Banggai Cardinalfish Ornamental Fishery: The Importance of Microhabitat

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Abstract. The Banggai cardinalfish (*Pterapogon kauderni*) is an iconic coral reef fish endemic to shallow waters (0-5m) around the Banggai Archipelago, Indonesia. The habitat of *P. kaudermi* includes some of the most valuable, yet also the most vulnerable, reefs in the archipelago. Highly sought after by the global marine aquarium industry, *P. kauderni* is considered "Endangered" by the IUCN, with both overexploitation and habitat degradation threatening this species. Monitoring and research of the Banggai cardinalfish trade, population and habitat since 2007 reveal temporal changes in these threats. There has been a marked increase in compliance with current fish quarantine regulations and other improvements in *P. kauderni* fishery and trade practices, despite ongoing concerns the ornamental fishery is becoming one of the major driving forces for conservation of both *P. kauderni* and its habitat. Conversely, threats to the *P. kauderni* habitat are increasing. In particular, *Diadema* urchins and sea anemones, both important as *P. kauderni* microhabitat, are under pressure from increasingly intensive harvesting. Both are consumed by fishing families turned seaweed farmers, and *Diadema* urchins are used as feed in the grow-out of carnivorous reef fish, especially *Cheilinus undulatus*. These recent serious threats to the sustainability of the fishery and the conservation outlook of the species require an integrated ecological and social approach.

Key words: *Pterapogon kauderni*, microhabitat, endemic species, monitoring, sustainable fishery

Introduction

The coral reef associated Banggai cardinalfish (*Pterapogon kauderni*, Koumans 1933), an apogonid with a maximum standard length (SL) of around 6.5 cm, is endemic to an area of ~5,500 km^2 in and around the Banggai Archipelago, Central Sulawesi, Indonesia. Within this distribution, *P. kauderni* habitat is limited to shallow (0-5m, mostly less than 3m depth) coastal waters including coral reefs and reef flats, sea grass meadows, and lagoons (Vagelli & Erdmann, 2002). The growing human population and changes in modern lifestyles are exacerbating the already heavy pressure on these shallow coastal ecosystems from a variety of direct and indirect anthropogenic impacts (Moore & Ndobe, 2009).

The Banggai cardinalfish is a paternal mouth-brooder with direct development, therefore no pelagic dispersal of eggs or larvae and relatively low fecundity (Vagelli, 1999). After settlement, *P. kauderni* exhibits high site fidelity (Kolm *et al*., 2005). These traits make the species especially vulnerable to local extinction. Often associated with sea urchins (*Diadema* sp.) the Bajo (sea gypsy) name for *P. kauderni* is *bebese tayung*, meaning little sea urchin fish (Ndobe and Moore, 2009). Other important microhabitat includes sea anemones and hard corals (Vagelli and Erdmann, 2002).

Traded as a marine ornamental fish since the 1980's (Ndobe and Moore, 2009) and in large numbers since the 1990's (Lunn and Moreau, 2004), the fate of the Banggai cardinalfish has attracted international attention (e.g. Bruins *et al*., 2004). In 2007 the IUCN Red-List placed *P. kauderni* in the "Endangered" category; overexploitation was given as the major threat, and habitat degradation was also mentioned.

Indonesia opposed a proposal by the USA for listing *P. kauderni* under CITES (Convention on the International Trade in Endangered Species of Wild Flora and Fauna) Appendix II in 2007. The proposal was withdrawn and Indonesia made a commitment to *P. kauderni* conservation with a sustainable use (ornamental fishery) approach and a national multi-stakeholder Banggai cardinalfish action plan (BCF-AP) was developed, focussed on three aspects: conservation, trade and management (Ndobe and Moore, 2009). Conservation of *P. kauderni* is also included in the Coral Triangle Initiative National Action Plan. In this context it is important to evaluate changes in the ornamental fishery and conservation outlook for *P. kauderni*, including the causes and impacts of habitat degradation.

Material and Methods

Data on *P. kauderni* biology, ecology, fishery and trade were collected from 2004 to 2011 during field visits and research programs, including activities in connection with BCF-AP implementation. Secondary data were sourced from Fish Quarantine records and other government and non-government stakeholders involved in the BCF-AP. In particular data from the trade monitoring scheme operated in 2008 and 2009 by the Marine and Fisheries Research Agency (BRKP) with enumerators from the District Marine and Fisheries Service (MFS) and the ornamental fishing community were obtained from the Banggai Cardinalfish Centre (BCFC). The data were analysed to identify changes in the *P. kauderni* fishery and trade, conservation status and outlook for *P. kauderni* populations and habitat.

Results

The Pterapogon kauderni fishery

In 2001, around 12 villages were engaged in *P. kauderni* collection (Lunn and Moreau, 2004), by 2011 the number had fallen to 3 (Table 1). In 2004 known *P. kauderni* fishing grounds included most of the endemic distribution, however by 2011 there were indications that the spatial extent of fishing grounds had declined (Fig. 1).

Island or Sub-District	Village	Status **			
		2001*	2004	2006-2009	2011
Banggai	Bone Baru	A	A	A	A
	Tinakin Laut	A	A	N	N
	Monsongan	A	A	N	N
	Tolokibit	A	A	N	A
	Matanga	A	no data	N	N
Bokan Kepulauan	Toropot	A	A	A	N
	Panapat	A	A	P	N
	Kokudang	A	N	N	N
	Mbuang-Mbuang	A	N	N	N
Bangkurung	Bone Bone	A	A	A	A
	Dunkean	A	N	N	N
Other	4 villages with very low volume	A	N	N	N

** Lunn and Moreau (2004)
*A = Active; N = Not Active; P = Possibly Active
Table 1. *Pterapogon kauderni* Fishing Villages.

Only two villages have remained consistently active, Bone Baru on Banggai Island and Bone Bone on Bangkurung Island. Fishermen in Toropot, still active in the *P. kauderni* fishery and trade up to 2010, were no longer collecting at the time of the 2011 survey. In 2011 fishers in Tolokibit (active 2001-2004) were once again collecting, trading via Kendari in SE Sulawesi, sometimes together with fish collected by Bone Bone fishermen. The main reason for villages such as Toropot, Tolokibit and Panapat to begin or cease activity seems to be the presence or absence of buyers, most of whom were (in some cases still are) roving fishers from Tumbak in North Sulawesi, Bali and East Java (especially Banyuwangi).

There is a growing tendency for fishers to remain closer to their bases (e.g. the reduction in extent of the Bone Baru fishing grounds). This is largely due to increased overhead costs, especially fuel. Despite minimal surveillance/enforcement, the increasingly negative attitude of local people to those perceived as "fish thieves" most likely played a role in the observed and reported decline of roving *P. kauderni* fisher/buyers, most of whom still operate illegally: without valid (or any) permits and often using poison to catch other ornamental species.

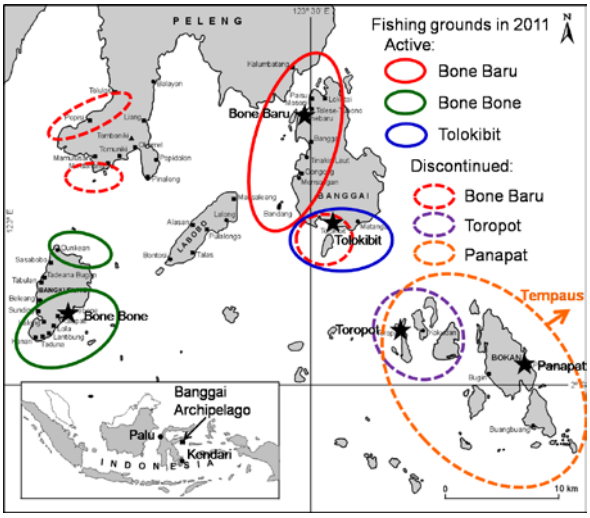


Figure 1: Fishing grounds of the main *P. kauderni* fishing villages

The Pterapogon kauderni trade

In 2000-2001 the estimated number of *P. kauderni* traded from the Banggai Islands was 700,000 to 1.4 million fish/year (Lunn and Moreau, 2004). Over the period 2004-2006, monitoring produced estimates of 600,000-700,000 fish/year. In 2008, the Marine Aquarium Council (MAC) and the Indonesian Nature Foundation (LINI) estimated international demand to be ~450,000 fish/year. The gap between supply and demand was thought to be due to high levels of mortality and rejects (e.g. fish with damaged fins) in the market chain, as well as the practice of collecting and buying speculatively rather than on demand (e.g. by intermediary buyers from Tumbak in North Sulawesi). The release of unsold fish, including rejects, resulted in several introduced *P. kauderni* populations along trade routes, including a recently discovered population in Kendari (Moore *et al*., 2011). A synopsis of the BRKP/MFS monitoring data for 2-3

villages during 2008 and 2009 is presented in Table 2. The data indicate a reduction in trade volume and mortality compared to 2000-2006, although observation and anecdotal information indicate there may be some under-reporting of rejects and mortality.

Parameter	Year	Bone Baru	Toropot	Bone Bone	Total
No. BCF caught	2008	162,940	73,433	no data	236,373
	2009	155,156	89,340	85,920	330,416
Mortality (%)	2008	2.60%	0.70%	no data	2.00%
	2009	0.10%	0.30%	0.80%	0.30%

Table 2: Catch and mortality rate data for 2008-2009 (BCFC)

Current legislation requires that all fish and fish products must go through Fish Quarantine procedures before crossing internal administrative boundaries as well as leaving the country (export). In 2004, only one *P. kauderni* trader (route via Luwuk and Palu) had ever followed Fish Quarantine procedures for *P. kauderni* leaving the Banggai Islands. The Fish Quarantine Service in Luwuk is an active BCF-AP stakeholder represented in the BCFC. In 2008, a branch office was established in Banggai town, on Banggai Island and has recorded the legal *P. kauderni* shipments since February 2008 (Table 3).

Parameter	**2008 (Feb-Dec)**	**2009**	**2010**	**2011 (to June)**
Number of fish traded legally	83,200	215,950	148,800	56,900
Average monthly volume*	7,564	17,996	12,400	9,483
% enumerator trade data	36%	66%	n/a	n/a

Table 3. Fish Quarantine Data: *P. kauderni* legal trade 2008-2011

The data indicate a marked increase in the legal trade, which prior to 2008 was a tiny proportion of total known *P. kauderni* trade volume. In 2010 there was a decrease in the numbers of *P. kauderni* traded through Bone Baru, largely due to a policy of linking capture to demand, with exporters ordering fish in line with the demand from overseas importers. This link was facilitated by LINI, the Fish Quarantine Service and the BCFC, and made possible by improvements in handling procedures (from capture to packing) as well as in transport (enlargement of Luwuk airport to handle regular domestic flights to Jakarta or Denpasar transiting through Makassar) and communication infrastructure (mobile phone network extension).

The price paid per fish remained at 200-300Rp from 2001 to 2006. In 2008/2009, most BCF were sold for 350 Rp./fish. By 2011 the new trade route and improved quality of fish supplied enabled Bone Baru fishers at least to increase the price per fish to 500Rp. It has been estimated that a price to fishers of around 1,000 Rp./fish should be economically viable, the fishermen consider this would be a fair price. Market chain economics make significantly higher prices to fishermen unlikely in the foreseeable future, one reason being the need to keep the cost of wild-caught fish below that of fish reared in captivity.

Pterapogon kauderni habitat and population

Significant coral reef degradation was reported by Moore and Ndobe (2009) at several sites in the Banggai Archipelago, based on survey/montioring data from 2004 and 2006. In 2011 there was evidence of a decline in coral cover since 2004 at 5 sites around Banggai Island, e.g. from 25% to 11% on a transect through *P. kauderni* habitat in Bone Baru. Previously identified threats mostly remained at similar levels or were increasing, including the gleaning of invertebrates for consumption (intensive, but not perceived as fishing); general fishing pressure, including the use of destructive methods; coastal development especially the construction of sea walls, public infrastructure (such as the new port at Tinakin Laut), and the replacement of traditional homes with "permanent" concrete and breeze-block dwellings, a shift strongly supported by government development policy. The use of illegally mined coral and sand by both public works and local communities was observed at several sites over the period 2004-2011.

Increasing pressure on the land-based resources of these small islands is resulting in increased sedimentation, deleterious changes in hydrology, and water quality issues. Several population explosions of the coral predator *Acanthaster plancii*, generally considered as an indication of ecological imbalance, have been observed since 2004. Temperature-related coral bleaching had not yet been observed or reported up to December 2011, though extensive bleaching had been observed in nearby Tomini Bay in 2010.

Kolm and Berglund (2003) found that heavy fishing pressure was correlated with lower *P. kauderni* population density, but no significant difference was found between lightly/moderately fished sites and un-fished sites in terms of population density. These findings have been confirmed by more recent surveys and monitoring of both the endemic and Palu Bay introduced populations. The data also indicate that all levels of fishing alter population structure. Higher percentages of recruits and smaller juveniles have consistently been observed at sites recently or regularly fished. The predation of newly released recruits by adult *P. kauderni* (cannibalism) in captivity was recorded (filmed) during research in Palu in 2010 and witnessed in the wild during the 2011 survey. There are indications that the survival rate of new recruits increases when the density of

adult and sub-adult fish is reduced whether by fishing or other causes such as severe weather. This is supported by the negative relationship between the density of *P. kauderni* and the juvenile:adult ratio across 6 sites around Banggai Island with various levels of fishing pressure (Fig. 2).

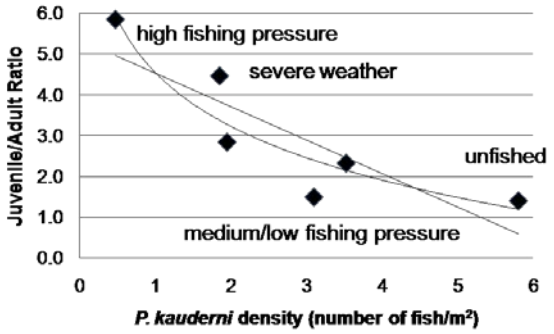
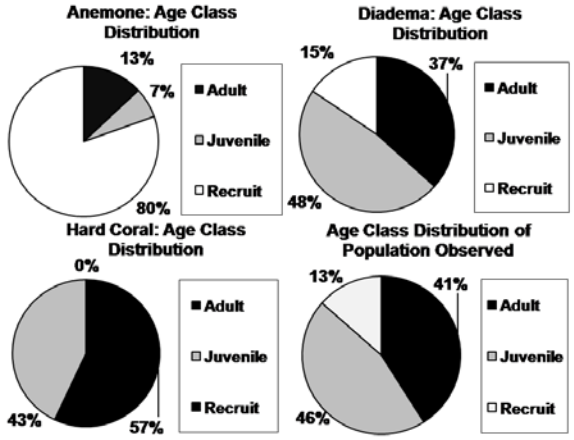


Figure 2. *P. kauderni* population structure versus density at 6 sites around Banggai Island in 2006 (logarithmic and linear trendlines)

Microhabitat

Data from a study of microhabitat use by *P. kauderni* of 3 age/size classes (recruits: SL 6-15mm; juveniles SL 16-35mm; adults SL >35mm) are shown in Fig.3. All size classes are generally found in *Diadema* microhabitat, and the age structure of fish observed in this microhabitat was close to that of the overall population sampled. Over 80% of new *P. kauderni* recruits (SL 6-15mm) observed, and all recruit groups of more than 3 individuals, were associated with sea anemones, often also inhabited by clownfish (*Amphiprion* sp.); conversely recruits comprised 80% of all *P. kauderni* associated with sea anemones. No recruits or small juveniles were observed in the hard coral microhabitat, though a few isolated recruits have since been seen in branching or foliose corals as well as mushroom corals of the Genus *Heliofungia.*



Recruit: SL 6-15mm; Juvenile SL 16-35mm; Adult SL > 35mm
Figure 3. *P. kauderni* population composition and microhabitat use by life stage class at Tinakin Laut, Banggai Island in 2007

In addition to cannibalism, predation of exposed *P. kauderni* recruits by fish of the Families Scorpaenidae, Labridae, Cirrhitidae and Gobiidae has been observed on several occasions, immediately or shortly after their release from the male parents buccal pouch. In particular, small stonefish (Scorpaenidae) have been seen in unusually high numbers around male *P. kauderni* brooding well-developed larvae, and subsequently actively predating recruits.

Microhabitat is important as a refuge from predation and anemones seem to be a particularly important microhabitat for newly released *P. kauderni* recruits and small juveniles. Nearly all predators, including adult and sub-adult *P. kauderni*, seem to avoid the tentacles among which the smaller *P. kauderni* often hide, also benefitting from protection of the anemone by resident clown fish when present. Brooding males close to releasing their larvae have been observed near anemones, later found to be occupied by *P. kauderni* recruits. While recruits in sea urchin microhabitat are often isolated, and have rarely been observed in groups of more than 3, it is not unusual to find groups of 20 or more *P. kauderni* recruits in one sea anemone.

A recent threat to *P. kauderni* populations, massive extraction of key recruit microhabitat (sea anemones) was first revealed by survey and monitoring activities in 2007 (Ndobe *et al.*, 2008). A drastic decline in *P. kauderni* population occurred at Tinakin Laut after the sea anemones (numerous in 2004 and 2006) all disappeared. A social survey revealed that the anemones had been collected and eaten, a long-standing practice of hill farming communities during drought periods when they have difficulty in obtaining other sources of protein, however in the past collection had been on a much smaller scale. A similar case of increasing collection and consumption by hill farmers was reported from Tolokibit, this time focused on *Diadema* sea urchins.

Numbers of *P. kauderni* recruits and small juveniles fell sharply (by an order of magnitude) at Mamboro in Palu Bay, a site observed since 2006, after sea anemones were collected by local children. After a recent reduction in sea urchin and sea anemone populations at another site in Palu Bay (cause unknown), almost all *P. kauderni* crowded into the remaining urchins were adults. No recruits or small juveniles were visible, despite large numbers of brooding males (i.e. high reproductive activity), indicating a sharp drop in recruit/juvenile survival.

In 2009 it became apparent that seaweed farming development is related to shifts in fishing and consumption patterns. Fishers turned seaweed farmers seek protein for themselves and their families in the shallow waters around their farms, resulting in intensive harvesting of all edible benthic invertebrates,

including the sea anemones and sea urchins that provide key *P. kauderni* microhabitat. In 2011 it also became clear that sea urchins were also being harvested in large numbers as feed for carnivorous fish destined for the live reef fish trade, especially Napoleon wrasse, another species of conservation concern whose exploitation is most often illegal.

Monitoring by LINI and the BCF Lestari fishermen's group in 2010/2011 confirmed that intensive harvesting of shallow-water invertebrates, including sea anemones and sea urchins, was becoming more widespread. The resulting declines in sea anemone and sea urchin populations were correlated with visible (and in some cases measured) reductions in *P. kauderni* populations, within and outside fishing grounds.

Discussion

The Banggai cardinalfish is an iconic species, native to a small area of Indonesia. Collection and trade in the Banggai Archipelago for the global aquarium market was once considered the main threat to the survival of this restricted range species (Bruins *et al*., 2004). Since 2006, the scale of the fishery appears to have been reduced, with a number of improvements in sustainability. Monitoring has shown an increase in compliance with legal requirements; improvements in organisational structure (fisher group) and technical aspects of the *P. kauderni* fishery and trade; and an increase in the price per fish paid to fishers. Although illegal and unreported fishing do still occur, there are efforts to curb these activities. For example just recently an illegal *P. kauderni* shipment was intercepted and released to the wild. Ongoing efforts and constant vigilance are necessary to maintain and extend these improvements, however the *P. kauderni* fishery seems to be on the way towards the sustainable ornamental fishery goal first set by local stakeholders in 2005 and underpinning the national BCF-AP in 2007.

The legal fishery is actually contributing to improved conservation of the shallow-water ecosystems of the Banggai Archipelago. For example, *P. kauderni* fishermen in Bone Baru have been active in local conservation efforts including the establishment and development of a community MPA and protecting *P. kauderni* habitat from destructive fishing and harvesting of ecologically important invertebrates.

In a review of marine biodiversity patterns, threats and conservation needs, Gray (1997) stated that "loss of habitat is the most serious threat to marine biodiversity". Overall, monitoring results indicate that loss of habitat, especially the key microhabitat organisms (*Diadema* urchins and sea anemones, under pressure from increasingly intensive harvesting), is now the main threat to conservation of the endemic *P. kauderni* population and indeed to the ornamental fishery. This recent and expanding threat, is linked to socio-economic trends, including the expansion of seaweed farming and live reef fish grow-out. Many stakeholders involved are unaware of Banggai cardinalfish conservation issues. There is a clear need for further research and monitoring of the situation, leading to the development of innovative approaches to address these concerns.

One cost-effective way of developing a long-term integrated monitoring program would be through empowerment and capacity building for the BCFC. Local community members, including the fishermen's group(s), could do much of the routine data collection, supplemented with less frequent but more detailed monitoring by academic and research institutions, all coordinated through the BCFC.

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