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IMPACTS OF FISHING AND HABITAT ON THE DENSITY OF BANGGAI CARDINAL FISH (*Pterapogon kauderni*, Koumans 1933) IN BANGGAI ARCHIPELAGO, INDONESIA

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ABSTRACT

Banggai cardinal fish (*Pterapogon kauderni*, Koumans 1933) is a rare example of a marine fish with an extremely limited geographic range and is in high demand as an ornamental fish. An underwater visual fish census survey was conducted in June to July 2010 at 18 fishing sites around Banggai archipelago to estimate the density of the stock and assess the impacts of fishing and habitat on density. The areas are divided among the three main islands, namely Banggai Island, Peleng Island, Toropot-Tumbak-Labobo Island. The lowest density index of the *P. kauderni* recorded at Kindand [illegible]age on Peleng Island, 0.014 fish/m^2 while the highest abundance index of 3.0 fish/m^2 found at Toropot village at Toropot Island. The total abundance of fish estimated from Banggai Island was 3.41 millions, Peleng Island 1.13 millions, and Toropot-Tumbak-Labobo Islands 3.94 millions, respectively. In three survey sites (Bonebaru and Toropot villages) where the fishing activities are still on going, the density has declined compared to a survey conducted in 2004. Majority of the villages in Peleng Island have lower density compared with the other islands possibly due to the degradation of microhabitat of *P.kauderni* as a result of collection of sea urchins and sea anemone for consumption. The limited available data did not show a significant effect of habitat type on density.

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1 INTRODUCTION

1.1 The Bangai Cardinal fish (*Pterapogon kauderni*)

The endemic Banggai Cardinal fish (*Pterapogon kauderni*) has received considerable scientific attention because of its limited range while at the same time being in high demand as an ornamental fish (Lunn and Moreau, 2004). The species inhabits a small area in the Banggai-Sula platform Archipelago, Eastern Indonesia as shown Figure 1.

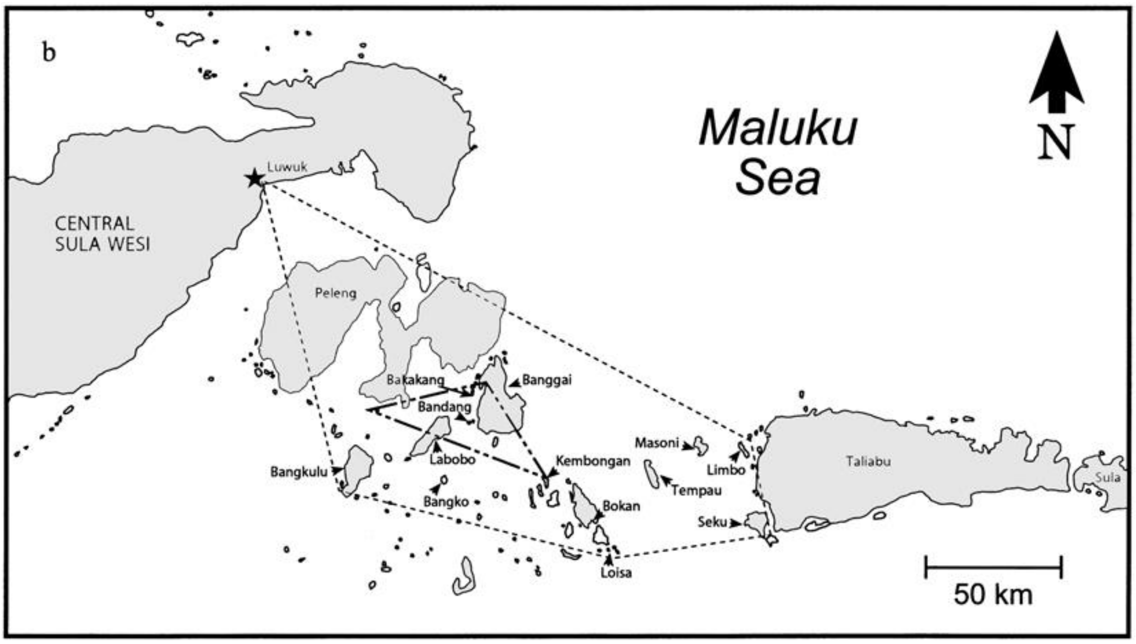

Figure 1: Distribution range of *P. kauderni* (Vagelli and Erdmann, 2002).

P. kauderni is mainly found in shallow sheltered bays and in harbours, on silty reef flats with sandy bottoms and sea grass beds. Depth distribution generally ranges between 0.5 and 6 m, but the species is most commonly found between 1.5 and 2.5 m (Vagelli, 2005). First described from specimens collected in the Banggai Islands of Sulawesi in 1920 by Koumans (1933), it was forgotten by the Western scientific community until 1991 when a Bali tour operator chanced upon the species and brought it to the attention of a taxonomist (Lunn and Moreau 2004). Since its rediscovery, *P. kauderni* became heavily exploited as it is highly-prized in the aquarium trade (Lunn and Moreau, 2004).

Fishing pressure may results a negative impact on *P.kauderni* population, such as affecting the density, group size and the density of its preferred associate fauna (sea urchins and sea anemones). Vagelli and Erdmann (2002) reported that in Bangkulu Island (located at southwestern part in distribution map in Figure 1), approximately 10.000 individual of Banggai Cardinalfish per month were caught and between 50.000-60.000 *P. kauderni* were received for export each month at North Sulawesi buyer alone. The cencuses carried out by Vagelli and Erdmann (2002) also reported that density in three different sites (Bokan, Limbo, and Masoni) islands was "cropped" due to heavy collecting pressure, namely 0.029, 0.031, and 0.027 individual fish/m^2 respectively. Moore and Ndobe (2005) also reported that density of *P. kauderni* had varied from 0.31 to 11.99 individual/ m^2 at several sites in Banggai Island, Peleng and Toropot Island.

In this study, the aim is to analyse the data collected from a survey conducted in 2010 and compare the findings to a previous survey conducted in 2004 (Moore and Ndobe, 2005). An attempt is made to define the habitable area for Banggai cardinal fish at each site so that density estimates may be converted to absolut abundance. The analysis will then focus on the effects of fishing and habitat on the observed densities of *P. kauderni* at 18 survey sites. The available biological data, collected in the 2010 survey and by field enumerators is summarized and analysed so that the estimates may in the future be used for management purposes.

1.2 Exploitation since re-discovery

A conservative estimate of 600.000 to 700.000 individuals were collected per year by local fishers prior to 2001 (Lunn and Moreau, 2004, Vagelli and Erdmann, 2002); In 2000 - 2001 the estimated number of *P. kauderni* traded from the Banggai Islands was 0.7 to 1.4 million fish/year. In the period between 2004 to 2006, Lunn and Moreau (2004) estimated the number of fish traded annually was around 600-700.000 fish/year. Similarly, Vagelli (2005) suggested that harvest rates in 2005 were between 700-900.000 fish. In 2008, the Marine Aquarium Council (MAC) and the Indonesian Nature Foundation (LINI) estimated international demand to be around 450.000 fish/year (Ndobe and Moore, 2012). The supply of *P. kauderni* and in or of demand was attributed to the high levels of mortality and rejecteds (such as damaged fins or small size caught) in the market chain. This and the speculative buying practices of local collectors would further increase the difference the numbers caught and the numbers sold. Most aquarium specimens are still captured in the wild while there are claims of successful captive breeding (Anonymous, 2007).

A study showed that, the exploitation of *P. kauderni* as an ornamental fish has had a negative impact on fish density and also a significant effect on school size in sites with high fishing pressure compared to sites with lower fishing levels (Kolm and Berglund, 2003). Vagelli (2005) describes the population of *P. kauderni* as threatened in the wild because of the heavy and unregulated trade of this ornamental fish. An example of the negative impact of harvesting of *P. kauderni* is the complete extinction of a local population, documented in 2004, off Limbo Island in the southeastern part of the distribution range (Figure 1). According to a 2001 survey, the population was composed of about 50.000 fish (densities = 0.02 fish/m^2). Similarly a small population off Bakakan Island that harbored 6,000 fish in 2001 was reduced to 17 individuals in 2004 (Vagelli, 2005).

In the period between 2006 to 2010 some of the villages previously engaged in the fishing were not active in the *P. kauderni* fishery and trade and the population of the fish may have recovered due to the low fish collecting activities. Ndobe and Moore (2012) reported that the reason some villages had stopped fishing appears to be the decreased demand for *P kauderni.* Catch data from 2008 to 2010 suggests a much reduced fishing 236.000 fish in 2008 and 232.000 fish in 2010.

1.3 Natural range of Banggai Cardinal fish

The Banggai Archipelago is located in the eastern part of Indonesia which lies in the Banggai Sula platform. The natural geographic range of *P. kauderni* extends from 01° 24' 57.6" of latitude South as its northern most distribution point to 02° 0' 53.5" of latitude South and from 123° 34' 11" of longitude East as its western most distribution to approximately 124° 23' 30" of longitude East and the south-east tip of Taliabu island. This distribution covers an area of approximately 5,500 km² (Figure 1). However, within this range, the estimated maximum potential available habitat is about 426 km of coastline extending from the shore to to depths of 6 to 10 meters, with a maximum available area of about 34 km² (Vagelli, 2005).

In its natural habitat, *P. kauderni* has been found in 69 sites at 27 islands. It was found in 17 of the 20 major islands and in 10 of the 27 minor islands around Banggai Archipelago. In four of the sites *P. kauderni* is an introduced species, that is in the Lembeh Strait (three islands and Sulawesi), in north Sulawesi which is by around 400 km from its natural habitat, where this species was introduced in 2000, and in one site in central Sulawesi (Luwuk) which is separated around 100 Km from Banggai island (Vagelli, 2005). Ndobe and Moore (2012) reported that *P. kauderni* was also found in Kendari (South eastern of Sulawesi island), around 300 km distance from its natural range. The introductions are the result of the release of unsold fish, including rejects.

1.4 Ecology

The Banggai cardinalfish is found in shallow waters around harbours, sheltered bays, or even under the dome of local houses in shallow water (less than 6 meters). *P. kauderni* is the only species of the 250 known species of the cardinalfish family (Apogonidae) that is diurnal and usually seen during the day in schools containing 20 or more individuals (Allen, 2000). Furthermore only the Banggai cardinalfish mouthbroods it's young until settlement, (Bernardi and Vagelli, 2004). This species is also unique as it shelters in sea urchins (*Diadema sp*), anemones and Heliofungia corals. The Banggai cardinalfish is often found in associates with various species of anemone fishes (Amphiprion) and anemone shrimps (Periclimenes), and with several other species of Apogonidae (*Apogon, Archamia*, *Cheilodipterus* and *Sphaeramia*) when living among the spines of sea urchins. The Banggai cardinalfish is also found in seagrass beds (predominantly composed of *Enhalus acoroides*) (Anonymous, 2007).

Sea urchins are however the favoured shelter for the Banggai cardinalfish as the black and white striped pattern of this fish are belived to make it difficult to spot by predators (including humans) when it retreats among urchin's spines (Lilley, 2008). Ndobe and Moore (2012) reported that all size classes of *P. kauderni* are generally found in sea urchins (*Diadema sp*.) which can be viewed as their micro habitat. Over 80% of young recruits (6-15 mm SL) observed, and all recruit groups of more than 3 individuals, were associated with sea anemones, often also inhabited by clown fish (*Amphiprion sp*.).

1.5 Maturity and reproduction

Females reach sexual maturity before the end of the first year and are able to exude an egg mass which contains 12-40 eggs (each 2.5 – 3.0 mm in diameter) which they release directly to the male's mouth (Allen, 2000). As a mouthbreeding fish, reproduction involves an elaborate courtship that last normally several hours, but sometimes 2 or 3 days and a breeding pair often allows a secondary male to intervene during mating. Only the males incubate the eggs (Vagelli, 1999).

According to Vagelli and Volpedo (2004), spawning is highly correlated with the lunar cycle. They reported that 57.2% of spawns occurred during full moon, 33% during the last quarter of full moon period, and 9.5% during the new moon. 76.2% of the embryos were released during the full moon period, 14.3% occurred during the last quarter, and 4.8% occurred during the new moon period. The percentage of female carrying maturing oocytes during the new moon was significantly higher than during any other moon phase.

In a laboratory, males have been observed incubating the eggs for 21-24 days. When the eggs hatch, at approximately 6 mm, the fry is slowly released from the male's mouth in 3-5 days. The fryes are able to eat artemia immediately after their release from their father's mouth (Marini, 1996).

2 MATERIALS AND METHODS

2.1 Underwater Visual Fish Census Survey

The underwater visual fish census surveys were conducted in June to July 2010 in 18 sites in the Banggai Archipelago area, which were identified as a habitat of Banggai Cardinal Fish. This was based on information obtained from local fishermen. Four survey sites were located at Banggai Island, nine sites were located at Peleng Island, three sites at Toropot Island, one site at Tumbak Island, and one site at Labobo Island. Table 1 gives an overview of the survey sites and the exploitation history of the sites.

Table 1: Sites surveyed for Banggai Cardinalfish density in June to July 2010 on the Banggai Archipelago, Indonesia. Longitude and Latitude are on a decimal form. X means that density estimates from 2004 are available.

No.	Island (survey site)	Long	Lat	Density estimates available from 2004 (Ndobe and Moore 2005)	Fishing activity
	Banggai Island				
1	Matanga	123.579	-1.7168889	X	2001-2006
2a	Bone Baru	123.494	-1.5320278	X	2001-present
2b	Bone Baru	123.493	-1.5320278	X	2001-present
3	Monsongan	123.483	-1.6375278	X	2001-2006
4	Tinakin Laut	123.492	-1.6027222	X	2001-2006
	Peleng Island				
5	Bajo	123.239	-1.548369		2001-2006
6	Boyomoute	123.251	-1.496031		2001-2006
7	Apal	123.259	-1.467544		2001-2006
8	Popidolon	123.231	-1.60165		2001-2006
9	Tolulos	123.139	-1.5524722		2001-2006
10	Kindandal	123.151	-1.6233889		2001-2006
11	Bobu	123.381	-1.503066		2001-2006
12	Boniton	123.444	-1.5083611		2001-2006
13	Lobuton	123.472	-1.4747222		2001-2006
	Toropot-Tumbak-Labobo Islands				
14	Minanga	123.708	-1.9238333		2001-2006
15	Kombongan	123.691	-1.9073333		2001-2006
16	Toropot	123.636	-1.9366944	X	2001-present
17	Tumbak	123.489	-1.9818333		2001-2006
18	Bontosi	123.269	-1.7844167		2001-2006

At each site, transect was set in shallow water close to shore at a depth between 30 cm to 150 cm. In areas where the habitat was wide (shallow area stretching far from the coast line) transects were started at a maximum of 200 m distance from beach line. This was mainly done to avoid having transects going through villages which are built into the water. All transects were 50 meters long (Figure 2) and it is assumed that the diver can observe fish up to 10 meters along transect (5 meters to each side) (Labrosse *et al.* 2002). The location of transect at each site was set in the main fishing areas as identified by local fishermen.

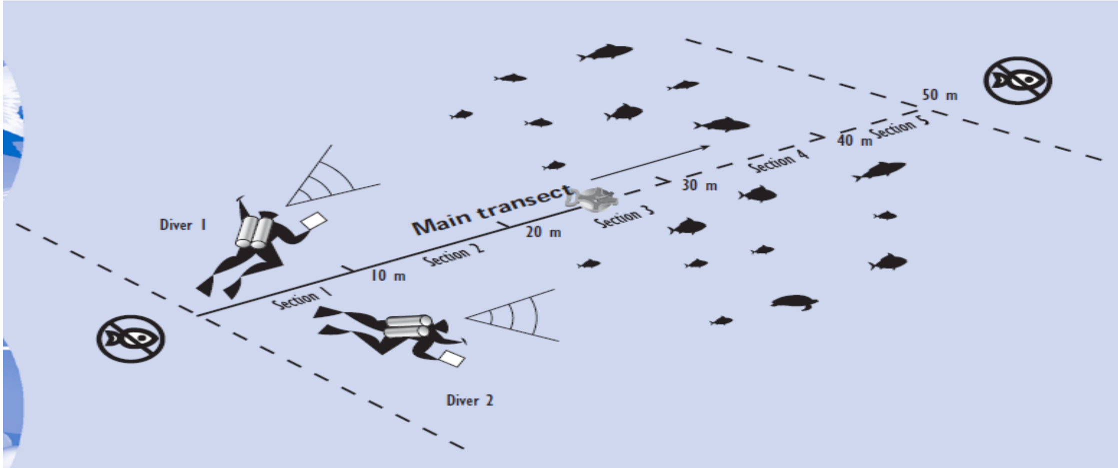

Figure 2: A schematic drawing of the underwater visual census survey design.

At each transect the following data were recorded:

1. The number of fish observed.
2. The habitat type along transect was estimated as percentage of the total surveyed area. The habitat types identified were
    a. Coral reef
    b. Sea grass bed
    c. Mangrove
    d. Sea urchin
    e. Anemone
3. After transect had been surveyed specimens for biological sampling were caught at the transect using a small scoop net with a mesh size of 4-5 mm and the length of net used was 60-80 cm. The material of the net is nylon monofilament. The material sampled was then analysed at the laboratory (See next section).
4. The following environmental parameters were measured at each transect: temperature, salinity, dissolved oxygen, pH, and depth. The depth was measured by depth sounder, while temperature, salinity, pH, and dissolved oxygen were measured by Lutron Digital Oxygen Meter with a polarographic type probe.
5. Fish density for each transect was calculated according to the formula: $D = n/w$, where D is density (individuals per m^2), n is the number of fish counted at transect and w is the size of the transect area in m^2.

2.2 Estimation of habitat size of Baggai cardinal fish

For estimation of the size of the area occupied by Banggai cardinal fish at each survey site information from local fisherman was used for estimation of the length of coast line at each site. Then using Google-earth the area was defined as the coast line and shallow water (depths less than 6 m) as could be estimated from the maps in Google-earth. Internal algorithims in Google-earth calculated the defined area in m^2. Maps for each site and the defined habitat are presented in Annex 1. Table 2 lists the sites and the estimated area.

Table 2: Survey sites and the size of areas.

Name	Estimated size of habitat (m^2)
Bonebaru	1,269,449
Matanga	407,399
Monsongan	281,592
Tinakinlaut	207,686
Apal	198,094
Bajo	324,797
Bobu	725,008
Boniton	324,093
Bontosi	1,143,170
Boyomoute	378,558
Kindandal	675,572
Kombongan	2,730,625
Lobuton	932,368
Minanga	442,597
Popidolon	754,818
Tolulos	243,394
Toropot	217,923
Tumbak	745,979

2.3 Biological data

The available biological data is aimed to explore the information in relation to population dynamics of *P.kauderni* such as length weight relationship, sex ratio, maturity state, and cohort slicing analysis to estimate growth of *P. kauderni*.

2.3.1 Material

The available biological data was listed by survey sites as shown in Table 3.

Table 3: The number of measurements of *P. kauderni* that were used in biological data analysis. FL is fork length, W is weight and Maturity stage.

	FL	W	Maturity stage
Banggai Island			
Bonebaru	1225	310	22
Tinakin	244	105	5
Monsongan	89	89	4
Popisi	247	147	44
Kotabanggai	100	0	0
Sub Total	**1905**	**651**	**75**
Peleng Island			
Apal	125	75	75
Bajo	1145	94	55
Bobu	93	43	43
Boniton	22	22	22
Bontosi	550	0	0
Boyomoute	123	23	21
Kapela	111	111	0
Kindandal	18	18	0
Popidolon	68	68	68
Lobuton	40	40	35
Balayon	400	0	0
Binuntuli	552	0	0
Sub Total	**3247**	**494**	**319**
Toropot-Tumbak-Labobo			
Minanga	106	0	0
Toropot	795	0	0
Total	901	0	0
Bokan Island			
Kokudang	200	0	0
Sub Total	**200**	**0**	**0**
Other Island			
Nggasuang	200	0	0
Paisubatango	151	0	0
Tangkop	250	0	0
Tolisetubono	160	0	0
Total Number of fish	**7014**	**1145**	**394**

The data was collected both as part of the 2010 survey but also by field enumerators. In the analysis no distinction is made between the survey data and the data collected by the field enumerators. This is because the raw data does not list the date nor who collected the data. In total 7014 length measurements (Fork length (FL)) were available for cohort slicing, 1145 weight measurements (W) for estimating the length-weight relationship for *P. kauderni*. For estimation of maturity ogives (GI) a total of 394 measurements were available.

2.3.2 Processing of the collected material

All fish were measured to the nearest millimetre, both total length (TL), and Fork Length (FL) was recorded. The specimens were weighed to the nearest gram, recorded as total weight (W).

The sex was determined by visual appearance of gonad maturity. Gonad samples were soaked in 10% formalin and stored in a plastic envelope before being analysed in the laboratory. To define the fecundity and the size of eggs, egg samples were preserved in a Gilson solution. Gonad and eggs samples were analysed in the Laboratory of Balai Riset Perikanan Laut Muara Baru, Jakarta.

Maturity was determined visually into the maturity stages outlined in table 4 which is slightly modified from those outlined by FAO (1974).

Table 4: Maturity stage visualisation of *P. kauderni.*

Stage	Criteria	
	Male	**Female**
1	**Immature**; testes extremely thin, flattened and ribbon-like, but sex determinable by visual examination	**Immature**; gonads elongated, slender, but sex determinable by visual examination
2	Testes thin, no milt in central canal	**Early maturing**; gonads enlarged and individual ova visible to the naked eye, pinkish to orange colour and translucent
3	**Maturing**; gonads withist-translucent with milt visible to the naked eye	**Late maturing**; gonads enlarged, individual ova very visible to the naked eye, more orange colour
4	**Ripe**; gonads determinable by visual, larger, withist-milt easy determinable by visual examination	**Ripe**; ovary greatly enlarged, ova more orange to red in colour, translucent, easily dislodged from follicles or loose in lumen of ovary
5	**Spent**; gonads flabby, little or no milt in central canal	**Spawned**; mature ova remnants in gonads.

2.3.3 Methods

Length Frequency and Cohort Slicing

The Banggai Cardinal fish is a tropical fish and as such, it is hard to define the age by reading annuli on hard parts such as scales or otoliths. Here the approach outlined by Stefansson and Taylor (2011) is used for cohort slicing. Length frequency distribution were plotted to define the most distinctive modes. In theory these modes would be assumed to be the mean length corresponding to relative ages. However the length frequency distribution for the Banggai Cardinal fish did not have any such distinctive modes and because limited data on the growth of the species exists several assumptions had to be made. First the values of the von Bertalanffy growth parameters were assumed to be known and fixed in the procedure. Secondly, the standard deviation of mean length at age was fixed and calculated from an assumed CV for mean age at length of 15%.

The only data on growth that was available to the study is that the species is approximately 6.6 mm FL at the age of one month and the maximum length at 36 months is assumed to be 69.3 mm (Black points on figure 3). The size at 50% maturity for females was 40.9 mm FL (section 4.3) that is thought to be at around the age of 12-13 months old while the size at 50% maturity for males is 39.1 mm FL which assumed to occur at around 12 months of age. The von Bertalanffy growth curve was fitted to these four points in figure 3 and the CV for mean length at age was assumed to be 15%.

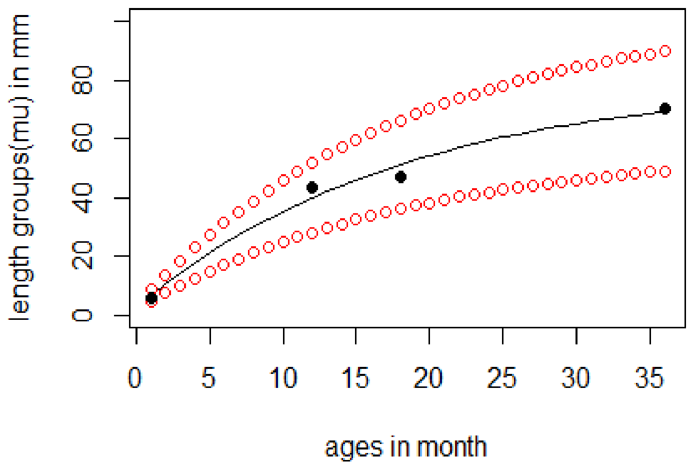

Figure 3: Von bertalanffy growth curve of *P. kauderni* (Black line). Red line means CV for mean length 15%.

Length-Weight Relationship

Length-weight relationship can be used to predict weight at a given length. Mathematically, this relationship is described by the formula:

$$W = \alpha * L^{\beta}$$

Where *W*, is the weight in grams, α and β are parameters of the function and *L* is the fork length (FL) of Banggai Cardinal fish samples.

The above equation can be made linear with a logarithmic transformation;

$$\text{Log W} = \text{Log } \alpha + \beta \text{ Log L}$$

Maturity ogives

Maturity ogives were fitted to the data for males and females using a logistic regression assuming a binomial error distribution. The fitting was done in R using the glm function.

Environmental parameters analysis

Analysis of Variance (ANOVA) was used to explore the effects of environmental parameters such as depth, pH, dissolved oxygen, salinity, and temperature on the density estimated in the 2010 survey.

3 RESULTS

3.1 Density estimates from the Underwater Visual Fish Census Survey

Density varied between the 18 different sites. It ranged from 0.014 fish/m^2 to 3 fish/m^2. The lowest density was found in Kindandal village at Peleng Island while the highest density recorded was in the Toropot village at Toropot Island. In the two villages where fishing is still on going, the average density decreased from 1.96 fish/ m^2 to 1.49 fish/ m^2 at Bonebaru village, and 11.99 fish/ m^2 to 3 fish/ m^2 at the Toropot village in Toropot Island (Table 5).

At two sites (Monsongan and Tinakinlaut) where fishing stopped in 2006, the density has increased from 0.48 fish/ m^2 to 2.63 fish/ m^2 at Monsongan village but from 0.31 fish/ m^2 in 2004 to 2.41 fish/ m^2 in the 2010 survey at the Tinakinlaut site. This means that density increased 5 to 8 fold after harvesting stopped (Table 5).

Contrary to Monsongan and Tinakinlaut the density in Matanga village were fishing also stopped in 2006 decreased. The density was 64% lower than estimated in the 2004 survey. Most of the survey sites in Peleng Island have low density estimates compared to the other islands. The lowest density estimate of 0.014 fish/ m^2 is from the Kindandal village while the highest density of 0.498 fish/ m^2 was from the Bobu village (Table 5).

The total abundance of fish estimated from Banggai Island was 3.41 millions. From Peleng Island 1.13 millions, and Toropot-Tumbak-Labobo Islands it was 3.94 millions, respectively. The lowest abundance was 9,500 fish at Kindandal fishing area at Peleng Island while the highest abundance estimated was 1.9 million fish at Bonebaru fishing area at Banggai Island.

Table 5: Results of the 2010 survey with density estimates and for comparison the estimates from the 2004 survey. Abundance is the density multiplied with the size of the area as estimated in table 2. The aesthetic (*) means survey data conducted by Moore and Ndobe (2005).

Island	Fishing history	Density (ind/ m^2) 2004*	Number of fish counted in the transect	Density (ind/ m^2) 2010	Abundance in 2010
Banggai					
Matanga	2001-2006	1.86	334	0.67	272,958
Bone Baru A + B	2001-present	1.96	1492	1.492	1,894,018
Monsongan	2001-2006	0.48	1316	2.63	740,587
Tinakin Laut	2001-2006	0.311	1205	2.41	500,523
Peleng					
Bajo	2001-2006		102	0.204	66,259
Boyomoute	2001-2006		63	0.126	47,698
Apal	2001-2006		113	0.226	44,769
Popidolon	2001-2006		157	0.314	237,013
Tolulos	2001-2006		58	0.116	28,234
Kindandal	2001-2006		7	0.014	9,458
Bobu	2001-2006		249	0.498	361,054
Boniton	2001-2006		53	0.106	34,354
Lobuton	2001-2006		162	0.324	302,087
Toropot-Tumbak-Labobo					
Minanga	2001-2006		174	0.348	154,024
Kombongan	2001-2006		219	0.438	1,196,014
Toropot	2001-present	11.99	1500	3	653,768
Tumbak	2001-2006		174	0.348	259,601
Bontosi	2001-2006		736	1.472	1,682,746

3.2 Habitat types in relation to the density index of *P.kauderni*

Table 6 lists the relative vegetation and substrate coverage along transects at the 2010 survey sites. Relative coverage is missing from Peleng Island as the team that surveyed there only recorded if a given habitat type was observed along the transect but did not attempt to estimate the relative coverage.

Table 6: Estimates of habitat types at transect sites in the 2010 *P. kauderni* survey and the associated density estimate.

Island	Type of Habitat					Density (ind/ m^2) 2010
	Fishing activity	Seagrass (%)	Coral (%)	Coral rubbles or sands (%)	Other fauna (Sea urchin or anemones) (%)	
Banggai						
Matanga	2001-2006	-	31	61	8	0.67
Bone Baru A	2001-present	-	12	62	26	2.01
Bone Baru B	2001-present	75	-	20	5	0.97
Monsongan	2001-2006	43	5	50	2	2.63
Tinakin Laut	2001-2006	42	20	6	32	2.41
Peleng						
Bajo	2001-2006	yes	na	Na	yes	0.204
Boyomoute	2001-2006	yes	yes	Yes	yes	0.126
Apal	2001-2006	yes	na	Na	yes	0.226
Popidolon	2001-2006	yes	yes	Yes	yes	0.314
Tolulos	2001-2006	yes	yes	Yes	yes	0.116
Kindandal	2001-2006	yes	na	Na	yes	0.014
Bobu	2001-2006	yes	yes	Yes	yes	0.498
Boniton	2001-2006	yes	na	Na	yes	0.106
Lobuton	2001-2006	yes	na	Na	yes	0.324
Toropot-Tumbak-Labobo						
Minanga	2001-2006	46	13	10	31	0.348
Kombongan	2001-2006	-	30	43	27	0.438
Toropot	2001-present	45	10	15	30	3
Tumbak	2001-2006	40	15	25	20	0.348
Bontosi	2001-2006	50	5	25	20	1.472

In Figure 4 the relationship between the percentage of habitat type and density are plotted. There is little correlation between the percentage covered by a given habitat type and density.

The results from a correlation test are summarised in table 7, in all cases the test do not show significant correlation between density and the coverage of a given habitat type.

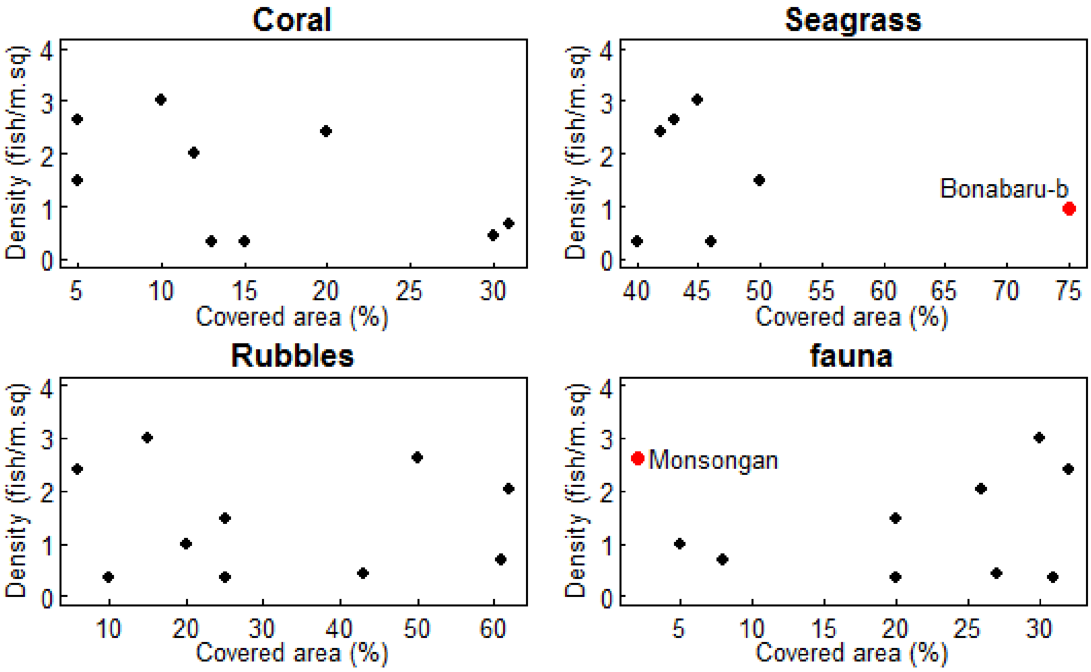

Figure 4: The correlation plot of habitat areas to the index density of *P. kauderni* in 500 m^2 transect (Monsongan and Bonebaru-b were excluded in sea grass and fauna habitat type).

Table 7: Value of Pearson's correlation (*r*) and probability value (*p-value*) obtained from linear model analysis.

Dependent variable	Dependent factor	Pearson's correlation (*r*)	p-value	remarks
Density index	seagrass	0.01	0.6525	weak positive correlation
Density index	Fauna (sea anemones and sea urchins)	0.39	0.672	Fairly positive correlation
Density index	Coral rubbles	-0.05	0.8907	Negative correlation
Density index	Coral	-0.37	0.2915	Negative correlation

4 BIOLOGICAL DATA

4.1 Length frequency distribution, mean length at age and proportion at age distribution of *P.kauderni*

The size of Banggai Cardinalfish in the samples available ranged from 3 mm FL to 82 mm FL. The length interval in the analysis was set at 2 mm. The overall length distribution is presented in Figure 5.

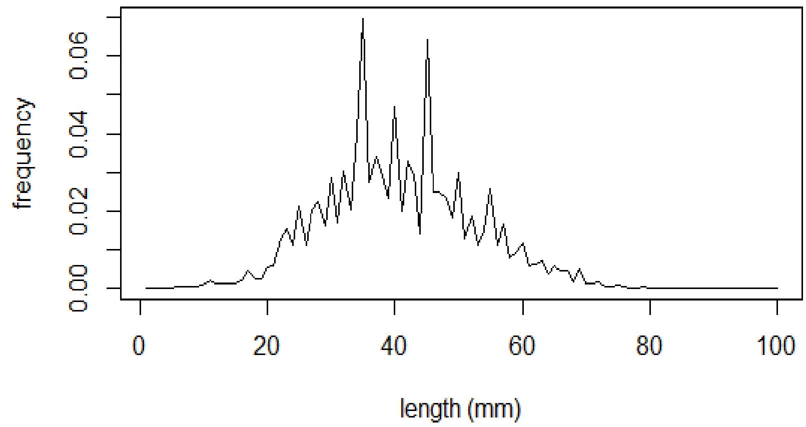

Figure 5: Length-frequency distribution of *P. kauderni* from Banggai archipelago.

The results of the cohort analysis are presented in table 8 that gives the estimated proportion of fish in each monthly age-group and the corresponding mean length and standard deviation (sigma) that is fixed in the analysis. The estimated age frequency by month is given in Figure 6 and shows that there are 5 monthly age groups of *P. kauderni*. That is age groups 1 to 3 months, 5 to 7 months, 13 to 17 months, and 20 to 25 months, respectively. The overall fit to the length distribution is shown in Figure 7.

Age groups 9 and 10 months are estimated to be around 36% of the population, while age groups of 14 to 15 months around 27% (Table 8, Figure 6). The relative length at age 9 to 10 months are between 33 to 35 mm FL, while 14 to 15 months ages are equivalent to 44 to 46 mm FL.

Table 8: Estimation length at age groups and proportion of age groups of P.*kauderni.*

Age(month)	Proportion at age (%)	Length at age (mm)	sigma
1	4.83E-04	6.618	0.992
2	3.63E-03	10.545	1.581
3	5.81E-03	14.262	2.139
4	1.14E-05	17.779	2.666
5	8.17E-03	21.109	3.166
6	8.11E-02	24.261	3.639
7	1.02E-05	27.244	4.086
8	2.76E-05	30.067	4.510
9	1.31E-01	32.739	4.910
10	2.32E-01	35.268	5.290
11	3.31E-05	37.662	5.649
12	3.50E-06	39.928	5.989
13	5.22E-02	42.072	6.310
14	1.53E-01	44.102	6.615
15	1.25E-01	46.023	6.903
16	5.43E-02	47.841	7.176
17	3.66E-03	49.562	7.434
18	1.41E-03	51.191	7.678

Age (month)	Proportion at age (%)	Length at age (mm)	sigma
19	1.48E-03	52.733	7.909
20	1.49E-02	54.192	8.128
21	3.48E-02	55.573	8.335
22	5.13E-02	56.880	8.532
23	3.01E-02	58.117	8.717
24	1.39E-02	59.288	8.893
25	1.05E-03	60.397	9.059
26	1.44E-05	61.446	9.216
27	1.60E-05	62.439	9.365
28	1.05E-04	63.378	9.506
29	1.71E-04	64.268	9.640
30	1.20E-04	65.110	9.766
31	3.89E-05	65.907	9.886
32	2.44E-05	66.661	9.999
33	2.35E-05	67.375	10.106
34	2.22E-05	68.050	10.207
35	2.53E-05	68.690	10.303
36	2.80E-06	69.295	10.394

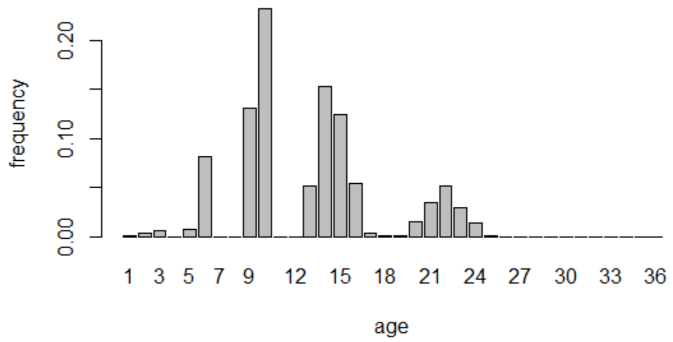

Figure 6: Age frequency distribution of *P. kauderni.*

Age groups 13 to 16 months account for around 38.4% of the measurements. The relative length of fish at the age 13 months old was 42.07 mm, while 14 to 16 months old were 44 mm, 46 mm, and 47.8 mm, respectively. The age groups 20 to 24 months old shared 14.5% of the total fish samples with relative length at 54.2 mm, 55.6 mm, 56.9 mm, 58.1 mm, and 59.3, respectively (Table 8 and Figure 6).

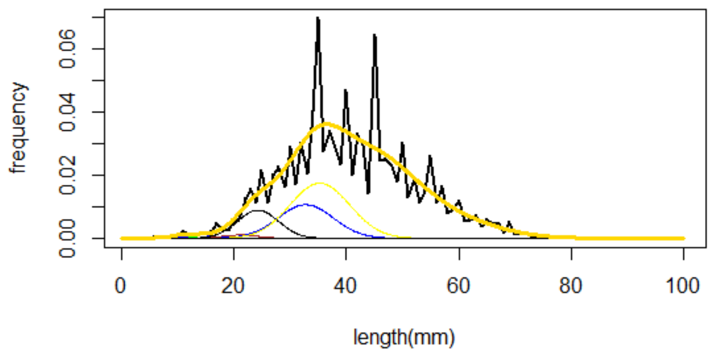

Figure 7: Length distribution of *P. kauderni* (black line) and the fit from the cohort slicing (yellow).

4.2 Length Weight Relationship

Length-Weight relationship obtained for *P. kauderni* is given below (Figure 8):

$$W = 0.02467 * L^{2.998} .$$

The value of the slope (β) was close to 3 that means that *P.kauderni* grows in an isometric way and follows the "cube law" of growth. The relationship was highly significant (F=1.947e+04, $df_{[1, 1121]}$, $p < 0.005$, R^2=0.95).

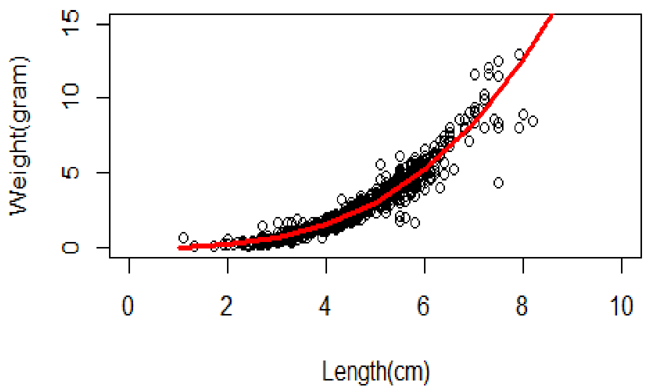

Figure 8: Observed length versus weight (black circles) and the estimated length-weight relationship (red line).

4.3 Maturity stage and sex ratio

Of the 394 individuals collected from Banggai and Peleng Island sites, 294 individuals (74.6%) were identified as males and 100 were identified as females or 25.4%. It means that the sex ratio was 3 males to 1 female. Specimens ranged in size from 2 cm FL to 8.6 cm FL for males and 3.2 cm FL to 8.2 cm FL for females. Size at 50% maturity for females was estimated at 4.09 cm FL (Figure 10) but at 3.91 cm FL for males (Figure 9).

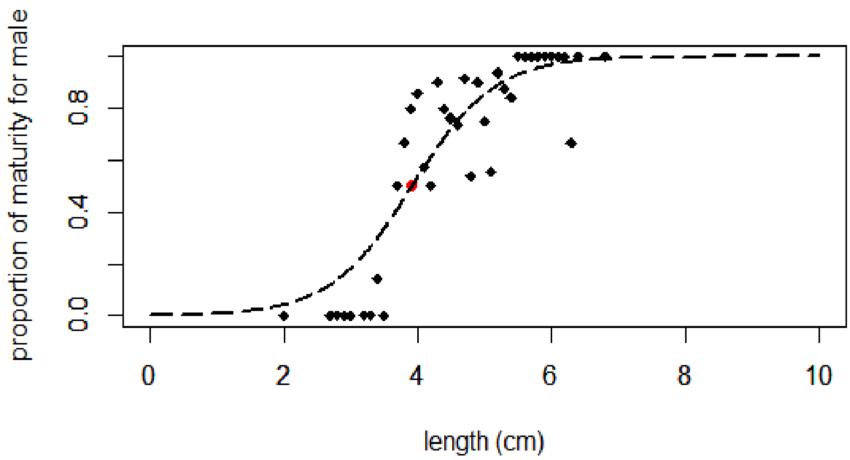

Figure 9: Proportion of maturity and length at 50% maturity of female *P. kauderni.*

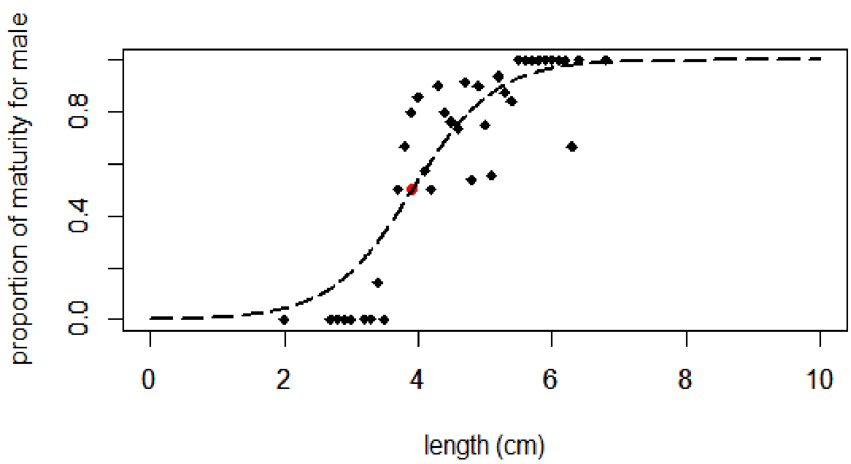

Figure 10: Proportion of maturity and length at 50% maturity of male *P. kauderni.*

The smallest female collected with signs of gonadal maturation measured at 4.3 cm FL, while the smallest mature male measured at 3.4 cm FL. The largest oocytes were 1400 µm and the smallest 600 µm in diameter size as shown in Figure 11. The fecundity ranged from 48 eggs to 127 eggs with majority of females having between 60 to 80 eggs. Most of the eggs were defined at stage 3 or 4 as shown in Figure 11.

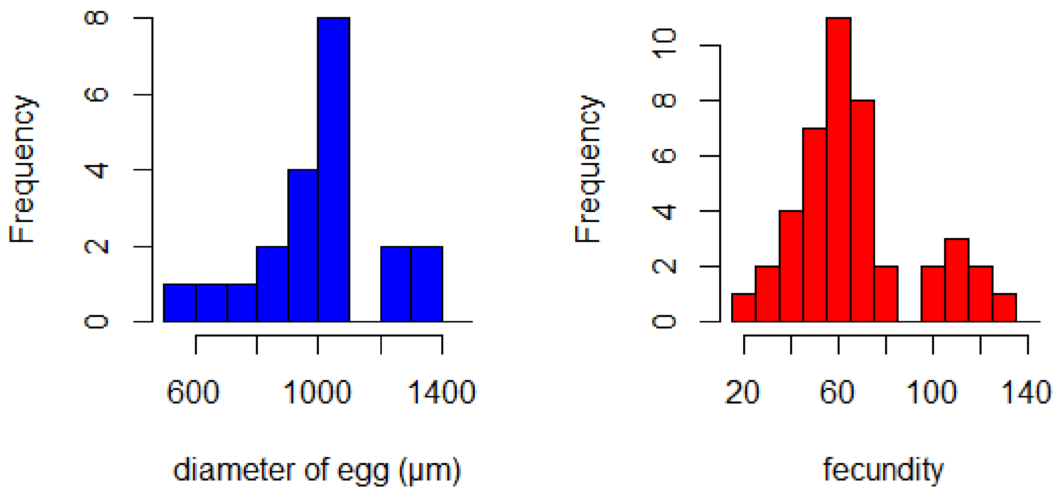

Figure 11: Fecundity and diameter of egg of *P. kauderni.*

4.4 Oceanographic parameters in relation to density of *P. kauderni*

Simple linear regression analyses showed that Dissolved Oxygen (DO) affected significantly the density of *P. kauderni* at the 18 different survey sites ($F_{[1,17]}$=18.74, p<0.005, R^2=0.5). Other environmental variables did not have significant effect on the density of *P. Kauderni* (Figure 12).

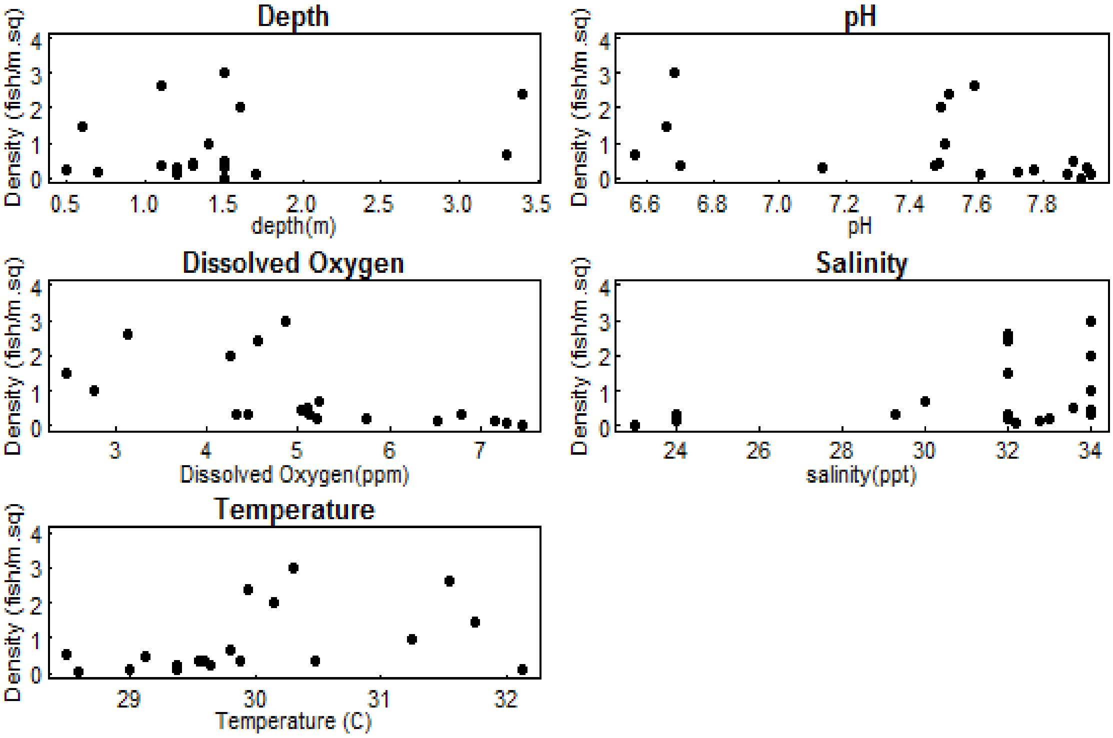

Figure 12: Correlation plot of each environmental parameter on density.

Table 9: Probability value (*P-value*) obtained from ANOVA between each environmental parameter on density.

Dependent variable	**Dependent factors**	***p-value***
Density index	depth	0.265
Density index	temperature	0.077
Density index	Dissolved oxygen	0.009***
Density index	salinity	0.124
Density index	pH	0.115

5 DISCUSSION

5.1 Fishing activity and habitat type and its impact to the density index of *P. kauderni*

In the two villages (Bonebaru and Toropot village) where fishing activities were still on going at the time of the 2010 survey, average density index decreased from 1.96 fish/ m^2 in 2004 to 1.49 fish/ m^2 in 2010 in Bonebaru and from 11.99 fish/ m^2 to 3 fish/ m^2 at the same time in Toropot. Fishing probably caused the decrease in the density of *P. kauderni* over the period. Another likely cause is habitat degradation in some villages as has occurred around Bonebaru.

Ndobe and Moore (2009) reported a significant coral reef degradation at five sites around Banggai archipelago including at Bonebaru from survey/monitoring data collected in 2004 to 2006 compared to the latest survey conducted in 2011. According to this data area covered by coral had reduced from 25% to 11% (Ndobe and Moore, 2012). The latest RRI survey also showed similar coverage by coral. The latest survey conducted by Wijaya (2010) revealed that densities of *P. kauderni* at Bonebaru were 0.65 fish/m.q, Mbato bato 0.42 fish/m.sq, Tolokibit 0.31 ind/m.sq, and Bandang Island 0.87 fish/m.sq, respectively. The survey results from Wijaya (2010) were similar to those obtained in the 2010 survey.

The correlation tests showed weak positive correlation between density of *P. kauderni* with the size area covered by other fauna such sea urchins and sea anemones and also sea grass bed. However the tests were not significant. Sea urchins and sea anemones are known as microhabitat of *P. kauderni*. Ndobe *et al*., (2008) reported that massive extraction of sea anemones was first observed in a survey in 2007. This resulted in a drastic decline of *P. kauderni* after the sea anemones, that were numerous in 2004 and 2006, had all disappeared. Moore and Ndobe (2012) also stated that all recruits groups of *P. kauderni* of more than 3 individuals were associated with sea anemones, often also inhabited by clownfish. Sea anemone seems to be a particularly important microhabitat for newly released *P. kauderni* recruits and small juveniles.

In two sites (Monsongan and Tinakinlaut) where fishing stopped in 2006, the density has increased from 0.48 fish/ m^2 to 2.63 fish/ m^2 in Monsongan village while 0.31 fish/ m^2 to 2.41 fish/ m^2 in Tinakinlaut site. It means that density increased 5 to 8 fold since fishing stopped in 2006. It also implies that the population of *P. kauderni* has recovered to some extend in the four years after fishing stopped in 2006.

Most of the survey sites in Peleng Island likely have lower density compared to the other islands. In Peleng Island, the lowest density of 0.014 fish/ m^2 was recorded in Kindandal village while the highest density of 0.498 fish/ m^2 was observed at Bobu village. Unfortunately, no survey data was available for comparison from 2004. Fishermen and local resident in Peleng Island collect sea urchins for consumption, as bait for *bubu* (trap), or as feed for Napoleon fish. The fishermen catch Napoleon fish and rear the fish temporarily in a small pond before they sell it to the buyer. The fish is fed on sea urchins collected by the fishermen. Collected sea urchins were found in Bajo, Kindandal, Apal, and Popidolon villages. Sea urchin (*Deadema setosum*) and sea anemone are the main shelter of *P. kauderni* and as one of important habitat in their lifecycle stage. Study related to the importance of microhabitat was conducted by Ndobe and Moore 2012, which stated that over 80% of new *P.kauderni* recruits were assosiated with sea anemones and sea urchin. This may explain the low density of *P. kauderni* at Peleng Island.

The total abundance of fish estimated from Banggai Island was 3.41 millions, 1.13 millions from Peleng Island, and in the Toropot-Tumbak-Labobo Islands it was 3.94 millions, respectively. The lowest abundance was 9500 fish at Kindandal fishing area at Peleng Island while the highest abundance estimated was 1.9 million fish at Bonebaru fishing area at Banggai Island. Vagelli (2005) reported that population estimated at Banggai Island in 2004 servey was 258.700 fish which occupied 3.696 Km^2 habitable area, 619.3600 fish at Peleng Island with 8.846 Km^2 habitable area, and 194.3200 fish in 2,766 Km^2 habitable area at Toropot-Tumbak-Labobo Islands. The results of abundance estimated by Vagelli were very low due to the very low density recorded in 2004 if compared with survey in 2010. Vagelli (2005) recorded that average density of *P. kauderni* at 34.134 Km^2 habitable Islands in Banggai Archipelago was 0.07 fish/m^2. The total abundance estimates presented here should be viewed as very preliminery as they rest on several assumptions. First the definition of the area inhabited by Banggai Cardinal fish at each site is not based on actual survey mapping of the area but rather information from local fishers and the sea-side definition of the area is estimated from airial photographs in Google-earth. The assumption of depth at the outer trim of 6 m may therefore not hold. This could result in considerably larger (or) smaller area than is in fact inhabitable by the species. The second assumption is that the density in all the area is uniform, this is unlikely to hold true. First the transects were located in previously known good fishing grounds. The indication from the two transects in Bonebaru indicated that density can vary a lot in the same site.

5.2 Von Bertalanffy growth parameters, Length frequency distribution, mean length at age and proportion at age distribution of *P.kaudern* by using cohort slicing

The cohort slicing method assumes that there is some prior knowledge of growth; therefore it can be used as simple method for converting length distributions to age compositions (Stefansson and Taylor, 2011). The results presented above showed 5 aggregations of monthly age groups of *P. kauderni*. These results are however quite sensitive to the assumed mean length at age and assumptions about the length-spread inside each age group (the CV). Therefore if the approach used here is to be of value for stock assessment and management purposes further investigations and collection of material for the estimation of mean length at age and growth of the species is urgently needed.

5.3 Length-Weight Relationship

The β parameter in the length-weight relationship indicates that *P. kauderni* grows close to *isometric* but that implies that the relationship between growth in length follows growth in weight by roughly a cube relationship. According to Pauly (1984), the value of exponent β should be between 2.5 to 3.5, and usually close to 3. Various factors may affect the β parameter in length-weight relationships, among them seasonal and annual effects such as temperature, salinity, food (quantity, quality, and size), sex, time of year, and stage of maturity (Pauly, 1984). Study of feeding ecology (quantity, quality, and sizes) of *P. kauderni* by Vagelli and Erdmann (2002) identified the species as a generalist planktivore-carnivore. The size range of the food items varied from about 0.1 mm (calanoid copepod) to 14 mm (teleosts, megalop larvae) with no significant difference in the size of food particles for different length of fish. The study furthermore indicated when food is plenty in their natural habitat, *P. kauderni* grows close to an *isometric* way.

5.4 Maturity state, sex ratio, and size of the eggs

In the maturity samples the length of males ranged from 2 cm FL to 8.6 cm FL while females ranged from 3.2 cm to 8.2 cm FL. The length of males with signs of gonadal maturity was 3.4 cm while for females it was 4.3 cm. These results are similar to a previous study conducted by Vagelli and Erdmann (2002) that ovary development can be observed in individuals ranging in size from 1.64 cm SL to 5.35 cm SL where the smallest female carrying maturing ova was 3.61 cm SL while a study conducted by Vagelli (1999) found the smallest female was 3.5 cm SL which was assumed to be nine months old. The study implied that there was no difference in the size of length at first maturity of the fish in less than 12 years over the periods of 1999 to 2010. Of 394 individuals collected from Banggai and Peleng Island, 294 individuals (74.6%) were identified as males and 100 individuals or 25.4% as females. The ratio between male and female fish was 1:3. The results are very different from those reported by Vagelli and Volpedo (2004) which stated that the sex ratio was close to 1:1.

The largest egg mesured in 2010 was 1400 µm and the smallest 600 µm in diameter. Vagelli and Volpedo (2004) stated that mature female of *P. kauderni* carried oocytes about 2000 µm and 2400 µm and that there is no correlation between male size and egg size. Large size of eggs can be advantageous for a fish like *P. kauderni* as a strategy for survival (and therefore it hatched larger as an embryo). Larger newly hatched embryos are better swimmers and better at feeding and seeking shelter. However Vagelli and Volpedo (2004) reported that the smallest juveniles of *P.kauderni* were quite able to swim and seek shelter soon after being released from the brooder mouth and that they can double their weight in about three days. Size at 50% maturity for females was estimated at 4.09 cm FL while for males it was estimated as 3.91 cm FL. This implies that many fish in the wild are caught before they can spawn. This is due to the fact that fish of 3 to 4 cm FL dominates the catches as they are the most desirable market size. From this study, upcoming recommendation should be not allow fish to be sold smaller than 4 cm FL.

5.5 Oceanographic parameters in relation to index of density *P. kauderni*

Simple linear regression analyses showed that Dissolved Oxygen (DO) affects significantly the density of *P. kauderni* at the 18 different survey sites. Kramer (1987) stated that when dissolved is oxygen reduced in the water, it will affect the behaviour responses of fish such as their activity, air breathing (increase), and vertical or horizontal habitat changes. Daskalov (2003) stated that anthropogenic factors such eutrophication was responsible for degradation of coastal ecosystems and that eutrophication often results in decreased availability of oxygen in the water.

Banggai cardinalfish (*P. kauderni)* is a shallow water fish that inhabit 0.5 to 5 m depth. This small habitat range means that the species are very susceptible to anthropogenic impact. Ndobe and Moore (2012) reported that in addition general fishing pressure including the use destructive fishing methods, another threats of Banggai cardinalfish habitat were coastal development especially the construction of new ports, increasing pressure on land-based resources which often results in increased sedimentation, and water quality issues such utilization of detergents by the local residence.

6 CONCLUSION AND RECOMMENDATION

Density seem to be increasing at sites were fishing activity has been stopped. Similarly at sites were fishing is on-going density is lower in 2010 than was recorded in 2004. Habitat types did not have a significant effect on density according to the data presented here but it has to be noted that the habitat data was very limited in scope.

In the future better monitoring of the fishery for *P. kauderni* is essential. This would include log-books that record daily catches by village, and more biological sampling (length measurements, maturity data etc.). For monitoring of population size mapping of the size of the areas occupied by the species at each site should be conducted and underwater visual survey transects should be set at random in the area. A major drawback in the 2010 survey was that with the exception of Bonebaru village only one transect was set out at each site. This makes estimation of variance and hence uncertainty impossible. Therefore having 3-4 transects set at random at each site should be considered if the objective is to monitor the population dynamics of the species.

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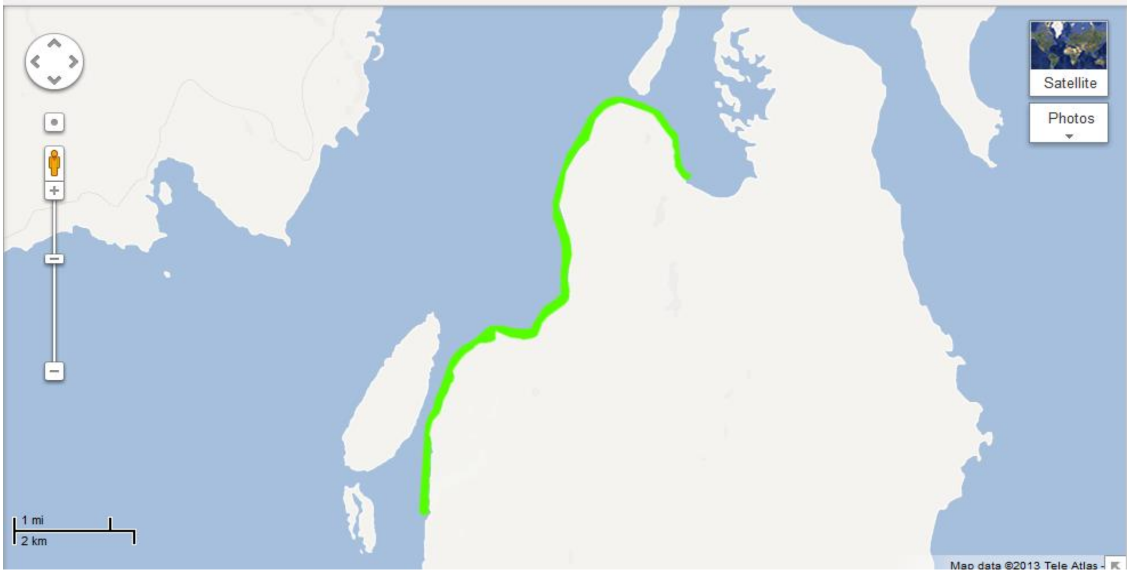
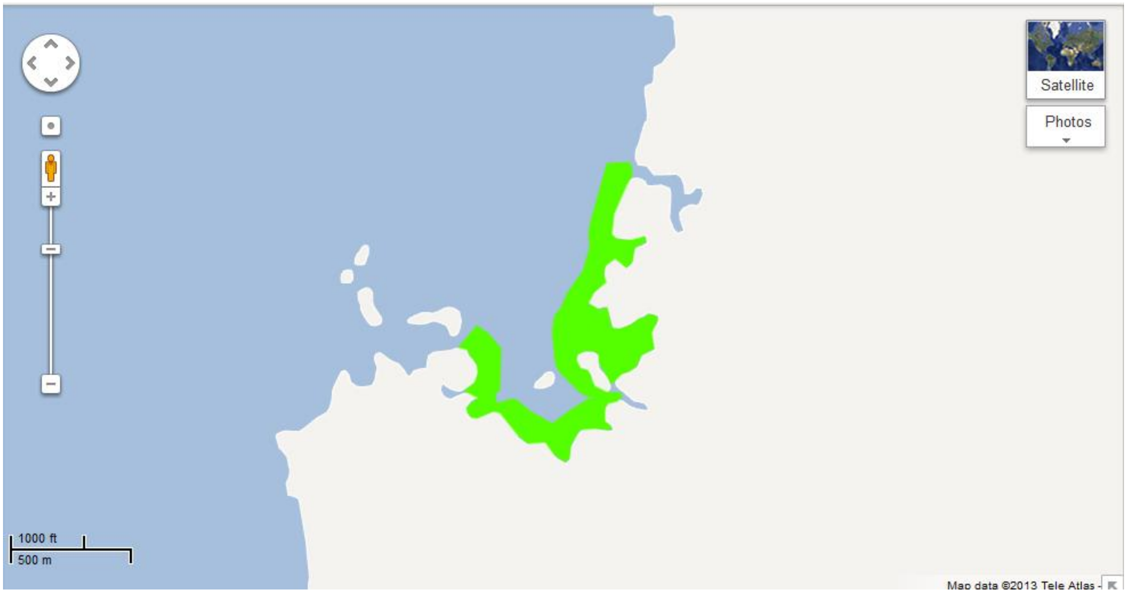
ANNEXES

Annex 1. Survey locations, the size areas, and abundance estimation of *P. kauderni* Bone baru and popisi village.



Name	Area (Sq Meters)	Perimeter /Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimates population(numbers of fish)
bonebaru	1,269,449	22,196	-01.495°, 123.518°	-01.560°, 123.477°	1,894,018

Annex 2. Survey locations, the size areas, and abundance estimation of *P. kauderni* Tinakin Laut village.

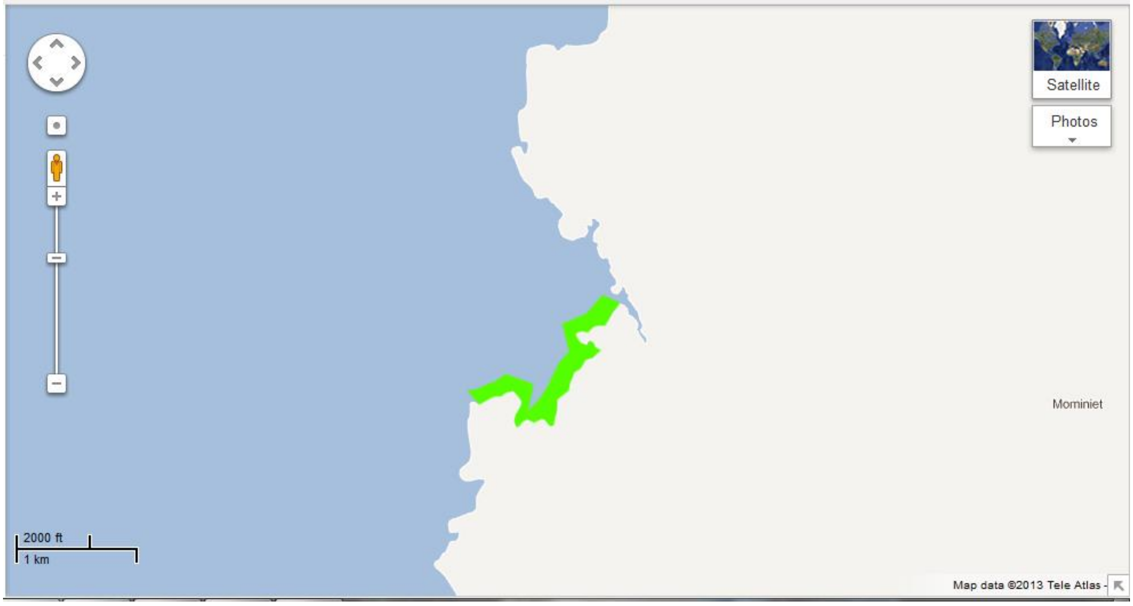


Name	Area (Sq Meters)	Perimeter/Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Tinakin Laut	207,685.7261	5,579.4231	-01.5959747°, 123.4988843°	-01.6068940°, 123.4915156°	500,523

Annex 3. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Matanga village.

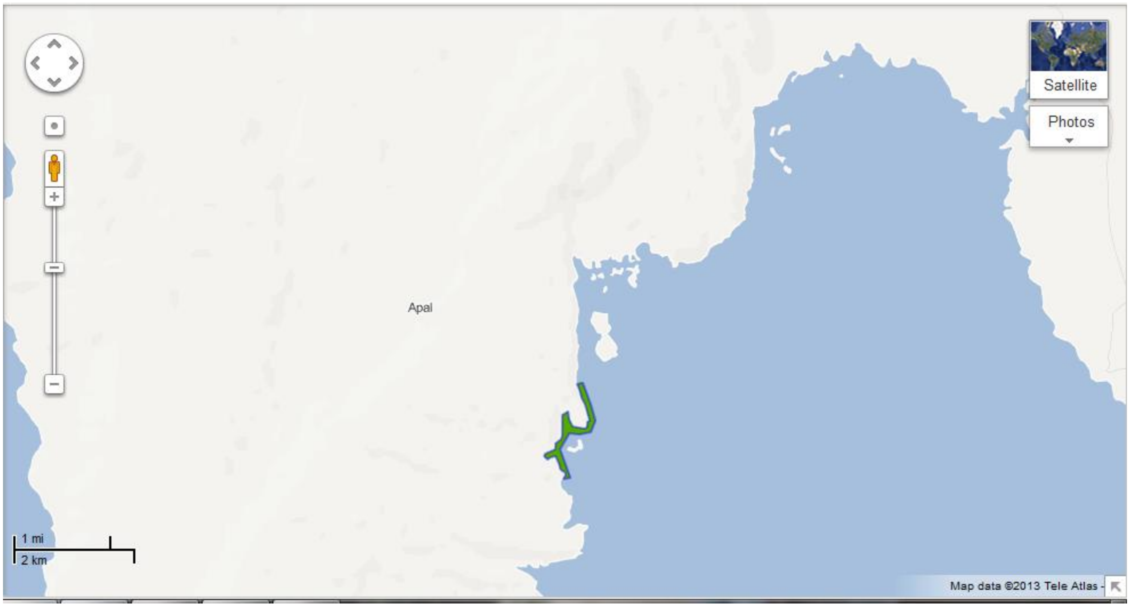
Name	Area (Sq Meters)	Perimeter/ Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Population estimated (numbers of fish)
Matanga	407,399	5,823	-01.7114769°, 123.5894066°	-01.7261898°, 123.5756060°	272,143

Annex 4. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Monsongan village.



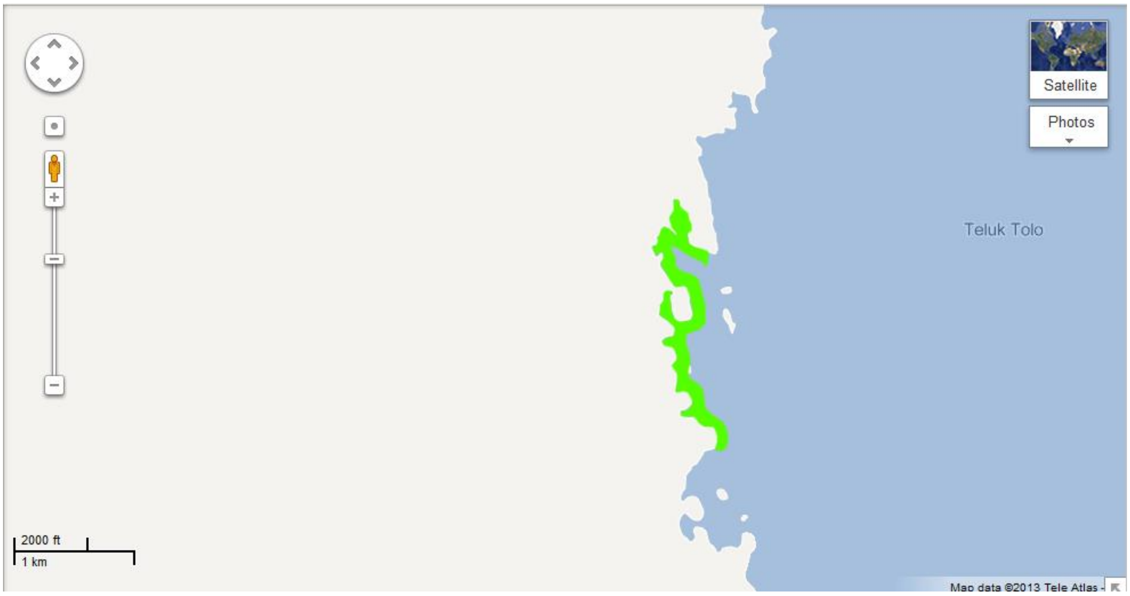
Name	Area (Sq Meters)	Perimeter/Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Monsongan	281,592	5,025	-01.6334154°, 123.4864810°	-01.6432533°, 123.4751439°	741,150

Annex 5. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Apal village.



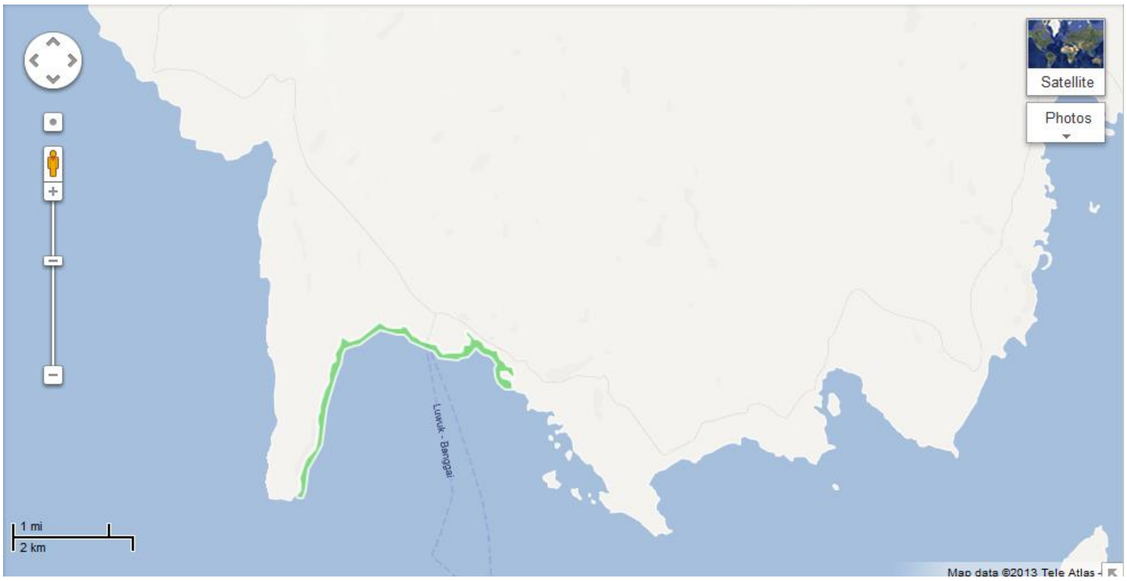
Name	**Area (Sq Meters)**	**Perimeter/ Length (Meters)**	**Bounding Box Maximum (Degrees)**	**Bounding Box Minimum (Degrees)**	Estimated population (numbers of fish)
Apal	198,093	4,798.3625	-01.4613289°, 123.2598192°	-01.4757505°, 123.2521411°	44,769

Annex 6. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Bajo village.



Name	**Area (Sq Meters)**	**Perimeter/ Length (Meters)**	**Bounding Box Maximum (Degrees)**	**Bounding Box Minimum (Degrees)**	Estimated population (numbers of fish)
Bajo	324,796	7,179.5211	-01.5473464°, 123.2434219°	-01.5661006°, 123.2377829°	66,259

Annex 7. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Bobu village.



Name	Area (Sq Meters)	Perimeter /Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Bobu	725,007.6610	13,952.2406	-01.4981258°, 123.3911424°	-01.5251055°, 123.3582915°	361,054

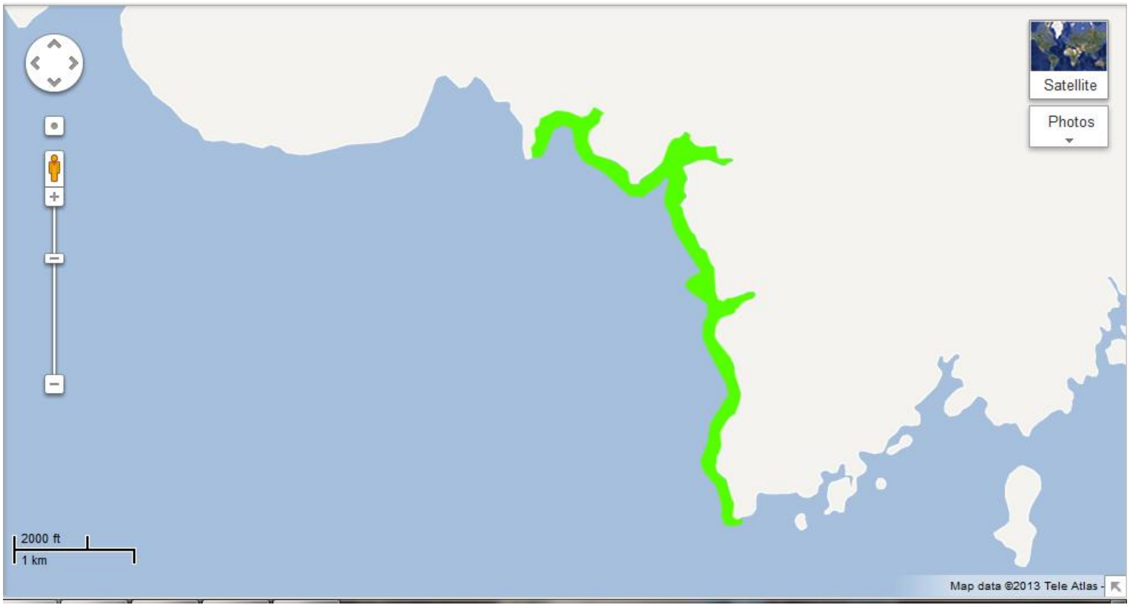
Annex 8. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Boniton village.

Name	Area (Sq Meters)	Perimeter/ Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Boniton	324,092	6,403.5603	-01.5049052°, 123.4470162°	-01.5182998°, 123.4363909°	34,354

Annex 9. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Boyomoute village.

Name	Area (Sq Meters)	Perimeter/ Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Boyomoute	378,557	7,633.4635	-01.4895011°, 123.2527075°	-01.5142922°, 123.2462212°	73,581

Annex 10. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Kindandal village.

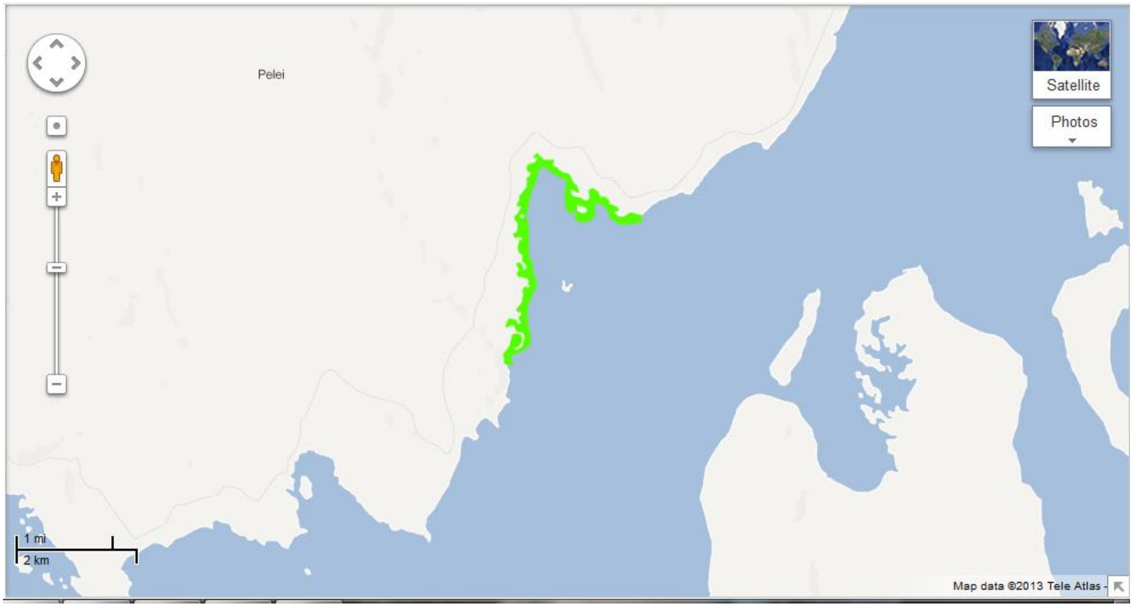


Name	Area (Sq Meters)	Perimeter/ Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Kindandal	675,571	12,502	-01.6098299°, 123.1562740°	-01.6411965°, 123.1395250°	9,458

Annex 11. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Kombongan village.

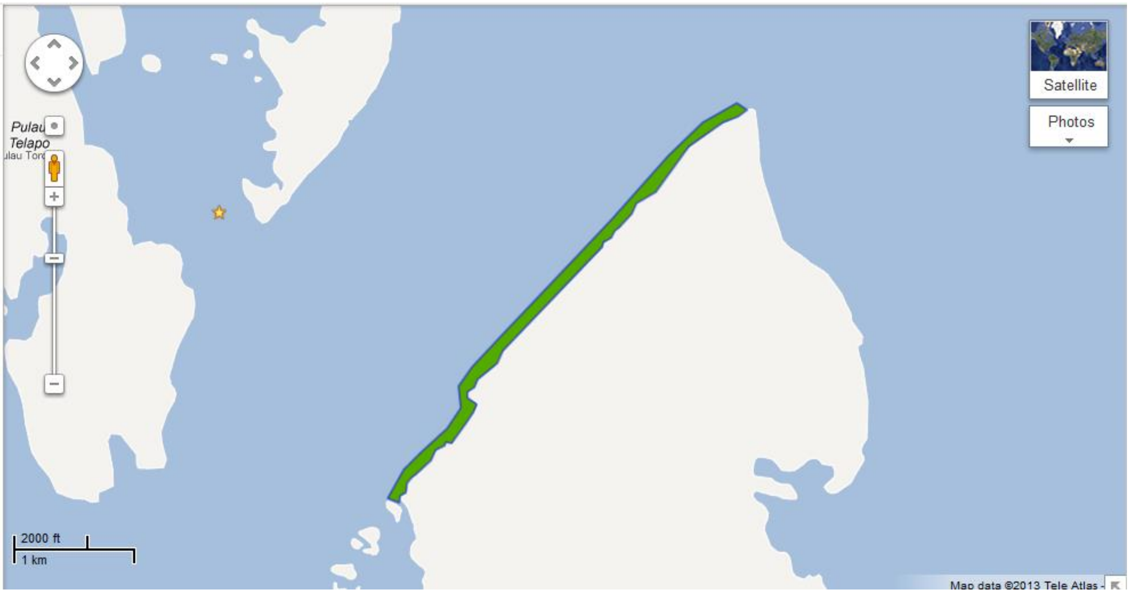
Name	**Area (Sq Meters)**	**Perimeter/Length (Meters)**	**Bounding Box Maximum (Degrees)**	**Bounding Box Minimum (Degrees)**	Estimated population (numbers of fish)
Kombongan	2,730,624	37,186	-01.8807490°, 123.6901320°	-01.9304390°, 123.6619110°	1,196,014

Annex 12. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Lobuton village.



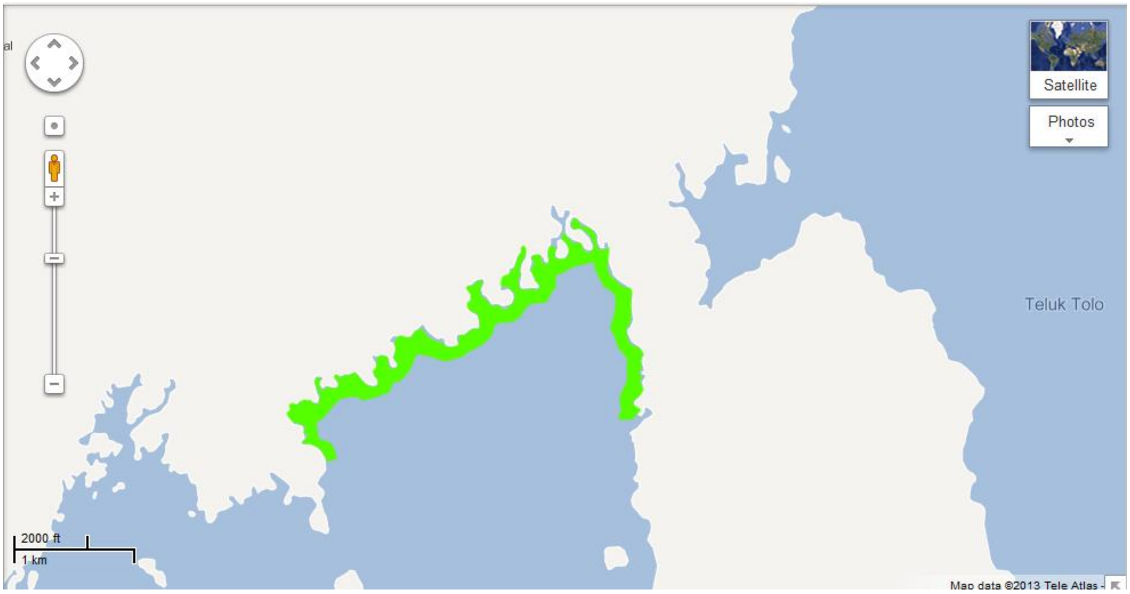
Name	Area (Sq Meters)	Perimeter/ Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Lobuton	932,367	17,099	-01.4605925°, 123.4898337°	-01.4922674°, 123.4689812°	302,087

Annex 13. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Minanga village.



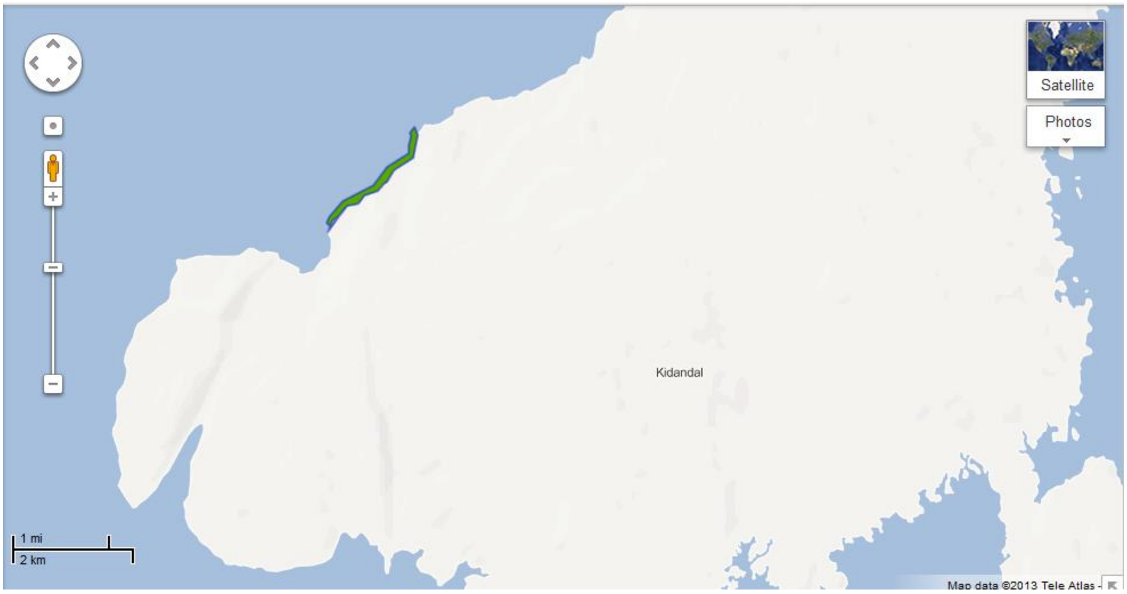
Name	Area (Sq Meters)	Perimeter/ Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Minanga	442,596	9,311.9936	-01.8991701°, 123.7303123°	- 01.9292168°, 123.7033283°	154,024

Annex 14. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Popidolon village.



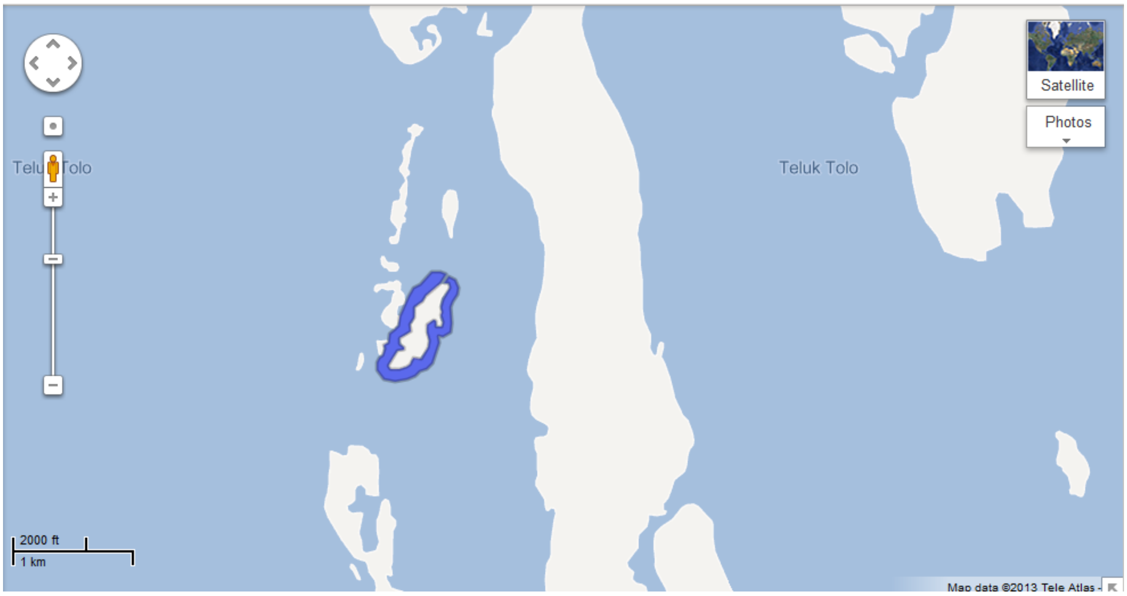
Name	Area (Sq Meters)	Perimeter /Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Popidolon	754,817	15,214.03 77	-01.5963234°, 123.2325306°	-01.6145319°, 123.2057469°	237,013

Annex 15. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Tolulos village.



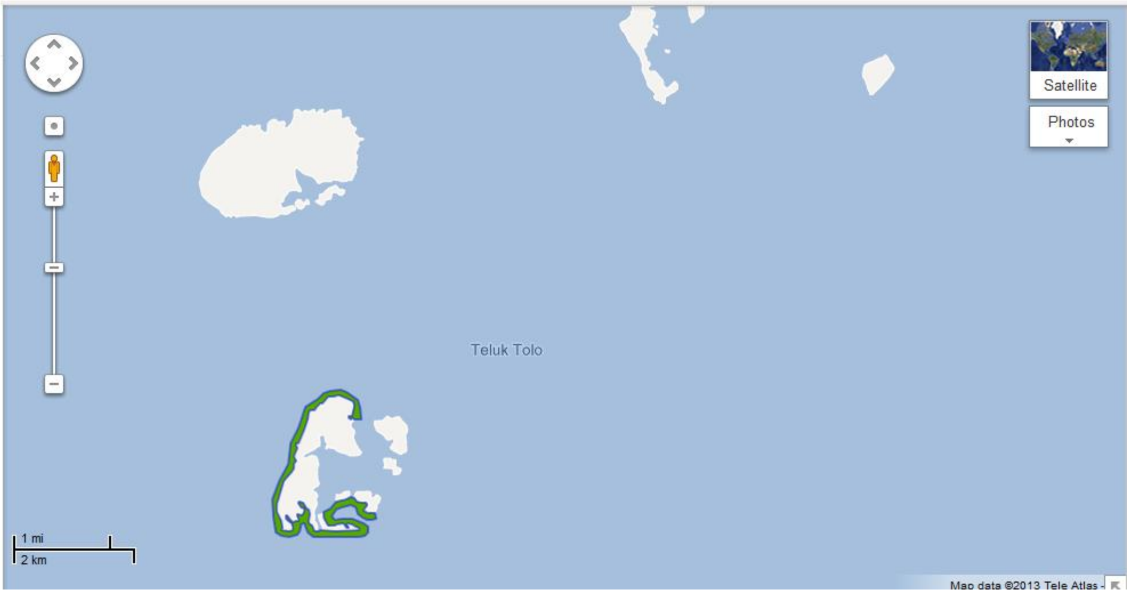
Name	Area (Sq Meters)	Perimeter/ Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Tolulos	243,394	5,772	-01.5465660°, 123.1437845°	-01.5622550°, 123.1300925°	28,234

Annex 16. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Toropot village.



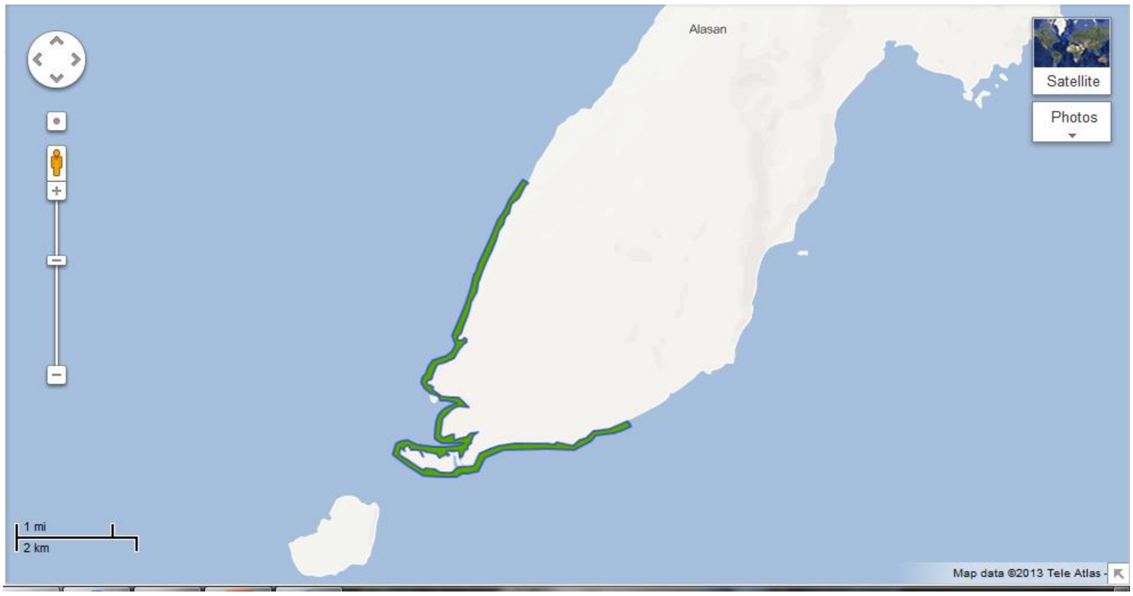
Name	Area (Sq Meters)	Perimeter/Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Toropot	217,922	4,897	-01.9299460°, 123.6418300°	-01.9381810°, 123.6356510°	653,768

Annex 17. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Tumbak village.



Name	Area (Sq Meters)	Perimeter /Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population (numbers of fish)
Tumbak	745,979	15,560	-01.9788058°, 123.4915847°	-02.0010295°, 123.4760393°	259,601

Annex 18. Survey locations, the size areas, and abundance estimation of *P. kauderni* at Bontosi village.



Name	Area (Sq Meters)	Perimeter/Length (Meters)	Bounding Box Maximum (Degrees)	Bounding Box Minimum (Degrees)	Estimated population
Bontosi	1,143,169	25,132.5493	-01.7541843°, 123.3003477°	-01.7996456°, 123.2645821°	1,682,746