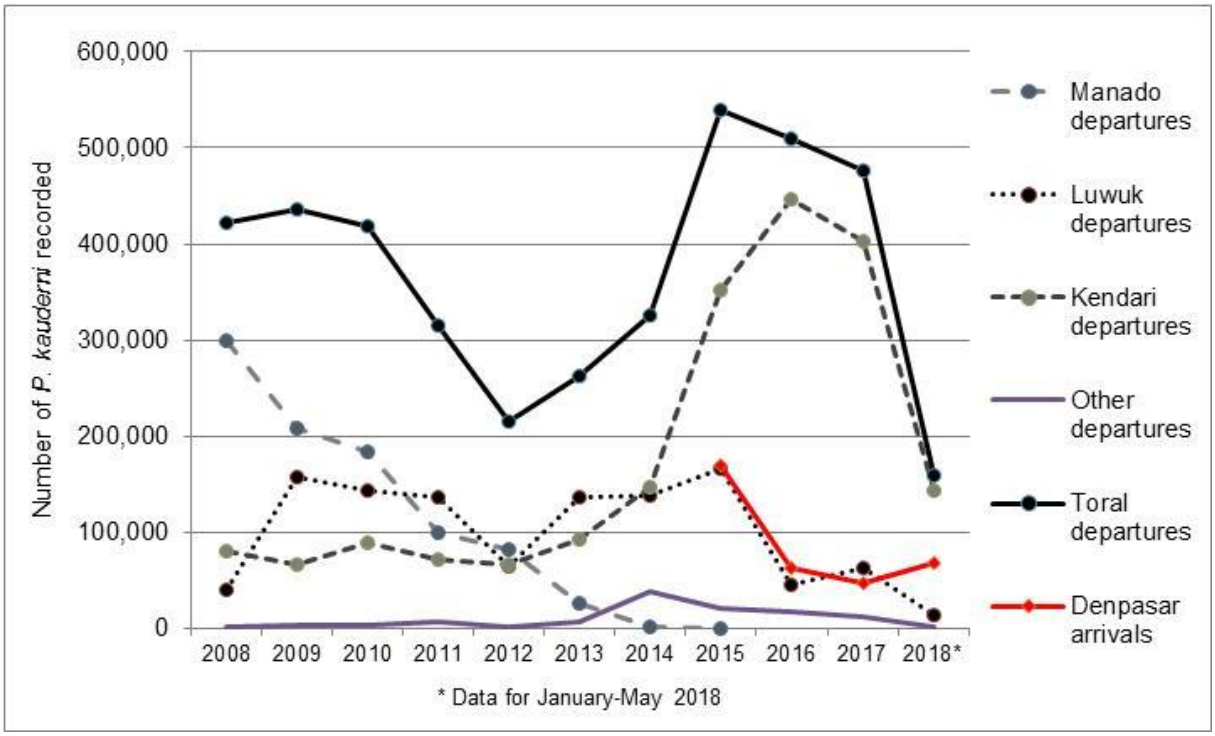

Figure 2. Recorded volume of *P. kauderni* dispatched to ornamental fish export centres (primarily Denpasar; less than 20% to other destinations) from 2008 to May 2018 and recorded arrivals in Denpasar from 2015 to May 2018 (Data source: http://bkipm.kkp.go.id/bkipmnew/?r=stats/)

Ornamental fish collected in the Banggai Archipelago are typically destined for major export trade centres, with Denpasar consistently the main point of export, followed by Jakarta and Surabaya. From the beginning of the trade up to the early 2000's, the majority of *P. kauderni* traded were collected by Bajo fishermen from Tumbak, working with local fishermen in the Banggai Archipelago, transported by sea to Tumbak in wooden boats, and then carried overland to Manado; the remainder were mostly collected and/or transported by ornamental fishing boats from Bali and Banyuwangi [20]. By 2008, three routes from shared most of the trade, with almost equal volumes (via Luwuk and/or Palu, via Kendari and via Manado) [28]; this was reflected in a quota system allocating 5,000 fish/month to each route. Thereafter, the route to Manado continued to decline, and ostensibly so did the route via Kendari, with Luwuk apparently becoming the main exit port, increasingly via air freight.

However, the national level data in Figure 2 show that dispatches from Kendari increased exponentially from 2014-2016. Recorded shipments of *P. kauderni* into Kendari represent a tiny fraction (approximately 2%) of this volume, and it is extremely unlikely the introduced populations in Kendari could have produced this volume of fish. Based on these data, the only logical conclusion is that most of these fish must have been caught in and illegally transported out of the Banggai Archipelago. While as yet unsupported by field verification in Kendari, this conclusion is supported by anecdotal evidence from the southern area of the Banggai Archipelago (sightings of fishing boats from outside the area by fishermen, unreported consignments of many commodities to Kendari known to now powerless district level fisheries officers).

The results of the T0 survey in 2017 under the NPOA-BCF [11] and additional data collected at the same sites (Moore, unpublished data) also support this conclusion. Low or extremely low *P. kauderni* densities were found at several remote sites reportedly not fished by the local ornamental fishers, and population structures displayed a tell-tale gap in the marketable juvenile size class (approximately 25-35 mm standard length). This gap was in fact more marked than it would appear from the official results. The size classes recorded were: under 18mm SL (recent recruits); 18-35 SL (juveniles); and over 35 SL (sub-adults and adults). The juvenile class at most sites in the southern Banggai Archipelago (Bokan Kepulauan Sub-District) was dominated by individuals under 25 mm SL.

3.1.3. Pterapogon kauderni and global change. The global bleaching event in 2016 affected *P. kauderni* coral reef habitat [30]. Coral genera and life-forms serving as *P. kauderni* microhabitat were fully or severely bleached; furthermore, *P. kauderni*-hosting sea anemones were also affected. Preliminary results from experimental research on the response of *P. kauderni* and *Diadema setosum* to elevated temperatures indicate that adult *D. setosum* are capable of survival for at least a month at sea temperatures of 32-33ºC, around 2ºC above recent average day-time values, and similar to temperatures recorded during the 2016 global bleaching event. However, the survival of adult *P. kauderni* decreased and morbidity increased above 31ºC, with close to 50% mortality after 1 week at 33ºC. Qualitatively, as temperature increased the amount of feed consumed by both organisms also increased, indicating an increase in metabolic rate. However, at around 33ºC *P. kauderni* began to appear emaciated, despite still consuming similar or higher amounts of feed compared to controls (ambient temperature, around 28ºC). Pairing behaviour (although no spawning) was observed in most experimental units below 32ºC, but none in units at 32-33ºC. Furthermore, predation of *D. setosum* on *P. kauderni* was observed at 32-33ºC.

A review of likely global climate change impacts on *P. kauderni* and its microhabitats (this volume) indicates that other negative impacts are likely, which cumulatively could reduce reproductive success, recruitment, and growth of *P. kauderni* and its major symbionts. This study concludes that while short term measures are vital, the long-term survival of native (endemic) *P. kauderni* populations most likely hinges on global success in limiting climate change.

3.2. National Initiatives

The umbrella national instrument for *P. kauderni* conservation (developed shortly after CITES CoP 17 in 2016) is the National Plan of Action (NPOA), the implementation of which is strongly linked to the

Banggai Dalaka MPA. One component of this NPOA is Ministerial Decree Kepmen 49/2018 by the Minister for Marine Affairs and Fisheries dated 4 April 2018 and socialised in early May. This decree gives limited protected status to the Banggai cardinalfish, with spatial and temporal limitations on harvest. Temporally, the closed seasons are February-March and October-November. The rationale behind this regulation is to reduce or eliminate disturbance of *P. kauderni* populations during peak breeding seasons. Although *P. kauderni* spawning can occur (subject to lunar cycles) throughout the year [7], there is strong evidence for an annual peak in recruitment during the inter-monsoonal calm season (September/October to November/December) [12].

Spatially, seasonal closures under Kepmen 49/2018 apply within the restricted use area of the Banggai Dalaka MPA (by definition the core zone is comprised of no-take areas). All or part of at least 10 *P. kauderni* populations (known or inferred ESUs) within the MPA are included in core zone areas, with the remainder in the restricted use zone (tourism, traditional fishery and aquaculture sub-zones), or rehabilitation zone (Figure 1). As pointed out in [11], to be effective these closures will need to be complemented by other fishing regulations (e.g. quotas during the fishing seasons), and management of *P. kauderni* habitat and microhabitats (e.g. prevent overexploitation of the microhabitat organisms such as *Diadema* urchins). This regulation does not include any provisions to promote ESU-based management or prevent a serial depletion of ESUs during the open seasons.

The NPOA is structured under 6 focal aspects. An overview of the main planned activities (period 2017-2021) under each aspect (Table 2) also contains remarks. These aim to provide clarification and highlight areas considered to be of particular concern.

Table 2. Overview of the NPOA for *P. kauderni* conservation

	Focal Aspect	Core components/activities	Remarks
1	Development of database, information and documentation of *P. kauderni* in natural habitat and introduced areas	• *P. kauderni* population monitoring (manual, training, 24 sites)	Initial survey in 2017 (T_0) with 24 sites selected; T_1 in late 2018
		• Conduct genetic tests on *P. kauderni* populations outside native habitat (Banggai Laut, Gilimanuk, Palu Bay, Kendari, Ambon, Jakarta, Kepulauan Riau, Lombok, Lampung)	Genetic characterisation of introduced populations is not meaningful until there is a comprehensive reference database on the endemic populations, with diagnostic markers to identify source ESUs Note: Banggai Laut is native habitat
		• Develop database and information system on *P. kauderni* fisheries	No information on progress; Fish Health and Quarantine Data show an urgent need for this component
2	Implementation of protection and preservation of *P. kauderni* and its habitat	• Spatial protection a. Identify crucial habitat b. Expansion of conservation area (MPA) under provincial authority to incorporate *P. kauderni* habitat c. Gazette the MPA d. Develop MPA management plan and zonation e. Establish MPA management unit	Steps a to c: achieved through the promulgation of the Banggai Dalaka MPA (Decree of the Governor of Central Sulawesi Number 523/635A/Dis.Kan GST/2017, dated 27 December 2017. Step d: well underway. Step e: no management unit to date.
		• Limited protected status for *P. kauderni* and asses benefit of moratorium	Status decreed through Kepmen 49/2018. Decree socialised in May 2018, no information on planned assessment.
3	Implementation of sustainable *P. kauderni* use and distribution	• Population assessments in designated areas (Banggai Laut, Gilimanuk, Palu Bay, Kendari, Ambon, Jakarta, Kepulauan Riau, Lombok, Lampung)	Banggai Laut: seems to be a duplicate of population monitoring under aspect 1. Introduced populations: strange that the Luwuk population is omitted, some sites probably captive *P. kauderni*.

	Focal Aspect	Core components/activities	Remarks
3	Implementation of sustainable *P. kauderni* use and distribution (continued)	• Conduct extraction rate assessments in each trade chain	Figure 2 confirms the urgency of this measure; as far as is known, assessments not yet conducted.
		• Establish and disseminate a quota system	Previous quota is still perceived as in vigour by many stakeholders, with conflicting views as to volume and allocation. Needs to be ESU-based; a potential quota system is outlined in [11].
		• Surveillance and enforcement on harvest, distribution, and trade	Currently very weak or non-existent; will require significant resources and strong community support/participation
		• Regulation of international trade, including export data collection; registration of potential exporters; establishing a *P. kauderni* business association	Exporters of all ornamental fish should be registered, and there is a trade association for these stakeholders. It is unclear what benefit could be gained from a species-specific association.
		• Develop SOP for *P. kauderni* extraction from other habitats and hatchery units	From a conservation viewpoint, the native habitat should be the priority.
4	Improving human resources capacity in *P. kauderni* management	• Community based surveillance	Empowering existing coast-watch groups/system has potential for wide-ranging positive impacts on conservation and community welfare. Potential for use of village regulations to make the system effective/efficient.
		• Establish sustainable use of BCF to deliver economic benefit for local community	Unlikely to have a significant impact if based on the fishery or culture. Tourism and "flagship" role of *P. kauderni* could have much wider impact.
		• Training on BCF management (aquaculture, restocking, trade chain, etc.)	Aquaculture training underway in Bone Baru (NGO LINI, supported by MMAF). So-called restocking to date is actually introduction, impoverishing endemic populations to found/enlarge introduced populations (e.g. Luwuk Kilo 5) Goal to train 50 people for restocking is questionable; one (small) team for exceptional circumstances should suffice.
		• Socialization and public awareness on the ecological importance of *P. kauderni* and its habitat and promotion of *P. kauderni* management by local communities to national and international forums	Various posters and other items produced. *P. kauderni* displayed at many events, often with significant fish mortality. Local community management needs to become a reality ; promotion of the concept could prompt support.
5	Improve Banggai Cardinal Fish Governance	• Optimize Banggai Cardinalfish Centre (BCFC) Note: under the 2007-2012 NPOA, the BCFC was designed as an umbrella organisation for all aspects of *P. kauderni* management	Original BCFC organisation and building left with unclear status after the separation of Banggai Laut from Banggai Kepulauan District in 2013. This issue, brought up at every stakeholder meeting since 2013, is still unresolved
		• Development of *ex-situ* aquaculture and training centre	Bali and Ambon (government research centres); possible role for the Bone Baru unit.

	Focal Aspect	Core components/activities	Remarks
5	Improve Banggai Cardinal Fish Governance (continued)	• Protect habitat to support *P. kauderni* resilience in Indonesia (Banggai Laut, Gilimanuk, Palu Bay, Kendari, Ambon, Kepulauan Riau, Jakarta, Lombok, Lampung)	This is clearly oriented toward introduced populations. Ideally limited resources should be focussed on the native (endemic) *P. kauderni* range.
		• Mainstream BCF within national fish governance; Trade network and national promotion; Increase the role of national forum or national working group on management of ornamental fish	The leading role of the MMAF in initiatives post CITES CoP 17 BCF is a positive sign. *P. kauderni* fishery and trade management should indeed be integrated into the ornamental fish system as a potentially sustainable mechanism.
6	Implementation of *P. kauderni* restocking activities	• Provide training to communities to breed *P. kauderni* (Bali, Jakarta, Ambon, Kepulauan Riau, Lombok, Kendari, Banggai Laut, Palu Bay, Lampung) and • Develop *P. kauderni* breeding program (Banggai Laut, Banggai, Banggai Kepulauan)	The rationale for training communities outside the native *P. kauderni* distribution in breeding this species is unclear, and likely to cause resentment in the native area. Breeding initiated in Bone Baru (Banggai Laut); facilities in Liang (Banggai Kepulauan) partial, not operational; unclear why Banggai District (Sulawesi mainland) is included unless as holding station for fish from the Archipelago (captive-bred or wild caught).
		• Conduct assessment on broodstock (Banggai Laut, Palu Bay, Gilimanuk, Ambon)	The three introduced /captive populations are of uncertain origin in terms of ESU, and thus unsuitable for true re-stocking (replenishment of native/endemic populations)
		• Needs assessment and guidelines on *P. kauderni* population and habitat rehabilitation	Guidelines currently under preparation. It is crucial that the guidelines address the issue of genetic structure to maintain ESU integrity.
		• Carry out socialization for re-stocking programs (Banggai Laut, Gilimanuk, Palu Bay, Kendari, Ambon, Jakarta, Kepulauan Riau, Lombok, Lampung)	This should be oriented towards well-studied sites in the endemic range only (Banggai Laut and Banggai Kepulauan Districts) The need for care in sourcing broodstock from the target ESU should be stressed.
		• Strengthen community group for surveillance of re-stocking program implementation and implement population monitoring in re-stocking areas (Banggai Laut, Gilimanuk, Palu Bay, Kendari, Ambon, Jakarta, Kepulauan Riau, Lombok, Lampung)	These items should not be a priority, and it is even questionable if they should be carried out outside the native *P. kauderni* distribution. The precautionary principle needs to be strongly implemented in protocols and in field implementation, especially with respect to genetic stocks/ESUs and biosecurity issues (e.g. pest and disease transmission).
		• Training on *P. kauderni* restocking and implement re-stocking program (Banggai District)	Fish captured in the endemic range were released at Luwuk Kilo 5 introduced site on 1-2 May 2018. Such actions are against accepted conservation principles.

Of the six NPOA focal aspects, aspect 6 is by far the most controversial. In the field of endangered fish management, it is vital to consider conservation genetics [31]. In particular, restocking should be limited to native fish and even then only in cases of exceptional need (e.g. extirpation or high risk of extirpation within the native distribution of a species) [11,31]. Furthermore, such restocking should follow good practices such as those developed by the IUCN [11]. In the case of *P. kauderni*, this means paying due attention to ESU issues. Furthermore, there needs to be a distinction between wild broodstock (F0), their offspring (F1) and further generations (F2 and beyond).

The issue of genetic structure and ESUs should not only be a prime consideration in restocking, but also in all release of *P. kauderni* (wild or captive bred) at sites other than their native site within the native (endemic) distribution of this species. In the case of introduced populations, the appropriateness of introducing and thereafter increasing the population of a new species should be given mature consideration. Invasive potential is a serious concern, especially as it has been reported that *P. kauderni* has become an invasive alien species in Lembeh Strait [7,21]. In all cases, biosecurity should be a concern, in particular the health of the fish being released, to avoid the potential spread of pests and disease [11].

In addition to the ecological aspects, socio-economic aspects of the proposed activities should be considered. Stakeholders in the Banggai Archipelago have expressed concern over what they see as a loss of identity of "their" fish when it is produced in other areas, and even sold under names which no longer reflect the origin of the species, for example “capungan Ambon”. This "branding issue", important in trade and other economic sectors, for example in tourism, is also reflected in the (erroneous) perception among some scientists that *P. kauderni* is no longer and endemic species because it is now found (as yet in comparatively small numbers) outside of its native distribution. This perception played a key role in the failure of efforts to give limited protected status to *P. kauderni* under the 2007-2012 NPOA, significantly delaying effective protection measures for the species.

3.3. Priorities, opportunities and risks

The future of *P. kauderni* is at a crossroads, where the success or failure of the current NPOA will have far-reaching effects. At this crucial point in time, a number of key priorities, opportunities and risks based on the findings of this study are presented in Table 3.

Table 3. Priorities for *P. kauderni* conservation

No.	Priority for action	Opportunities	Risk factors/needs
1	Prioritise endemic (not introduced) *P. kauderni* populations.	Central government support for Banggai Dalaka MPA. CITES recommendations and international concern. Local stakeholder awareness.	Scarce resources may be allocated to actions with little or no impact on native (endemic) *P. kauderni* populations. Risk of negative impacts, e.g. loss of ESU integrity.
2	Protect genetic diversity through site/stock-based management (including conservation ornamental fishery, monitoring), ideally ESU-based.	Can be initiated using existing genetic population structure data, while seeking to develop a database of genetically unique (reproductively isolated) stocks (ESUs). Potential support for research to determine ESUs and diagnostic markers.	Risk of delay while waiting for comprehensive ESU data. Such delay is likely to enable further loss of ESU integrity through inappropriate actions at all levels, as well as increase the risk of further extirpations; this is likely even with measures (e.g. quotas) applied effectively, if they are set and implemented at a spatial resolution greater than the ESU/site/stock level.
3	Protect and rehabilitate *P. kauderni* habitat and microhabitat (especially *Diadema* urchins and sea anemones).	Potential for regulations and other mechanisms through Banggai Dalaka MPA as well as village regulations and funds. Growing body of relevant research as well as growing awareness of and interest in the (lack of) sustainability of invertebrate fisheries, including gleaning.	Poorly designed rehabilitation could be counterproductive (e.g. damage to donor sites/organisms, as well as target site) Risk of low compliance (e.g. urchin collectors, traders and consumers) and horizontal conflict (e.g. between local communities and roving fishers). Need for knowledge and technology, e.g. on connectivity and culture to support urchin conservation.

No.	Priority for action	Opportunities	Risk factors/needs
4	Investigate, record (and where necessary restrict) in-country movements of *P. kauderni*, especially removal from the endemic range	Existing Fish Health and Quarantine systems, including trained staff, promotional materials, stakeholder relations, and on-line database (albeit database could be made more user-friendly). National and international interest (linked to CITES). Potential for wider application to ornamental/other fisheries.	Transport by sea and overland much less well documented than airfreight; fish arrivals poorly documented compared to dispatches. These discrepancies need to be studied and remedied. The logistics involved in compliance provide some justification for unrecorded shipping (e.g. to Kendari). Need to improve data on export and international as well as in-country movements [11].
5	Regulate and restrict the release of *P. kauderni* to the wild from captivity and/or between known/suspected genetic stocks	Regulations being drafted with MMAF support under the *P. kauderni* NPOA. Potential for synergetic measures under the Banggai Dalaka MPA and through village ordinances. Awareness among fishermen of subtle differences between *P. kauderni* populations [11,22]	Risk that commercial and sectoral interests could over-ride science-based approaches, and allow (*de jure* or *de facto*) the inappropriate release of fish. The health and genetic integrity of an ESU could be compromised through the introduction of fish: from a different ESU; descended from mixed/uncertain strains; in poor health; poorly adapted or acclimated to the release site; etc.
6	Institutionalisation at multiple levels in a holistic socio-ecological context to provide robust and resilient conservation management	*P. kauderni* as an icon at village to regional level, including on the Banggai Laut District shield. Opportunity to capitalise on the "flagship species" potential of the Banggai cardinalfish to promote more sustainable coastal resource management, especially in the intensively used shallow-water ecosystems comprising *P. kauderni* habitat.	Lack of capacity at some levels and lack of integration between levels, including substantial decline in capacity through dismantling of previous systems and many other mechanisms under the new regional autonomy law (UU 23/2014). Project-oriented, short-term, and partial or sectoral approaches driven by the regulatory framework, including annual budgetary mechanisms and political (e.g. electoral) time-frames and systems.
7	Further research on potential climate change impacts and their mitigation in a local context (spatial scale)	Growing body of research and research methods/tools. Current momentum and concern at national level and globally, likely to increase as the 15th IPCC report [3] is disseminated.	Risk of "too little, too late". Risk of "ego-sectoral" approaches impeding research and its application. Limited appropriate funding for research and its dissemination/application.

Despite the potentially grim threats we all face in the Anthropocene [1,3], it is important to maintain optimism, and work to conserve our irreplaceable natural heritage at the local level, while at the same time working to address issues requiring concerted global action, in particular on climate change. We hope that this study and the suggestions it contains will be of use to stakeholders in working to sustain the Banggai cardinalfish, together with its habitat and microhabitat, as part of a vibrant socio-ecological system.

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