Banggai cardinalfish
(Pterapogon kauderni)

5-Year Review:
Summary and Evaluation

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National Marine Fisheries Service
Office of Protected Resources
Silver Spring, MD

5-YEAR REVIEW

Species reviewed: Banggai cardinalfish (*Pterapogon kauderni*)

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5-YEAR REVIEW
Banggai cardinalfish (*Pterapogon kauderni*)

1.0 GENERAL INFORMATION

1.1 Reviewers
Lead Regional or Headquarters Office:
Erin Markin, Office of Protected Resources, (301) 427-8416

1.2 Methodology used to complete review
A 5-year review is a periodic analysis of a species' status conducted to ensure that the listing classification of a species currently listed as threatened or endangered on the List of Endangered and Threatened Wildlife and Plants (List) (50 CFR 17.11 – 17.12) is accurate. The 5-year review is required by section 4(c)(2) of the Endangered Species Act of 1973, as amended (ESA) and was prepared pursuant to the joint National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service's 5-year Review Guidance and Template (NMFS and USFWS 2018). The NMFS Office of Protected Resources (OPR) conducted the 5-year review. We updated information from the status review (Conant 2015) based on peer-reviewed publications, government and technical reports. We gathered information through May 2021. The information on the Banggai cardinalfish (*Pterapogon kauderni)* biology and habitat, threats, and conservation efforts was summarized and analyzed based on ESA section 4(a)(1) factors (see Section 2.3) to determine whether a reclassification or delisting may be warranted (see Section 3.0).

NMFS initiated a 5-year review of the Banggai cardinalfish and solicited information from the public on March 29, 2021. One public comment was received and incorporated as appropriate in this review.

1.3 Background

1.3.1 FRN Notice citation announcing initiation of this review
FR Notice: 86 FR 16326, March 29, 2021

1.3.2 Listing History
<u>Original Listing</u>
FR notice: 81 FR 3023
Date listed: February 19, 2016
Entity listed: Banggai cardinalfish (*Pterapogon kauderni*)
Classification: Threatened

1.3.3 Associated rulemakings
On April 22, 2021, NMFS received a petition from the Center for Biological Diversity, Animal Welfare Institute, and the Defenders of Wildlife requesting we promulgate a rule under section 4(d) of the ESA to provide for the conservation of the Banggai cardinalfish (*P. kauderni*). On August 4, 2021, NMFS announced receipt of a petition to promulgate a rule under section 4(d) of the Endangered Species Act (ESA) to provide

for the conservation of *P. kauderni* (86 FR 41935) and requested information and comments in evaluating the request.

1.3.4 Review History

The initial status review (Conant 2015) concluded that the Banggai cardinalfish is at moderate risk of extinction. This is the first 5-year review since its listing on February 18, 2016.

1.3.5 Species' Recovery Priority Number at start of 5-year review

Not Applicable

1.3.6 Recovery Plan or Outline

Not Applicable – the range of the Banggai cardinalfish is entirely under the jurisdiction of Indonesia.

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?

__X__**Yes**
_____**No**

2.1.2 Is the species under review listed as a DPS?

_____**Yes**
__X__**No**

2.1.3 Is there relevant new information for this species regarding the application of the DPS policy?

_____**Yes**
__X__**No**

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan[1] containing objective, measurable criteria?

_____**Yes**
__X__**No**

[1] Although the guidance generally directs the reviewer to consider criteria from final approved recovery plans, criteria in published draft recovery plans may be considered at the reviewer's discretion.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

The Banggai cardinalfish (*P. kauderni*) is a relatively small marine fish endemic to the Banggai Archipelago, Central Sulawesi, Indonesia, where its distribution is limited to 20-34 km^2 of shallow-water habitat around 34 islands (Figure 1; Vagelli 2017; Ndobe et al. 2018a; Wiadnyana et al. 2020). There is very little natural dispersion of *P. kauderni* between islands and local populations, which leads to local populations displaying distinct genetic and morphometric traits. While some authors (Ndobe et al. 2018b; Moore et al. 2019c) have indicated these local populations may constitute separate Evolutionarily Significant Units (ESUs), we note here that NMFS (56 FR 58612) restricts the term ESU only to Pacific salmon (*Oncorhynchus* spp.) populations and for the purposes of this 5-year review, these groups of *P. kauderni* will be referred to as "populations".

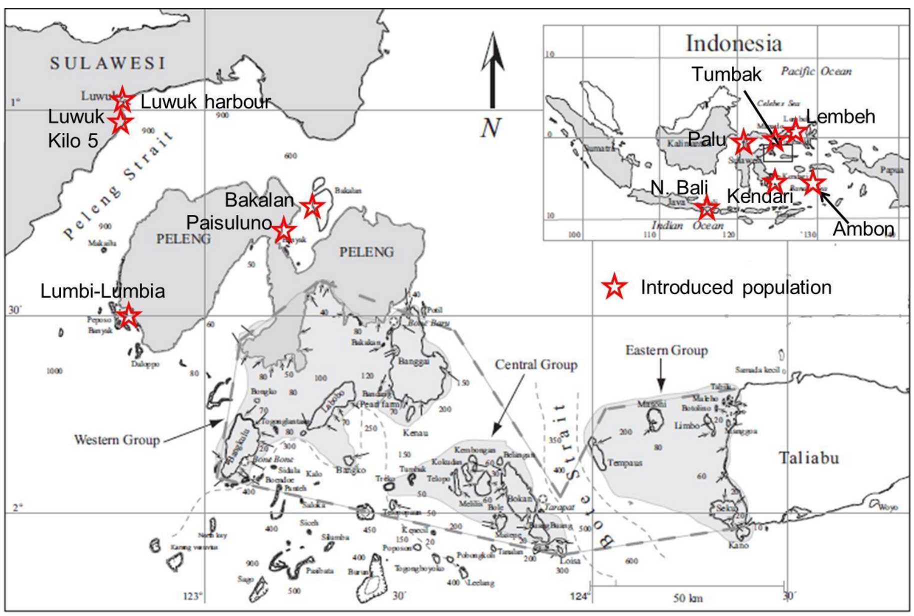


Figure *1*. Banggai cardinalfish *(Pterapogon kauderni*) endemic (native) distribution (dotted lines indicate the external boundaries of the endemic range of ≈ 5000 km^2, within which potential *P. kauderni* habitat extent ≈ 20- 24 km^2 around 34 of the islands in the relatively shallow sea areas is shaded in grey), and known (published) introduced populations (red stars) in the Banggai Archipelago (Lumbi-Lumbia, Bakalan, Paisuluno); Central Sulawesi (Luwuk, Palu Bay); North Sulawesi (Lembeh Strait); Southeast Sulawesi (Kendari) and North Bali (Gilimanuk, possible other sites), and Maluku (Ambon). (Source: Ndobe et al. 2018a Figure 1).

The smallest female Banggai cardinalfish found showing signs of gonadal development were approximately 33mm standard length (SL) (Vagelli 2017). Brooding males are typically >40mm SL, although two males, 32mm and 34mm SL, were found incubating eggs (Vagelli 2017). Banggai cardinalfish are gonochoric meaning they do not change sex as they mature (Vagelli 2017). Females produce clutches with approximately 60-70 eggs (Vagelli 2017). As noted in the 2015 status review, *P. kauderni* is a paternal mouthbrooder where the males incubate the eggs in their oral cavity and release the young after about 5-7 days when they are about 6-8 mm SL. Because there is no larval pelagic stage, dispersal is limited (Vagelli 2017).

After the juveniles are release from the male's mouth, these recruits find cover in benthic organisms for protection and to avoid cannibalism (Moore et al. 2019; Wiadnyana et al. 2020). Both recruits and small juveniles associate with sea urchins (Family Diadematidae), sea anemones (*Entacma quadricolo*, *Heteractis crispa, Actinodendron* spp., *H. magnifica*, *Stichodactyla gigantea*), hard corals (*Heliofungia* spp.), and upside-down jellyfish (*Cassiopea* spp.) (Ndobe et al. 2018b; Moore et al. 2019a; Moore et al. 2020a). At six study sites (i.e., Liang, Popisi, Bone Baru, Tinakin Laut, Tolokibit, and Kapela), 93.4% of *P. kauderni* found were recruits/small juveniles associated with sea anemones and indicating sea anemone are hosts and important for reproductive success via survival of recruits (Moore et al. 2019a; Moore et al. 2020a). Adult *P. kauderni* are commonly associated with corals such as hard corals from the eight genera (*Acropora*, *Seriatopora*, *Stylophora*, *Goniopora*, *Echinopora*, *Hydnophora*, *Holiofungia*, and *Porites*), fire coral (*Millepora* spp.), soft corals (*Sinularia* spp.), branching sponges, and seagrass (*Enhalus acaroides*) (Ndobe et al. 2018b; Moore et al. 2019a). All sizes classes of Banggai cardinalfish have been observed associating with sea urchins (*Diadema* spp., *Echinothrix* spp. and *Astrophyga* spp.) (Ndobe et al. 2018b; Moore et al. 2019a; Moore et al. 2019b). Occasionally, all life stages of *P. kauderni* are associated with abiotic microhabitat such as manmade structures and marine debris (Ndobe et al. 2018b; Moore et al. 2019c). For additional information on habitat, refer to Section 2.3.1.6 below.

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

The 2015 status review of *P. kauderni* summarized data collected in population surveys conducted in 2001, 2002, 2004, 2007, 2011, 2012, and 2015 (Conant 2015). It is difficult to compare the results of these surveys because the area included in the surveys was not consistent between years and therefore the population trends are difficult to interpret as population estimates have been based on total habitat area multiplied by an average *P. kauderni* density (Ndobe et al. 2018a). Since the 2005 estimate of 2.4 million Banggai cardinalfish over approximately 34 km^2, both the number and habitat size have been reduced to 1.4 million fish across approximately 20 km^2 in 2015 (Ndobe et al. 2018a).

Additional surveys have been conducted since the 2015 status review and ESA listing to determine population densities of *P. kauderni*. In October 2017 (baseline survey) and November-December 2018 (T1; first annual survey) were conducted as part of the National Plan of Action (NPOA) for Banggai cardinalfish. A standard survey method was developed and data were collected at 24 sampling sites within the Banggai Archipelago through visual surveys using a belt transact method (Wiadnyana et al. 2020). Individuals were counted by size class: recruits <1.8 cm SL, juvenile 1.8-3.5 cm SL, and adults >3.5 cm SL, and microhabitat of each *P. kauderni* was also recorded. Overall, in 2017, recruits and juveniles were more abundant than in 2018 while mean adult abundance was higher in 2018 than in 2017 (Wiadnyana et al. 2020). Specifically, abundant populations of *P. kauderni* were found at Bone Baru Village, Toado, and Toropot, with mean densities of 6.35, 4.48, and 3.29 fish/m^2, respectively (Wiadnyana et al. 2020). Juveniles were not observed at the Mandel site in 2017 and 2018, and in 2018 no adults were observed at Tj Nggasuang (Wiadnyana et al. 2020). Both the Bone Baru Village and Toropot sites have been a focus for conservation efforts; Toado habitat is predominately *Rhizophora* and the prop roots makes capture of *P. kauderni* very difficult thus impacting density measurements (Wiadnyana et al. 2020). The dominant density trend from 2004-2012 was negative (Ndobe et al. 2013), however, four sites (Bone Baru, Tinakin Laut, Monsongan, and Toropot) showed generally positive trends from 2012 surveys summarized by Ndobe et al. (2013) to the baseline and T1 surveys conducted under the NPOA (Wiadnyana et al. 2020). The negative trend from 2017 to 2018 at Tolokibit has been attributed to local sea urchin collection that became commercialized around 2017 and has resulted in a decline of sea urchin abundance (Wiadnyana et al. 2020). At Liang, the decline in the *P. kauderni* population appears to be due to microhabitat loss as well, specifically the collection of sea anemones and sea urchins (Wiadnyana et al. 2020). Remote sites within the southern Banggai Archipelago had generally low densities with negative population trends from 2017-2018 for some or all size classes: these sites include Mandel, Mbuang-Mbuang, Minangga, and Tj Nggasuang (Wiadnyana et al. 2020). The 2017 baseline survey found extremely low *P. kauderni* densities at four sites, with the Mandel site consider at risk for extirpation as well as a low percentage of juvenile fish at 14 of the 24 sites surveyed (Ndobe et al. 2018a; Ndobe et al. 2019). The majority of juveniles observed at the Bokan Islands' sites were below 25 mm SL. The marketable size range for the aquarium trade (25-35 mm SL) was depleted except at two sites: Toado and Minanga (Ndobe et al. 2018a).

It is important to note that the 2017 surveys are being used as the baseline to assess the effects of conservation efforts, not for evaluating population status since many sites have densities below previously reported densities (Ndobe et al. 2018a). Prior to the 2017 baseline survey, the most comprehensive survey conducted was in 2015, however, comparisons between the 2015 and 2017 surveys are difficult due to differences in survey locations, survey methods, data analysis, and data presentation (Ndobe et al. 2018a). In October 2019, a third survey (T2; second annual survey) was conducted at eight sites using the standard belt transact method (Ndobe et al. 2020). Overall, the 2019 data (Ndobe et al. 2020) showed a declining trend in the abundance of *P. kauderni* and key microhabitat organisms including sea urchins (*Diadema)* and nine of the ten host sea anemone species compared to the baseline and T1 surveys (see Section 2.3.1.6). However, it is important to note the timing of surveys related to timing of Banggai cardinalfish reproduction. In 2019, while very few recruits were observed at Toado, despite a high abundance of host sea anemones, a large number of brooding males were observed (Ndobe et al. 2020). If the survey were conducted several days later after the release of the young by the males, the results for the abundance of recruits would have been very different (Ndobe et al. 2020). The Toado site is in relatively good condition, with a close to stable *P. kauderni* population and with the appropriate protection, the short-term outlook is good (Ndobe et al. 2020). The sites within the marine tourism zones of the newly established Marine Protected Area (MPA) as descried in Section 2.3.1.5 (Mbuang-Mbuang, Melilis, part of Minanga, Kombongan, and Toropot) were in average condition and able to support a stable *P. kauderni* population, despite the sites having suffered significant habitat degradation, however, decline in microhabitat is the greatest threat to these sites (Ndobe et al. 2020; Section 2.3.1.6). In 2019, these sites had the highest abundance of sea urchin or anemone host species of the 8 sites surveyed (Ndobe et al. 2020). Mandel, located within the aquaculture sub-zone of the MPA, is on the verge of extirpation due to *P. kauderni* habitat (i.e., sea anemones and urchins) being intensively collected as observed during the 2019 survey (Ndobe et al. 2020). In addition, no juvenile *P. kauderni* were found at Mandel, reportedly due to intensive harvesting for the ornamental aquarium trade (Ndobe et al. 2020). Adult *P. kauderni* at Mandel were in a continuous decline from 2017-2019, however recruits were noted. The low numbers of adult *P. kauderni* at Mandel makes it appear that the recruits did not make it to adulthood, although the reason for this is unclear. Possible causes could be microhabitat collection, collection for the ornamental fish industry, or a combination of the two (Ndobe et al. 2020). At the Mandel site, 13 adult fish were present in 2019 and were mostly found in pairs, which may be a strategy to maximize breeding potential (Ndobe et al. 2020). According to Ndobe et al. (2018a) and presented at the 17th meeting of the Conference of the Parties (CoP17 Prop 46), all surveys since 2000 have reported declining trends in native *P. kauderni* populations at a majority of sites surveyed (total population declines range from 36-90%) and extirpation of several populations.

In 2000, an earthquake damaged *P. kauderni* habitat in Liang Harbor, completely destroying a jetty used as habitat. Later in 2004, *P. kauderni* had a thriving population among the ruins but habitat degradation due to coral mining reduced the population to just one group of 11 individuals in 2012 (Moore et al. 2019c). No fish were found at this location in 2014 or in May 2018 (Moore et al. 2019c) but another survey in November-December 2018 (Wiadnyana et al. 2020) indicated signs of recovery with densities improving from < 0.05 fish per m^2 in October 2017 to between 0.05 to 0.1 fish per m^2 in 2018. A study conducted in July 2017 by Ndobe et al. (2018b) noted 0.266 fish per m^2. It is difficult to determine if the studies occurred in the same locations and used the same sampling methodology.

In 2018, a storm affected the village of Monsongan, impacting benthic habitat and reducing the population abundance of *P. kauderni* (Moore et al. 2019c; see Section 2.3.1.6). The population after the storm was an adult/sub-adult-dominated size structure due to the loss of several cohorts, with recent recruits and small juveniles absent in most groups (Moore et al. 2019c). The missing cohorts may have been a result of direct mortality during the storm event as well as the elevated risk of predation (including cannibalism) after the storm due to the lack of microhabitat available for protection (Moore et al. 2019c).

Demographic features of *P. kauderni* are summarized in the 2015 status review (Conant 2015) and briefly in Section 2.3.1.1 as well as in Ndobe et al. 2018a (based on Ndobe et al. 2013). *P. kauderni* mature at <1 year of age which corresponds to approximately 40 mm SL. The number of eggs in an egg mass ranges 20-102 (mean = 59) while the number of egg brooded ranges 45-99 (mean = 59). The minimum population doubling time is 1.4-4.4 years. The natural mortality (M; based on water temperature 28ºC) and the fishing mortality (F) are both 2.2. The sex ratio is approximately 1:1, with a tendency towards male bias. *P. kauderni* live 3-5 years.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

No genetic data exists for many sites in the Banggai Archipelago, but the data that does exist suggests that each small island and bay could be treated as separate stocks or populations (Figure 2; Ndobe et al. 2018a; Moore et al. 2019c). Larger islands may host several *P. kauderni* populations; several reproductively isolated populations have been identified, separated by as little as 2 km (Ndobe et al. 2019). At least 21 populations are supposed by existing genetic data, 18 of which are within the Banggai Archipelago (Ndobe et al. 2019). As noted below in Section 2.3.1.5, populations of *P. kauderni* have been introduced in some areas complicating the understanding of genetic diversity and structure (Ndobe et al. 2019) as the capture and release within its endemic distribution has resulted in the mixing of genetic strains that may have been reproductively isolated for 100,000 years or more (Vagelli et al. 2009; Ndobe et al. 2019). The restocking plans proposed in Indonesia's NPOA for conservation and management may further mix populations of *P. kauderni* (Moore et al. 2021). Genetic swapping could be a concern if wild-caught *P. kauderni* or captive-bred descendants are released into an area with individuals of different populations within their natural distribution (Moore et al. 2021).

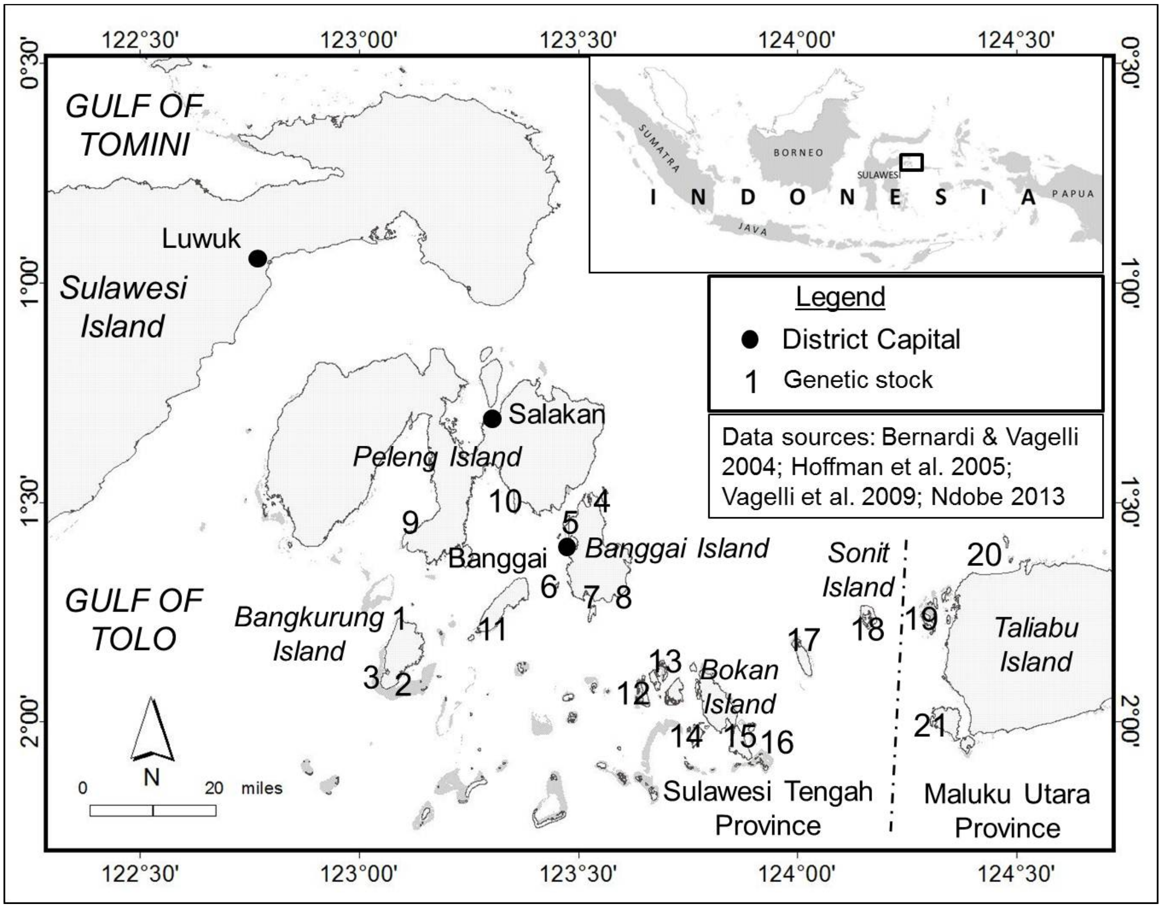


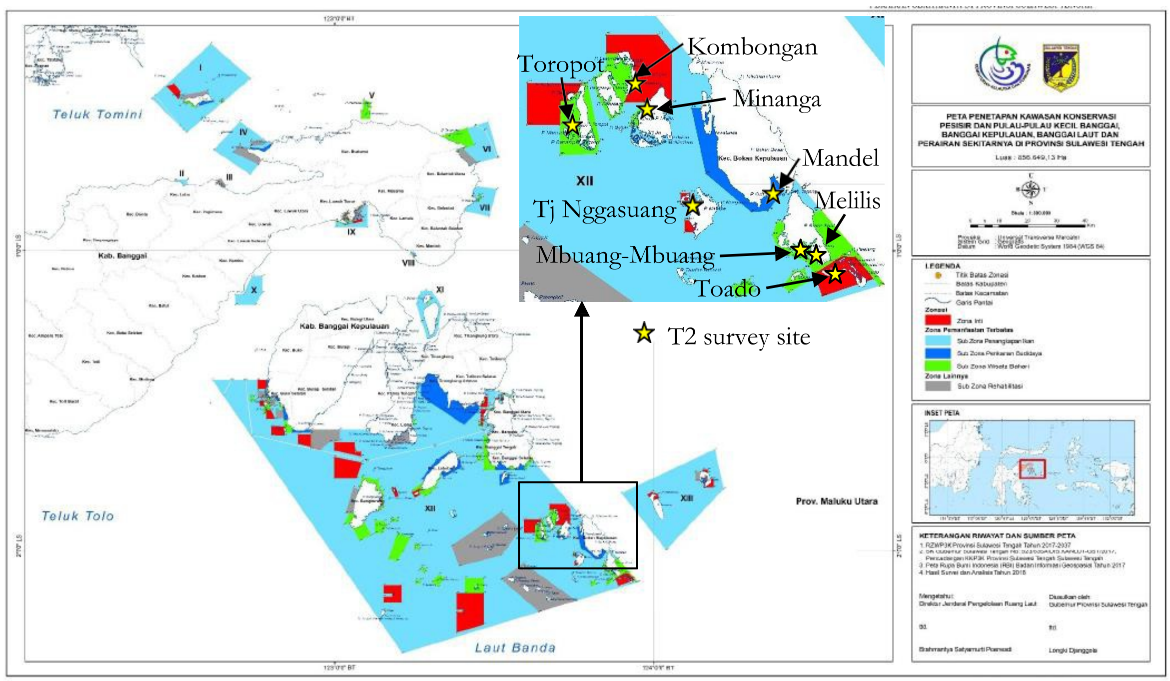
Figure *2*. Inferred Banggai cardinalfish (*Pterapogon kauderni*) stocks based on existing genetic (mtDNA & microsatellite) data (adapted from Moore et al.[35], compiled from several studies[12,19,21,42]). (Source: Ndobe et al. 2018a Figure 2).

2.3.1.4 Taxonomic classification or changes in nomenclature:

No changes since the status review (Conant 2015).

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

P. kauderni is a relatively small marine fish endemic to the Banggai Archipelago, Central Sulawesi, Indonesia, where its distribution is limited to 20-34 km^2 of shallow-water habitat around 34 islands (Figure 3; Vagelli 2017; Ndobe et al. 2018a; Wiadnyana et al. 2020). On November 27, 2019, the Banggai MPA was officially established (Ndobe et al. 2019; Ndobe et al. 2020; Figure 3). The rationale for establishing the MPA was for the conservation of *P. kauderni* and its habitat; the MPA includes approximately 90% of the endemic distribution (Ndobe et al. 2019; Ndobe et al. 2020). The spatial distribution and historical range of the endemic *P. kauderni* remain unchanged from what was described in the 2015 status review (Conant 2015).



Locations of introduced populations of Banggai cardinalfish reported in literature include Lembeh Strait, Tumbak, Luwuk harbor, Luwuk Kilo 5, Mamboro and Kadongo in Palu Bay, Kendari, and North Bali (Ndobe et al. 2018a; Ndobe et al. 2019). Within the Banggai Archipelago but outside of the endemic range of *P. kauderni*, aquarium traders are known to have released this species at Lumbi-Lumbia, Pulau Bakalan, and Paisuluno (Ndobe et al. 2018a). In 2017, it was reported that approximately 10,000 individuals were released in Ambon, Maluku Province by the Indonesian Ministry for Marine Affairs and Fisheries (MMAF) Ambon Mariculture Centre (Ndobe et al. 2018a). *P. kauderni* is also known to have been introduced in Bali Strait around the Secret Bay (Gilimanuk), a narrow bay with a depth of approximately 10 meters (Putra and Putra 2019). In June 2018, an underwater visual census surveys were conducted, using a transect set in areas identified by fishers as the main areas of *P. kauderni* to record the number of fish groups, the number of fish in each group, and the habitat types (Putra and Putra 2019). The surveys found 30 groups with a mean group size of 12.7 individuals (range 2-133) and average densities of 0.76 individuals per m^2 (Putra and Putra 2019). Introduced populations seem to have lower numbers of individuals per group and densities compared to endemic *P. kauderni* populations which may have 2-500 individuals per group and 0.5-3 individuals per m^2 (Putra and Putra 2019). Anecdotal information indicates there may have been further introductions of *P. kauderni* at other sites (Ndobe et al. 2018a). Releases of *P. kauderni* outside of its natural distribution do not comply with IUCN guidelines for species conservation (Moore et al. 2020a).

As noted in the final rule to list the Banggai cardinalfish as threatened under the ESA (81 FR 3023), introduced populations outside of the Banggai cardinalfish's natural range may not contribute to the species' ability to persist, and therefore were not included in the analysis of the overall extinction risk to the species. For further discussion on introduced populations and collections for the aquarium trade, see Section 2.3.2.2 below.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

In mid-2015, initial signs of coral bleaching in Central Sulawesi were noted in all four seas around the Indonesian Province of Central Sulawesi: Sulu-Sulawesi Sea, Makassar Straits, Tomini Bay, and Gulf of Tolo (Moore et al. 2017a). These areas include three major small island groups: the Togean, Menui, and Banggai Archipelagos. The Banggai Archipelago, encompassing the natural range of *P. kauderni,* is close to, if not at, the centroid of coral distribution for all Indo-Pacific corals, specifically the genus *Acropora*, and is thus considered the heart of the coral triangle (Moore et al. 2017a). Coral bleaching data were collected during May 2016 when the MMAF issued a call to stakeholders requesting assistance in collecting data to record the extent and severity of coral bleaching as the 4th global scale mass bleaching became apparent (Moore et al. 2017a). The coral bleaching data were collected from seven sites in the Banggai Archipelago using the CoralWatch method that was modified to include collection of data on coral colony lifeform using the Global Coral Reef Monitoring Network categories (Figure 4; English et al. 1997; Moore et al. 2017a). Observed coral colonies were identified to the genus level and a thermometer affixed to measure water temperature (Moore et al. 2017a). Data were concurrently collected on *P. kauderni* abundance and size class as well as the abundance and size of *Diadema* sea urchins (Moore et al. 2017a). The majority of coral colonies were partially bleached but otherwise normal in color (Moore et al. 2017a). In the Bone Baru community-based marine protected area, a decline in *P. kauderni* and *Diadema* species was noted, as well as a decrease in live coral cover and an increase in rubble and dead coral with few fish and non-sessile invertebrates recorded (Moore et al. 2017a). On average, water temperature in the shallow coastal waters of the Banggai Archipelago range between 25ºC to 31ºC (average 28ºC), however, the average water temperature during the May 2016 survey was about 4ºC above the average for the area (Moore et al. 2017a). Ndobe et al. (2017) compared the 2016 coral bleaching survey data to that collected in 2004 and noted a sharp decline in abundance of both *Diadema* sea urchins and sea anemone and attributed it most likely due to harvest for human consumption. They also noted coral reef degradation due to both local-scale human activities as well as climate-related coral bleaching and in these areas where microhabitat was greatly reduced so was the abundance of *P. kauderni* regardless of fishing pressure. In 2018, Moore et al. (2019a) confirmed that increased harvest, mostly for human consumption, of *Diadema* urchins is the driver for reduced abundance across much of the endemic range of *P. kauderni*. The decline in sea urchin numbers is increasing the importance of the cover provided by corals, specifically scleractinian corals, for larger size classes of *P. kauderni* (Moore et al. 2019a). During the 2016 bleaching event, corals and other life forms that serve as *P. kauderni* microhabitat were disproportionately affected and higher than normal water temperatures at Tolokibit in 2018 affected more potential microhabitat (Moore et al. 2019a). Sea anemones that were totally or partially bleached were inhabited by *P. kauderni* and clownfishes (*Amphiprion* spp.) in 2016 and 2018 at Tolokibit and at Bone Baru in 2016 (Moore et al. 2019a). It is unknown if bleaching of sea anemones and corals will impact *P. kauderni* by a disruption of food changes or symbioses (Moore et al. 2019a; Moore et al. 2019c).

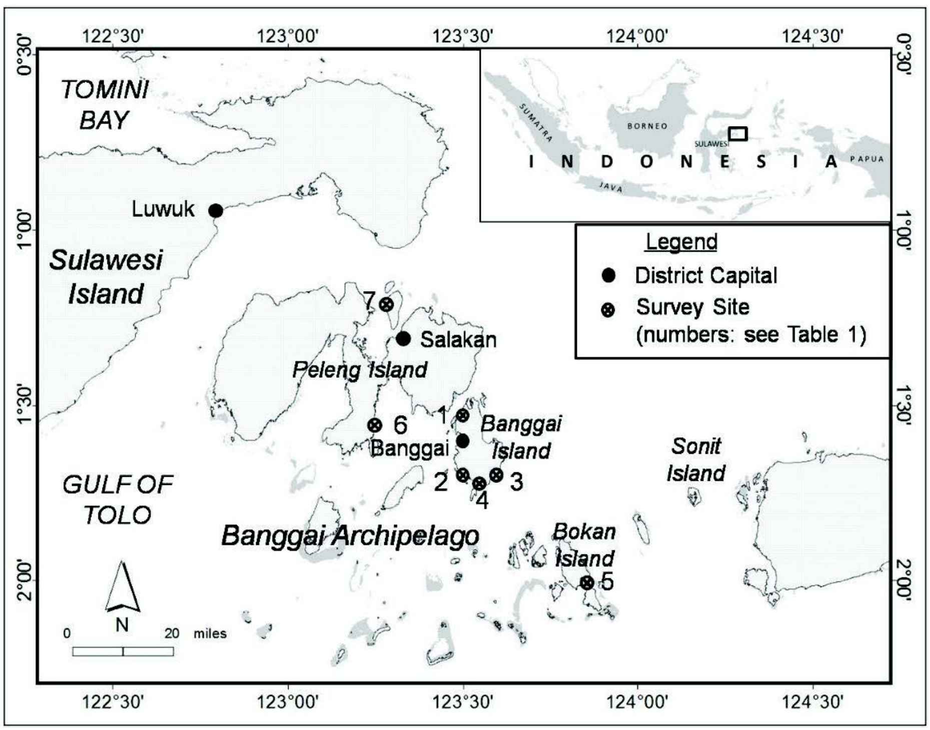


Figure *4*. Map of Central Sulawesi Province showing survey sites. Approximate coordinates: Bone Baru S1º32', E123º29'; Tolokibit: S1º43', E123º31'; Pompon: S1º44', E123º33'; Kapela: S1º42', E123º34'; Mbuang-Mbuang: S2º05', E123º52'; Bakalan: S1º12', E123º16'; Liang: S1º33', E123º14'. (Source: Moore et al. 2017a Figure 1). These locations were surveyed for coral bleaching in May 2016. Surveys also included abundance of *P. kauderni* and *Diadema* urchins.

In October 2017, Moore et al. (2020a) evaluated *P. kauderni* associations with sea anemones through field surveys at 15 sites. Across the 15 surveyed sites, six species of sea anemones were recorded as hosting *P. kauderni*: *Actinodendron* spp., *Heteractis crispa*, *Entacmaea quadicolor*, *Stichodactyla gigantea*, *S. haddoni*, and *H. aurora* (Moore et al. 2020a). Most of the *P. kauderni* associated with these species were recent recruits and small juveniles, however, a few adults were also observed as well as brooding males (Moore et al. 2020a). The sea anemone *Stichodactyla gigantea*, the fourth most common host noted in this study, was rare or absent from many of the sites during the survey (Moore et al. 2020a). However, the abundance of sea anemones (genus *Actinodendron*) remained relatively consistent over time, even at sites with environmental degradation, thus the availability of these species could be a reason for the high frequency of *Actinodendron* spp. acting as a host for *P. kauderni* (Moore et al. 2020a). On average, *Actinodendron* spp. hosted more *P. kauderni* per sea anemone than other anemone species (Moore et al. 2020).

In 2017, a survey was conducted at 20 sites in the Banggai Archipelago and Makassar Strait to determine the biodiversity and distribution of *Diadema* sea urchins and to identify at the species level the urchins associated with each size class of *P. kauderni* (Moore et al. 2019d). Based on morphology, 74% of sea urchins observed were identified as *D. setosum*, 24% as *D. savignyi*, and approximately 2% were undetermined; *P. kauderni* associated with all species and structures present (Moore et al. 2019d). Individuals and groups of *P. kauderni* were found to move between sea urchins without making any apparent distinction between species or form within mixed *Diadema* species flocks (Moore et al. 2019d). In the Banggai Archipelago, *Diadema* urchins overlap but have different patterns of habitat use, for example, *D. setosum* was more abundant closer to villages and port areas where *D. savignyi* tended to be rare or absent (Moore et al. 2019d). At Toado, *Diadema* urchins and other typical microhabitats for *P. kauderni* are rare so the majority of *P. kauderni* observed at this site were swimming between the prop roots of mangroves (genus *Rhizophora*) (Moore 2019d). Moore et al. (2020b) conducted experimental behavioral trials in a laboratory setting and concluded imprinting may play a significant role in *P. kauderni* microhabitat preference since *P. kauderni* recruits collected from sea anemones showed little or no interest in sea urchins while those recruits collected from *Diadema* microhabitat swam towards sea urchins immediately or shortly thereafter during choice experiments.

A survey conducted at eight sites in October 2019 using the standard belt transect method showed microhabitat abundance and *P. kauderni* association with specific microhabitat differed between sites (Ndobe et al. 2020). The percentage of *P. kauderni* associated with sea urchins showed a decline and the proportion associated with hard corals increased from 6% to 27.4% from 2017 to 2019 (Ndobe et al. 2020). There was a decline in the diversity and abundance of host anemone species but an increase in proportion of fire anemones (genus *Actinodendron*) (Ndobe et al. 2020). The shift in microhabitat association towards corals mirrors the decline of sea urchins (*D. setosum* and *D. savignyi*) (Ndobe et al. 2020). However, recruit and juvenile survival is highly dependent on sea urchin and sea anemone microhabitat (Moore et al. 2019a; Moore et al. 2020a; Ndobe et al. 2020). At Mbuang-Mbuang, Melilis, part of Minanga, Kombongan, and Toropot (sites located within marine tourism zones in the

MPA), the greatest threat to *P. kauderni* populations appeared to be declines in microhabitat abundance; the main driver of these declines is the harvest mostly for human consumption (Ndobe et al. 2020). Ndobe et al. (2020) recommends the promulgation of regulations to limit or impose a moratorium on *Diadema* and sea anemone collection at these sites in order to protect *P. kauderni* habitat.

At the Mandel site, intensive collection was observed during the 2019 survey. No live adult sea urchins were observed in 2019, however a few juvenile sea urchins were in crevices and empty shells were visible (Ndobe et al. 2020). In 2017, *Diadema* sea urchins were abundant at the Mandel site, with over 75 individuals per transect, a density higher than the sites surveyed in 2019. The decrease in *Diadema* sea urchins is likely due to collection (Ndobe et al. 2020). Ndobe et al. (2020) recommends an immediate moratorium on microhabitat collection to allow sea urchin stocks to rebuild and protect the remaining sea anemones. Protecting the microhabitat at the Mandel site may encourage recruitment of *P. kauderni* (Ndobe et al. 2020; see Section 2.3.1.2).

In early 2018, a severe storm affected the village of Monsongan, shifting large stones and tossing a variety of benthic organisms ashore, including a considerable number of *Diadema* sea urchins (Moore et al. 2019c). While *P. kauderni* probably perished during the storm, the loss of key habitat resulted in impact lasting beyond the event as noticed 2-3 months later when mortality of *Diadema* urchins was still visible (Moore et al. 2019c). During that time, 10%-25% of sea urchins were present compared to October 2017, and these were mostly juveniles, occupying a reduced spatial extent (Moore et al. 2019c).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

In 2015, an estimate of suitable habitat within *P. kauderni* endemic range was 20 km^2, a reduction in the initial estimate made in 2005 (34 km^2) (Ndobe et al. 2018a). The 2015 status review noted a total inhabited area encompasses approximately 30 km^2 around 34 islands (Conant 2015). Due to threats discussed here and in Sections 2.3.1.6 and 2.3.2.5, there is heavy pressure on shallow ecosystems and the microhabitat needed for *P. kauderni* (Ndobe et al. 2018a).

Sea anemones that host *P. kauderni* have several life history traits that make them vulnerable to overexploitation: long life, limited breeding seasons, and density-dependent fertilization (Moore et al. 2020a). Overexploitation and direct anthropogenic damage are the immediate causes of *P. kauderni* habitat degradation, despite the likelihood of impacts from climate change (Table 1; Moore et al. 2019a). In 2017, during a survey of over 15 sites, the sea anemone *S. gigantean* was absent from most sites (Moore et al. 2020a). In the Banggai Archipelago, this sea anemone has been collected more than any other sea anemone species for the marine ornamental trade and also for human consumption (Moore et al. 2020a). The 2016 bleaching event (see Section 2.3.1.6) may have been the worst (to date) in Indonesian waters when sea temperatures reached 32-33ºC (34ºC peak) with inferred mortality disproportionately impacting coral genera, sea anemones, and other life-forms serving as microhabitat for *P. kauderni* (Moore et al. 2019c). Temperature-related bleaching is likely to impact habitat quality and availability for *P. kauderni* affecting reproductive potential and success (Moore et al. 2019c). For example, bleaching may disrupt symbiosis and food chains (Moore et al. 2019c). Inferred mortality from bleaching events indicate a high impact on coral genera and other life-forms that serve as microhabitat for *P. kauderni*, which may limit their availability for use as micro-habitat (Moore et al. 2019c). There is also evidence of predation of *D. setosum* on *P. kauderni* in laboratory studies when temperature was maintained at 33ºC (Moore et al. 2019c).

Table *1*. Synopsis of some likely impacts of global change on *P. kauderni* and its microhabitats. (Source: Moore et al. 2019a Table 4).

Type of change	Type of impact	Likelihood of negative effects[a]			
		BCF	DD	AN	HC
Seawater temperature • higher averages, daily minima and maxima	Metabolism/physiology/ risk of exceeding thermal tolerance/acclimation capacity/ disruption of symbioses	yes	yes	yes	yes
• more frequent and longer extremes	Lower O2 availability	yes	?	?	?
	Disruption of food chains	yes	yes	yes	yes
Weather patterns	Physical damage/mortality	yes[c]	yes[c]	?	yes
• more frequent/ severe storms	Elevated risk of predation on/mortality of recruits	yes			
• precipitation patterns	Water quality: salinity, pH, turbidity, pollution, etc. (direct/indirect on habitat)	yes	yes	yes	yes
Ocean acidification • lower seawater pH	Impaired calcification affecting skeleton growth and/or strength	?	yes	no	yes
• lower aragonite saturation/other chemical changes	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

[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
[c] Moore, unpublished data, 2018. *Diadema* and some *P. kauderni* thrown ashore during a storm in early 2018

Trends from 2011-2012 compared to 2017-2018 shows declining trends in both abundance and average size of *Diadema* urchin microhabitat which may be a result of the increase in scale and shift towards commercial exploitation as noted at Tolokibit where bi-monthly collection and sale of sea urchins occur (Table 2; Ndobe et al. 2019). While the sea urchin fishery is not illegal, the unregulated and unreported harvest of shallow-water invertebrates can be a major threat to endemic populations of *P. kauderni* (Moore et al. 2017a). One of several policy options discussed by Moore et al. (2017b) is a concept to rebuild *P. kauderni* populations and rehabilitate and protect important micro-habitat. Although *P. kauderni* associate with abiotic habitat (e.g., manmade structures), their association may be temporary (Ndobe et al. 2018b).

Table 2. Trends in *P. kauderni* habitat (ecosystem) and microhabitat at 10 sites (Source: Ndobe et al. 2019 Table 1).

Survey Site				Ecosystem		Habitat Condition 2011/2012		2017/2018	Micro-habitat trend
No.	Name	Typology	Exposure	Main type[a]	Extent (trend)	State	Trend[b]	Trend[c]	
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

Damage from mining coral as building material has been observed and may get worse under planned reconstruction and development following tectonic activity (Moore et al. 2015). More information is needed to determine whether coral is still being mined for these purposes.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

The Banggai cardinalfish (*P. kauderni*) is a popular marine ornamental fish which has been heavily traded in the aquarium trade since its rediscovery in the mid-1990s (Conant 2015; Vagelli 2017; Ndobe et al. 2019). Using criteria developed by the Nature Conservancy for identifying species at high risk Moore et al. (2019b) noted *P. kauderni* fulfills 6 of the 8 criteria: 1) Easy to catch; 2) Economic value; 3) Low reproductive capacity; 4) Exploited and/or at risk throughout life-cycle; 5) Limited distribution; and 6) Limited habitat within distribution.

Using a report released annually by the MMAF, Republic of Indonesia, Akmal et al. (2020) noted the number of fish species and total weight of fish captured and exported as ornamentals in the aquarium trade between 2015 and 2019 from Indonesia. Of the 501 fish species, only *P. kauderni* was noted to have been cultured in captivity but also captured in the field (Akmal et al. 2020). Akmal et al. (2020) noted that *P. kauderni* reproduces well in captivity and could serve as a model for breeding ornamental fish in aquaria. *P. kauderni* is captured in large quantities; current estimates are between 500,000 and 900,000 individuals annually (Ndobe et al. 2018a; Akmal et al. 2020). Introduced populations are not yet protected, therefore no collection permit is needed for these populations such as the introduced population in Bali Strait (Putra and Putra 2019). Under ministerial regulation (MMAF Regulation No. 61/2018), utilization and trade of *P. kauderni* requires a fish utilization permit, a harvest quota permit, and a fish transport permit (CITES 2021). Around 16 species of cardinalfish have been cultured; the most commonly cultured species are *P. kauderni* and *Sphaeramia nematoptera* (pajama cardinalfish) (Groover et al. 2020).

P. kauderni was ranked 10th, 11th, and 8th most imported aquarium fish into the United States in 2008, 2009, and 2011, respectively (Rhyne et al. 2017a). Wild-captured *P. kauderni* imported into the United States between 2005 and 2011 range from approximately 118,000 to 160,000 individuals annually (Figure 5; Rhyne et al. 2017a). Imports of captive-bred *P. kauderni* from Thailand in 2013 was approximately 75% of the average import total for 2008, 2009, and 2011 and import declarations listed the size range as 1 to 1.5 inches; a 1 inch fish is smaller than the average wild-caught fish (Rhyne et al. 2017a). Shipment manifests also listed the number of dead fish on arrival as < 0.5% for wild-caught *P. kauderni* (Rhyne et al. 2017a). In several cases, the shipments were incorrectly labeled as wild-caught when they were in fact captive-bred which emphasizes the need for accurate and timely trade data to sustainably manage the species (Rhyne et al. 2017a).

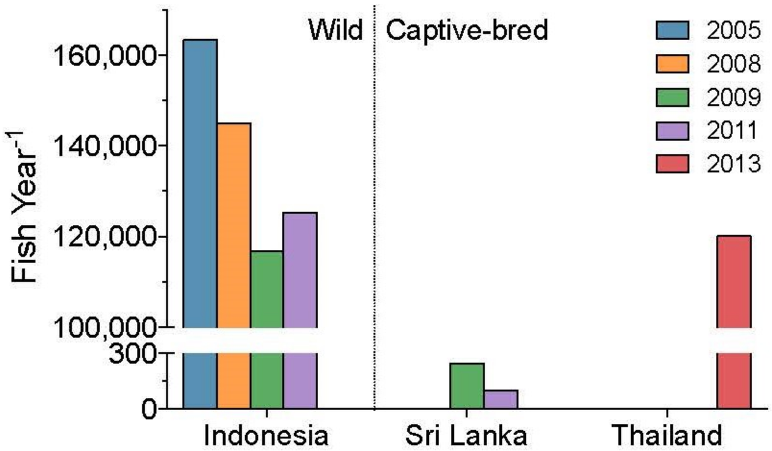


Figure 5. Annual volume of Banggai cardinalfish (*Pterapogon kauderni*) into the United States by top export countries. Exports from Sri Lanka (2009-2011) and Thailand (2013) illustrate the likely prevalence of previous unrecognized captive-bred *P. kauderni* in the trade. (Source: Rhyne et al. 2017a Figure 8).

Ndobe et al. (2018a) noted government and private sector *P. kauderni* breeding facilities in Ambon, Makassar, Bali, and the Jakarta area, yet the contribution of cultured animals from Indonesia to overall trade is not yet significant in terms of numbers of fish. In February 2018, a breeding facility in Bone Baru was established with the support of MMAF and was successfully producing large numbers of offspring, however, the facility was trying to find solutions to high broodstock mortality they were experiencing (Ndobe et al. 2018a). In summary, the majority of trade in *P. kauderni* is of wild-caught fish from Indonesia (Ndobe et al. 2018a) while the majority of fish exported from Thailand are captive bred. A productivity-susceptibility analysis conducted by Baillargeon et al. (2020) noted *P. kauderni* had high vulnerability and high susceptibility scores (related to the fishery and trade) and recommended its listing under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to require trade restrictions. Dee et al. (2019) used a Productivity Susceptibility Analysis to evaluate the vulnerability of 72 species popular in the U. S. aquarium fish trade and found *P. kauderni* is one of the top ten most vulnerable species (combination of productivity [low] and susceptibility [high]). For vulnerable species, management (e.g., species-specific harvest limits) and increased monitoring of population trends could reduce vulnerability as well as sourcing "most vulnerable" species with individuals produced from aquaculture (Dee et al. 2019). Biondo et al. (2017) quantified the trade of marine ornamental fishes into Switzerland and *P. kauderni* ranked 6th (413 specimens) in 2009, the only species listed as endangered on the International Union for Conservation of Nature (IUCN) Red List. These authors also suggested the listing of *P. kauderni* in CITES is warranted. While past attempts to include *P. kauderni* in the CITES appendices has failed (Ndobe et al. 2019), Indonesia has responded with a commitment to better manage and conserve the species. Rhyne et al. (2017b) and others (Biondo 2017; Biondo and Burki 2019) have noted a need to track trade and develop data resources that include all species in wildlife trade regardless of their CITES status. In general, researchers noted it is difficult to track collection and aquarium trade of *P. kauderni* including collection of introduced populations. In north Bali, a location known to have an introduced population of *P. kauderni*, significant numbers of *P. kauderni* are collected for the aquarium trade (Lilley 2008). However, additional information is needed to determine if other introduced populations are collected and the volume these populations account for in the aquarium trade.

Indonesia noted successful trials have been carried out in several aquaculture facilities to rear captive-bred individuals to supply the aquarium trade - Ambon Marine Aquaculture Fisheries Center (BPBL Ambon), Gondol Center for Marine Aquaculture Research and Fisheries Counseling (BBRBLPP Gondol), Paisubatango Estuarine Fish Hatchery Center (BBIP Paisubatango), and Bitung Marine Biota Conservation Center (LKBL Bitung) (CITES 2021).

2.3.2.3 Disease or predation:

Wild *P. kauderni* can carry internal parasites, ectoparasites, and pathogens (*Vibrio alginolyticus*). Internal parasites include trematodes and nematodes, incysted isopods, pleurocercoid cestode larvae, and unidentified parasite eggs (Ndobe et al. 2018a). Potentially pathogenic ectoparasites of the following genera have been reported from wild *P. kauderni* traded from the Banggai Archipelago: *Chilodonella, Trichodina, Amyloodinium, Vorticella, Zoothamnium,* and *Ichthyopthirius* (Ndobe et al. 2018a). Bacteria identified in fish collected from fishermen include: *Alcaligenes faecalis, Micrococcus luteus, Acinetobacter* spp., *Plesiomonas shigelloides, Yersinia enterocolitica,* and *V. alginolyticus* (Ndobe et al. 2018a). Prior to export, it is estimated that there is 55% mortality (die or are destroyed prior to export) (Dodds 2009), although the cause of the deaths is not discussed in detail. According to Dodds (2009), during shipping from exporter to the distributor, it is estimated that 99% of *P. kauderni* suffer mortality; although this may be an unrealistic estimate. The stressful conditions during holding and shipping have an impact on the survival of the species with iridovirus (Banggai cardinalfish iridovirus or BCIV) and bacteria (genus *Vibrio*) contributing to mortality (Akmal et al. 2020; Ndobe et al. 2018a).

2.3.2.4 Inadequacy of existing regulatory mechanisms:

In 2014 under the regional autonomy law, there was a shift in jurisdiction from District to Provincial level over waters 0-4 nm from the coastline which, at the time, was a factor in the increase in illegal and destructive fishing practices (Ndobe et al. 2019). As a result by 2017, many informal (e.g., community MPA) and formal (e.g., routine patrols) management practices ceased to function (Ndobe et al. 2019).

In 2016, a second proposal to list *P. kauderni* in CITES Appendix II was unsuccessful but resulted in decisions that tasked Indonesia with ensuring sustainability of international trade of *P. kauderni* by implementing conservation and management measures (Ndobe et al. 2019). Indonesia has begun implementing a NPOA that identifies both effective management and establishes the Banggai Dalaka Marine Protected Area (MPA) (Ndobe et al. 2019). In 2018, the MMAF issued a decree which gave *P. kauderni* limited protected status with spatial and temporal limitations on harvests; closed seasons are February-March and October-November. These closures apply within the restricted use area of the Banggai Dalaka MPA (Ndobe et al. 2019). The regulation does not include any provisions to promote population-based management or prevent depletion of populations during then harvest season (Ndobe et al. 2019). NPOA priorities for *P. kauderni* conservation, as listed and assessed by Ndobe et al. (2019), include: 1) prioritize endemic populations; 2) protect genetic diversity through site/stock-based management; 3) protect and rehabilitate *P. kauderni* habitat and microhabitat; 4) investigate, record in-country movements of *P. kauderni*; 5) regulate and restrict the release of *P. kauderni* to the wild from captivity and/or between known/suspected genetic stocks; 6) institutionalization to provide robust and resilient conservation management; and 7) further research on potential climate change impacts and their mitigation in a local context. Ndobe et al. (2019) believe these priorities will help the NPOA to succeed in implementing its six focal aspects and planned activities during the period of 2017-2021.

On November 27, 2019, the Banggai Dalaka MPA was officially established (Ndobe et al. 2019; Ndobe et al. 2020). The MPA was established for the conservation of *P. kauderni* and its habitat. Most of the endemic distribution area (approximately 90%) lies within the MPA (Ndobe et al. 2019; Ndobe et al. 2020). The MPA spans three districts (Banggai, Banggai Kepulauan, and Banggai Laut) and has four main conservation targets: tropical coastal ecosystems, *P. kauderni* populations and habitat, other protected/priority conservation species, and fisheries resources (Ndobe et al. 2019). Moore et al. (2019c) suggest that in order for *P. kauderni* conservation to be effective, measures should be aimed at the population level and any transfer of *P. kauderni* between populations should be avoided except in exceptional circumstances. In 2020, the Central Sulawesi Government formed the Banggai Dalaka MPA management unit through the Central Sulawesi Governor Regulation No. 51 (CITES 2021). The main task of the management unit is to manage and oversee utilization of marine and fishery resources in Banggai Dalaka MPA (CITES 2021).

The NPOA requires reporting fish ornamental consignments to the Fish Health and Quarantine Service. This has led to improved reporting and the volume of consignments from Luwuk Fish Quarantine represents the legal trade volume of *P. kauderni* in the Banggai Archipelago (Ndobe et al. 2019). However, these data do not represent all *P. kauderni* leaving the Banggai Archipelago and the analysis of the data from the Fish Health and Quarantine Service database shows a mismatch between recorded dispatches and arrivals, with no record of the arrival of the majority (50-90%) of the fish dispatched between 2015 and May 2018 (Ndobe et al. 2019). Ornamental fish collected in the Banggai Archipelago are sent to major export trade centers, with Denpasar the main point of export followed by Jakarta and Surabaya. However from 2014-2016, exports from Kendari increased exponentially from approximately 150,000 to 450,000 *P. kauderni* (Ndobe et al. 2019). Shipments into Kendari represent a small fraction (~2%) of the volume and it is unlikely that introduced populations in Kendari could have produced this volume, thus it is assumed that fish may have been caught and illegally transported out of the Banggai Archipelago (Ndobe et al. 2019). Although only supported by anecdotal evidence, potential illegal capture within the southern area of the Banggai Archipelago may be occurring given the sighting of fishing boats from outside of the area along with low *P. kauderni* densities at several remote sites reportedly not fished by local fisherman and the population structure displayed a gap in marketable-size juvenile *P. kauderni* (approximately 25-35 mm SL) (Ndobe et al. 2019).

On June 1, 2021, the CITES Animals Committee met and briefly discussed *P. kauderni* and the information provided by Indonesia as an update to previous proposals seeking listing (CITES 2021). Indonesia reported on actions and measures to conserve and manage *P. kauderni* which includes harvest quota, business registration, and permitting (CITES 2021). The Animals Committee acknowledged Indonesia's efforts which it determined have resulted in positive outcomes for *P. kauderni* conservation and management. The Committee acknowledged the current status of *P. kauderni* as a non-CITES-listed species and, referring to Indonesia's progress, encouraged it to continue its work to promote the conservation, management and sustainable trade in *P. kauderni* and to present this case to the upcoming CITES technical workshop on marine ornamental fishes. The Animals Committee decided it will no longer specifically discuss *P. kauderni* as its own agenda item at each Animals Committee meeting. Instead, *P. kauderni* will be included in the discussions on CITES work on marine ornamental fish.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

The Banggai Archipelago region is at risk from earthquakes and tsunamis of a magnitude to be considered disasters and past events have damaged *P. kauderni* habitat and possibly resulted in changes in habitat availability (loss or gain) due to altered bathymetry at some sites (see Sections 2.3.1.2 and 2.3.1.6; Moore et al. 2019c). In addition, climate-related disasters, such as severe weather events and high temperature anomalies have and could continue to occur in the Banggai Archipelago that could affect *P. kauderni* or the microhabitats it depends upon (see Section 2.3.1.6; Moore et al. 2019c). Results from laboratory research suggest the survival of adult *P. kauderni* decreased and morbidity increased above 31ºC with close to 50% mortality after one week at 33ºC (Ndobe et al. 2019). Global climate change along with observations on *P. kauderni* and its microhabitat indicate under current trends extirpation of this species in the wild within its endemic range may occur (Moore et al. 2019c; Ndobe 2019).

2.4 Synthesis

Since the initial status review and listing of the species as Threatened under the ESA, there have been several studies published that evaluate the abundance of *P. kauderni*. These population studies are difficult to compare to determine trends because survey sites and methods varied among years. However, these studies have noted a decline in populations at several sites but also an increase at some sites within the endemic range of *P. kauderni*. It was noted that the timing of the surveys is important to adequately reflect the life stages present. Using a 2015 revised total habitat area of approximately 20 km^2, the current population is estimated to be approximately 1.4 million fish, which was also noted in the 2015 Status Review (Conant 2015).

No genetic data exists for many sites in the Banggai Archipelago, but the data that does exist suggests that each small island and bay could be treated as separate populations. Genetic swapping could result from the mixing of *P. kauderni* from different areas for the restocking plans proposed in the NPOA and could be a concern if wild-caught *P. kauderni* or captive-bred descendants are released into new areas within their natural range. The Indonesian government is planning to conduct genetic analysis of populations when funding and resources become available (CITES 2021).

The spatial distribution and historical range of the endemic *P. kauderni* remain unchanged from what was described in the 2015 status review. On November 27, 2019, the Banggai Dalaka MPA was officially established for the conservation of *P. kauderni* and its habitat. Most of the endemic distribution (approximately 90%) lies within the MPA. Releases of *P. kauderni* outside of its natural distribution have been reported at 15 sites within Indonesia. Introduced populations seem to have lower numbers of individuals and densities per group compared to endemic *P. kauderni* populations which may have 2-500 individuals per group and 0.5-3 individuals per m^2.

The Banggai Archipelago is considered the heart of the coral triangle where in 2016, data were collected to record the extent and severity of coral bleaching as the 4th global scale mass bleaching became apparent. The average water temperature recorded during the May 2016 was 32-33ºC, about 4ºC above the average for the area and bleaching was observed at survey sites. Researchers have noted coral reef degradation due to both local-scale human activities as well as climate-related coral bleaching and in these areas where microhabitat was greatly reduced, so was the abundance of *P. kauderni* regardless of fishing pressure. Increased harvest, mostly for human consumption, of *Diadema* urchins is affecting sea urchin populations across much of the endemic range of *P. kauderni*. The decline in sea urchin populations has increased the importance of corals that provide cover, specifically scleractinian corals, for larger size classes of *P. kauderni*. The threats to *P. kauderni* habitat and microhabitat are the same as those discussed in the 2015 status review (Conant 2015).

As noted in the 2015 status review, *P. kauderni* is a popular marine ornamental fish that has been heavily traded in the aquarium trade since its rediscovery in the mid-1990s. The current trade estimates are between 500,000 and 900,000 individuals annually (Ndobe et al. 2018a; Akmal et al. 2020) which is comparable to the annual numbers noted in the 2015 status review (Conant 2015). Tracking the trade of *P. kauderni* is very difficult given it is not a CITES-listed species. However, the Indonesian government has implemented several actions and measures to conserve and manage *P. kauderni* that includes harvest quota, business registration, and permitting (CITES 2021).

The Banggai Archipelago region is at risk from earthquakes and tsunamis of a magnitude to be considered disasters and these risks will continue in the future. In addition, climate-related disasters, such as severe weather events and high temperature anomalies have and could continue to occur in the Banggai Archipelago that could affect *P. kauderni* (see Section 2.3.1.6; Moore et al. 2019c). These threats remain unchanged from the 2015 status review (Conant 2015).

In summary, variability in abundance of *P. kauderni* continues to be reported between surveys. A knowledge gap remains on how much trade currently occurs and if captive-bred individuals will be able to alleviate trade pressure. However, it is known that wild-caught *P. kauderni* are collected for the aquarium trade and mortality occurs after its capture from the wild. The level of mortality occurring at each step in the trade process is unknown. While *P. kauderni* microhabitat is being affected by human activities and climate change, the Indonesian government continues to target actions to protect *P. kauderni* habitat. Based on these factors, *P. kauderni* is not presently in danger of extinction, but is likely to become so in the foreseeable future. Consequently, reclassification should not occur and the status of this species should remain as 'threatened.'

3.0 RESULTS

3.1 Recommended Classification

_____**Downlist to Threatened**
_____**Uplist to Endangered**
_____**Delist** *(Indicate reason for delisting per 50 CFR 424.11):*
    _____*Extinction*
    _____*Recovery*
    _____*Original data for classification in error*
__*X*__**No change is needed**

3.2 New Recovery Priority Number

Not applicable.

3.3 Listing and Reclassification Priority Number

Not applicable.

4.0 RECOMMENDATONS FOR FUTURE ACTIONS

Existing knowledge and data gaps for *P. kauderni* make it difficult to properly assess the status and abundance of the populations given the variability in survey locations and methods over the years. Future survey efforts should follow the same protocol as those implemented in recent years to accurately estimate the current abundance and trends. In addition, it is important to determine if management actions are increasing suitable microhabitat for *P. kauderni* within its endemic range. The changes in habitat conditions that accompany warming ocean temperatures and other anthropogenic issues may make it challenging for this species to thrive within its endemic range.

Perhaps the most import work needed is to determine the current impact of collection for the aquarium trade of the species. Due to the species popularity in the aquarium trade, additional data is needed on the number of individuals removed from the wild for the purpose of trade, the number of individuals exported from Indonesia, and the mortality rates that occur during each steps of the trade process. Additional knowledge is needed regarding captive breeding facilities and the numbers of individuals produced for the aquarium trade.

5.0 REFERENCES

Akmal, S.G., P.D.B. Zámečníková-Wanma, R.E. Prabowo, A.M. Khatami, J. Novák, M. Petrtýl, L. Kalous, and J. Patoka. (2020). Marine ornamental trade in Indonesia. *Aquatic Living Resources* 33(25). 8 pages. https://doi.org/10.1051/alr/2020026

Baillargeon, G.A., M.F. Tlusty, E.T. Dougherty, and A.L. Rhyne. (2020). Improving the productivity-susceptibility analysis to assess data-limited fisheries. *Marine Ecology Progress Series* 644: 143-156.

Biondo, M.V. (2017). Quantifying the trade in marine ornamental fishes into Switzerland and an estimation of imports from the European Union. *Global Ecology and Conservation* 11: 95-105.

Biondo, M.V. and R.P. Burki. (2019). Monitoring the trade in marine ornamental fishes through the European Trade Control and Expert System TRACES: Challenges and possibilities. *Marine Policy* 108. https://doi.org/10.1016/j.marpol.2019.103620

CITES. 2016. Convention on International Trade in Endangered Species of Wild Fauna and Flora: consideration of proposals for amendment of Appendices I and II. Seventeenth Meeting of the Conference of the Parties. September 24 – October 5, 2016. 16 pages.

CITES. 2021. Convention on International Trade in Endangered Species of Wild Fauna and Flora: Thirty-first meeting of the Animals Committee. 31 May, 1,4,21, and 22 June 2021. AC31 Doc. 31.

Dee. L.E., K.A. Karr, C.J. Landesberg, and D.J. Thornhill. (2019). Assessing Vulnerability of Fish in the U.S. Marine Aquarium Trade. *Frontiers in Marine Science* 5: 527. https://doi.org/10.3389/fmars.2018.00527

Dodds K. (2009). Cardinal sin: The plight of the Banggai cardinalfish *Pterapogon kauderni* Koumans 1933. *Tropical Fish Hobbyist* 57: 92–98. Accessed online on September 2, 2021: Tropical Fish Magazine.

English, S. C. Wilkinson, and V. Baker. (1997). Survey Manual for Tropical Marine Resources. 2nd Edition, Australian Institute of Marine Sciences, Townsville, Australia. 390 pages.

Groover, E.M., M.A. DiMaggio, and E.J. Cassiano. (2020). Overview of Commonly Cultured Marine Ornamental Fish. UF IFAS Extension University of Florida. FA224.

Lilley, R. (2008). The Banggai cardinalfish: An overview of conservation challenges *in* Live Reef Fish Information Bulletin 18. 40 pages.

Moore, A.M., S. Ndobe, A.I.M. Salanggon, and D. Wahyudi. (2015). Coral Reefs of Sonit Island, Banggai Archipelago: Biodiversity and Management Issues. *Simposium Nasional Kelautan dan Perikanan II, Makassar*, May 9, 2015.

Moore, A.M., S. Ndobe, and J. Jompa. (2017a). Fingerprints of the Anthropocene: the 2016 Coral Bleaching Event in an Equatorial Archipelago. *Proceedings of the 4th International Marine and Fisheries Symposium*. Hasanuddin University, Makassar. 20 May 2017.

Moore, A.M., S. Ndobe, and J. Jompa. (2017b). A site-based conservation approach to promote the recovery of Banggai cardinalfish (*Pterapogon kauderni*) endemic populations. *Coastal and Ocean Journal* 1(2): 63-72.

Moore, A.M., S. Ndobe, I. Yasir, R. Ambo-Rappe, and J. Jompa. (2019a). Banggai cardinalfish and its microhabitat in a warming world: a preliminary study. *IOP Conference Series: Earth and Environmental Science* 253. doi: 10.1088/1755-1315-253-1-012021

Moore. A.M., S. Ndobe, R. Ambo-Rappe, J. Jompa, and I. Yasir. (2019b). Dietary preference of key microhabitat *Diadema setosum*: a step towards holistic Banggai cardinalfish conservation. *IOP Conference: Earth and Environmental Science* 235. doi: 10.1088/1755-1315/235/1/012054

Moore, A.M., S. Ndobe, I. Yasir, and J. Jompa. (2019c). Disasters and biodiversity: case study on the endangered endemic marine ornamental Banggai cardinalfish. *IOP Conference Series: Earth and Environmental Science* 253. doi: 10.1088/1755-1315/253/1/012036

Moore, A.M., A.C.M. Tassakka, R. Ambo-Rappe, I. Yasir, D.J. Smith, J. Jompa. (2019d). Unexpected discovery of *Diadema clarki* in the Coral Triangle. *Marine Biodiversity* 49: 2381-2399.

Moore, A.M., I. Yasir, R. A-Rappe, S. Ndobe, and J. Jompa. (2020a). Asexual propagation of two sea anemone taxa for Banggai cardinalfish microhabitat enhancement. *IOP Conference Series: Earth and Environmental Science* 473. doi: 10.1088/1755-1315/473/1/012011

Moore, A.M., I. Yasir, R. Ambo-Rappe, S. Ndobe, and J. Jompa. (2020b). Microhabitat preference of the Banggai Cardinalfish *(Pterapogon kauderni*): a behavioral experimental approach. *IOP Conference Series: Earth and Environmental Science* 564. doi:10.1088/1755-1315/564/1/012019

Moore, A.M., S. Ndobe, and I. Yasir. (2021). Importance of monitoring an endangered endemic species – intra-species biodiversity perspectives on the Banggai cardinalfish conservation and trade. *IOP Conference Series: Earth and Environmental Science* 681. doi:10.1088/1755-1315/681/1/012120

Ndobe S, Soemarno, Herawati EY, Setyohadi D, Moore A, Palomares MLD, Pauly D (2013) Life History of Banggai Cardinalfish, *Pterapogon kauderni* (Actinopterygii: Perciformes: Apogonidae), from Banggai Islands and Palu Bay, Sulawesi, Indonesia. *Acta Ichthyologica et Piscatoria* 43(3): 237–50.

Ndobe, S., A. Moore, A.I.M. Salanggon, Muslihundin, D. Setyohadi, E.Y. Herawati, and Soemarno. (2013). Banggai cardinalfish (*Pterapogon kauderni*) Management an Ecosystem-Based Approach. *Marine Fisheries* 4(2): 115-126.

Ndobe, S. A.M. Moore, and J. Jompa. (2017). Status of and threats to microhabitats of the endangered endemic Banggai cardinalfish (*Pterapogon kauderni*). *Coastal and Ocean Journal* 1(2): 73-82.

Ndobe, S., I. Yasir, A.M. Moore, M.V. Biondo, and S.J. Foster. (2018a). Study to assess the impact of international trade on the conservation status of *Pterapogon kauderni* (Banggai cardinalfish). Convention on International Trade in Endangered Species of Wild Fauna and Flora. Thirtieth meeting of the Animals Committee. Geneva (Switzerland), 16-21 July 2018. AC30 Inf. 16.

Ndobe, S., J. Jompa, and A.M. Moore. (2018b). A Tale of Two Urchins – Implications for In-Situ Breeding of the Endangered Banggai Cardinalfish (*Pterapogon kauderni*). *Aquaculture Indonesiana* 19(2): 65-75. doi: http://dx.doi.org/10.21534/ai.v19i2.110

Ndobe, S., A.M. Moore, I. Yasir, and J. Jompa. (2019). Banggai cardinalfish conservation: priorities, opportunities, and risks. *IOP Conference Series: Earth and Environmental Science* 253. doi: 10.1088/1755-1315/253/1/012033

Ndobe, S., K. Handoko, D. Wahyudi, M. Yasir, Y. Irawati, W.A. Tanod, A.M. Moore. (2020). Monitoring the endemic ornamental fish *Pterapogon kauderni* in Bokan Kepulauan, Banggai marine protected area, Indonesia. *Jurnal Illmu-Llmu Perairan, Pesisir dan Perikanan* 9(1): 18-31.

Putra, I Nyoman Giri and I Dewa Nyoman Nurweda Putra. (2019). Recent Invasion of the Endemic Banggai Cardinalfish, *Pterapogon kauderni* at The Strait of Bali: Assessment of the Habitat Type and Population Structure. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences* 24(1): 15-22.

Rhyne, A.L., M.F. Tlusty, J.T. Szczebak, and R.J. Holmberg. (2017a). Expanding our understanding of the trade in marine aquarium animals. *PeerJ* 5:e2949. https://doi.org/10.7717/peerj.2949

Rhyne, A.L., M.F. Tlusty, and J.T. Szczebak. (2017). Early Culture Trials and an Overview on U.S. Marine Ornamental Species Trade. *Marine Ornamental Species Aquaculture*, First Edition. Edited by Ricardo Calado, Ike Olivotto, Miquel Planas Oliver and G. Joan Holt.

Wiadnyana, N.N., S.R. Suharti, S. Ndobe, S. Triharyuni, G.R. Lilley, S. Risuana, D. Wahyudi, and A.M. Moore. (2020). Population trends of Banggai cardinalfish in the Banggai Islands, Central Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science* 420. doi:10.1088/1755-1315/420/1/012033

NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW
Pterapogon kauderni

Current Classification:

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X_ No change is needed

Review Conducted By:

LEAD OFFICE APPROVAL:

Approve DAMON RANDALL.KIMBERLY.B.1365821093 Digitally signed by DAMON RANDALL.KIMBERLY.B.1365821093 Date: 2021.10.26 10:45:55 -04'00' Date: 10/26/2021

HEADQUARTERS APPROVAL:

Assistant Administrator, NOAA Fisheries

__X___Concur _____ Do Not Concur

Signature RAUCH.SAMUEL.D.III.1365850948 Digitally signed by RAUCH.SAMUEL.D.III.1365850948 Date: 2021.10.27 14:43:04 -04'00' Date________