Comparative stock assessment of freshwater kai (*Batissa violacea*) between 1996 and 2019 in the Ba River

Tomasi Tikoibua[1] and Rosemary Dautei[2]

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Abstract - *The comparative study of freshwater clam (Batissa violacea) in the Ba river was prepared in accordance with Activity 1.1.1.3 of the Global Environment Facility (GEF) funded Fijian Government's Ridge to Reef (R2R) project, implemented by the United Nations Development Programme (UNDP) and the Ministry of Waterways and Environment. As part of this component of the Fiji R2R project, freshwater clam biological surveys were undertaken in the Ba River in Viti Levu by the Institute of Applied Sciences of The University of the South Pacific. This document provides a comparative analysis of a B. violacea (Lamarck, 1818) study conducted by the Pacific Community (also known as SPC) in 1996 with a recent research of the same species over a two week period between June and September 2019. Key survey findings include the change in lower and upper limit of kai bed with a drastic reduction of range in the Ba River. The total number of kai sampled in this study was 12,688 individuals compared to 17,304 individuals sampled in the 1996 study. In the 1996 study, kai abundance was notably higher at mid-river (Upper Nailaga – Upper Vaqia), but that has been changed as per this present study where kai individuals dominated in abundance in the upper river (Upper Vaqia – Lower Navisa). The population dynamics of kai in the Ba River has been reduced and therefore suspected to be due to the following factors; river dredging for flood alleviation that was focused only on the lower Ba River (where kai was most abundant during the 1996 study);*

[1] Senior Scientific Officer, The Institute of Applied Sciences, University of the South Pacific
[2] Marine Project Officer, The Institute of Applied Sciences, University of the South Pacific

overharvesting; and unrestricted harvesting of juvenile kai. Further, a critical area with high abundance of kai in the upper river was demarcated and recommended as the highest priority area for management. This paper supports the Ba River as a likely and viable target area for freshwater kai conservation.

Introduction

Batissa violacea is an edible mollusk reportedly present across the western Pacific including Malaysia, Indonesia, Northwestern Australia, Fiji and Papua New Guinea (Richards, 1994, Ledua et al., 1996, Morton, 1991, Mayor et al., 2016). The clam can be found in sandy or muddy beds of river, restricted to the lower freshwater reaches of rivers (Lewis, 1985, Mayor et al., 2016). It is reported to be present between the upper limit of tidal influence and the upper limit of saltwater penetration (Lewis, 1985, Ledua et al., 1996). Some can even be spotted on almost freshwater areas of mangrove swamps.

Freshwater clam fishery in Fiji

In Fiji, *B. violacea* is one of the commonly targeted freshwater bivalve mostly present in major rivers of Viti Levu (includes Rewa, Navua, Sigatoka, Nadi, Ba, and various Tailevu areas) and Vanua Levu (Labasa, Wainikoro & Dreketi). The freshwater clam is locally known as *kai ni waidranu*. Kai is one of the largest freshwater fishery in the country and top three in the Pacific (Gillett, 2016). It is an important commodity to communities, particularly those living next to the major rivers in Fiji. The majority of these communities consume kai as a subsistence food on a daily basis and is also traditionally used for bartering and as a gift for friends (Anonymous, 1975). It also forms an important source of income for these rural communities who live close to the river system. According to Musuota (2015), people who sell kai were able to support their financial household needs such as daily living expenses, children's school expenses and village contributions.

The harvesting of kai is reportedly undertaken by women during low tide using hands and feet. According to Tuqiri (2015), out of the total number of women (101 interviewees) that were interviewed, 68% spent 3 – 4 hours per day and 3 – 4 days per week harvesting kai. The study further revealed that even though the kai fishery is dominated by rural women, men were also employed as kai processors, transporting agents and exporters (Lako et al., 2019). That research also revealed that the majority of the harvesters have more than twenty years of experience.

According to Tuqiri (2015), out of the total number of women (101 interviewees) that were interviewed, 68% spent 3 – 4 hours per day and 3 – 4 days per week harvesting kai. The majority of harvesters have more than twenty years of experience. The time devoted to marketing (including transport and market type e.g. main domestic market or roadside stalls) largely depends on the distance of the kai harvesting sites from the main market - kai beds that are closer to the market usually takes one day from harvest to market, while areas further away usually takes two days before it reaches the market. The value chain analysis conducted by Tuqiri (2015) found that apart from local consumers, other potential buyers include supermarkets, hoteliers, restaurants and exporters. Interestingly, Tuqiri (2015) research also revealed that the main buyers at domestic level are Fijians of Indian descent (95%) who prefer large sized kai and good quality products.

This is aside from local consumers and other potential buyers like supermarkets, hoteliers, restaurants and exporters.

Status of freshwater kai in the Ba River

Several researchers (WWF, 2018, Lee et al., 2018, Tuqiri, 2015, Ledua et al., 1996) have highlighted the significant decreases in mean sizes of kai harvested from the Ba River and sold in various outlet markets in Ba. This has led to the reduction of the number of kai individuals per heap thus decreasing the weight of each heap (WWF, 2018).

A kai study that was conducted by WWF in 2018 using qualitative research methods (questionnaires - anecdotal evidence, fishing activity and market survey) suggested changes in kai bed locations in the Ba River. This resulted in WWF, through the Fiji R2R Project, requesting the Institute of Applied Sciences to undertake a replicate freshwater kai biological assessment study to compare with the Ledua et al., 1996 results to validate outcomes from the WWF (2018) study. This current study is expected to determine the current kai bed limit as well as quantify kai stock in the Ba River.

Research Objectives

There are two main objectives of this research;

1. To compare two kai data sets (1996 & 2019) on biomass, density and size classes in the Ba River.
2. To identify if there is any change in the lower and upper limit of kai bed location in the Ba River.

The outcome is to support the identification of a critical habitat area in the Ba Riveras the basis for the demarcation of areas critical for protection and again shed light on the importance of regulating the harvesting of marketable size limits (>25mm) for kai.

Methodology

Sample collection area

This study was a replica to a research conducted in June 1996 by Ledua et al. (1996). In replicating the 1996 study, eight sampling stations were chosen along the downstream area of the Ba River where the B. violacea are harvested (Ledua et al., 1996). The location of these eight stations (Appendix 1) and sampling techniques employed were similar to the study that was conducted back in 1996. The mean distance between stations is approximately 2.33 km with a range of 0.95 km to 8.48 km. Given that there were no specific GPS coordinates provided from the previous study, the following were carried out to identify the most accurate 1996 sampling stations;

The research team used google maps in conjunction with the detailed information provided in Ledua et al.'s 1996 report. The team also consulted Votua and Nasolo kai harvesters.
Formal discussions were held with Mr. Esaroma Ledua (lead researcher/author of the 1996 study report) to gather recollected descriptions of each of their 1996 sampling sites.
A thorough reconnaissance survey was conducted at each study site. The resource owner's assistance were also sought including ground truthing and physically visiting and verifying the area in conjunction with the map.

This report includes the Global Positioning System (GPS) coordinates for each station and transect (Appendix 3) and their local names are included on top of the station number (Table 2).

Table 2: Names of different sampling locations between 1996 & 2019

	Surveyed Locations	
Station number	**1996 study sites**	**2019 study sites**

S1	Lower Nailaga	Lower Nailaga
S2	Nailaga village	Nailaga village
S3	Mid Nailaga	Mid Nailaga
S4	Upper Nailaga	Upper Nailaga
S5	Lower Ba town	Lower Ba town
S6	Upper Vaqia	Upper Vaqia
S7	Lower Kumukumu	Lower Kumukumu
S8	Upper Kumukumu	Upper Kumukumu
S9	N/A	Lower Navisa

Sampling technique and materials

A total of four transects were laid at each station although the distance between transects was determined by river width. These transects were placed parallel to river flow. An assessment across the river was conducted to determine the distribution and density of freshwater kai at that station. Due to the variations in tide and river inflow at survey locations, sampling teams used scuba diving, snorkeling and intertidal sampling where areas were fully exposed.

At each transect, eight grid samples were taken. Grid size was 50 x 50 cm. All grids started at point 0 and thereafter at every 6.25 m along the transect ending at the 50 m point. Using hand trowels, each sampler shifted sediments within the grid into a sieve. The depth of the grid was varied depending on the presence of kai sample. Freshwater kai were then collected into a bucket, measured on site before release back into the river.

Kai data collection

All freshwater kai collected on site were measured individually using calipers (Digital caliper: Guang Lu, 1.5v) as well as weighed using an electronic balance (High Precision Balance; Model: KD-BN; Capacity: 1100 g; Division: 0.01 g; e = 10d; Power: DC8V; Serial No.; G70308001). The four data parameters collected for each individual bivalve were; (1) density; (2) shell length; (3) shell height; and (4) kai weight. Both shell length and height were measured in millimeters and weight in grams. All data parameters were collected and labelled for each site, each transect, and each grid. Measurement of shell (length and height) are shown on Figure 3. All measured kai samples were then returned to the site.

Results

Comparison of kai abundance and distribution between 1996 and 2019

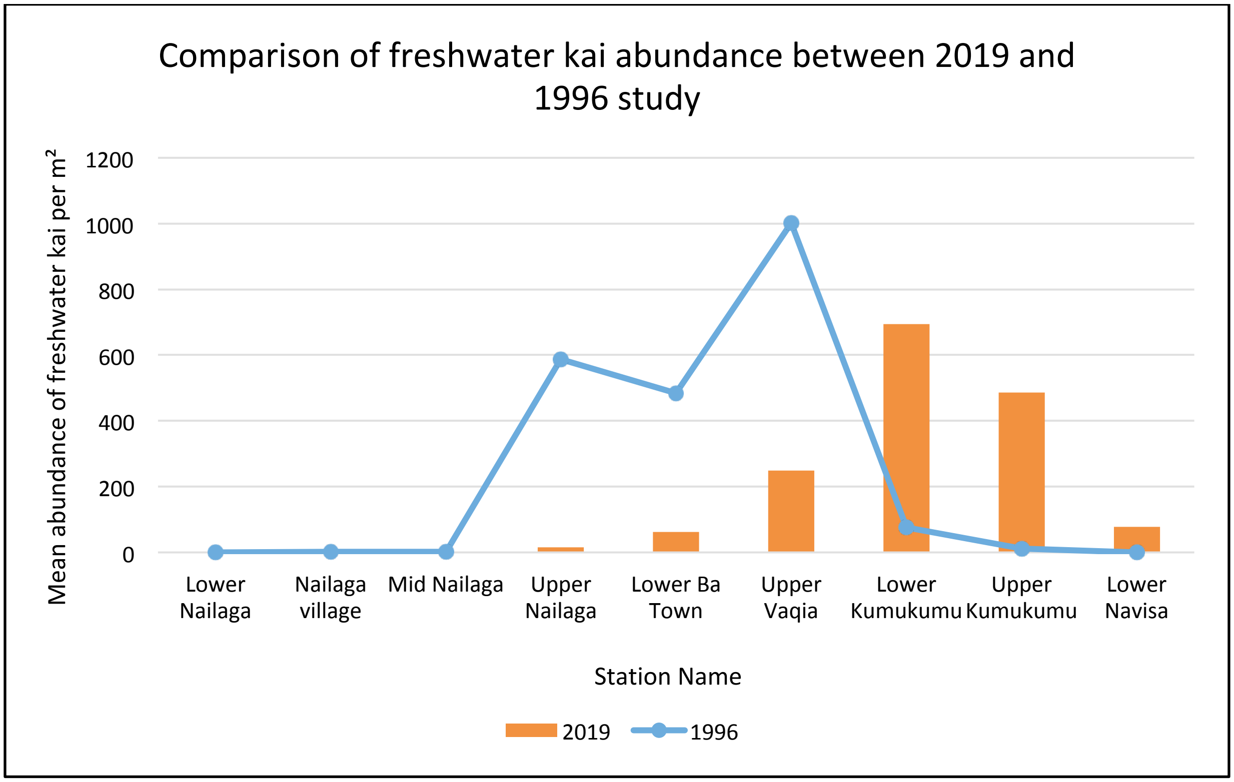

Figure 1: Comparison of freshwater kai abundance between 2019 and 1996 study

Results highlighted the absence of kai from Lower Nailaga – Mid Nailaga during the 2019 study as compared to the low kai abundance recorded in 1996. In this 2019 study, a new lower kai bed limit was established at Upper Nailaga. It was also found that kai abundance was substantially reduced in 2019 from Upper Nailaga – Upper Vaqia (Figure 4). A significant decrease in kai abundance was also seen at Upper Vaqia from 1002.38 kai/m^2 in 1996 down to 248.25 kai/m^2 in 2019 (at a decreasing rate of 3.84 %). While Lower Kumukumu and Upper Kumukumu recorded a substantial increase in kai abundance (at an increasing rate of 5.05 % Lower Kumukumu and 3.77 % increase at Upper Kumukumu). In 2019, the highest kai abundance was found at Lower Kumukumu with 694.75 kai/m^2 compared to 74.88 kai/m^2 in the 1996 study. Again, in the 2019 study, the new upper limit was established at Lower Navisa since kai presence was only recorded up to Upper Kumukumu in 1996.

Comparison of kai biomass between 1996 and 2019

Kai biomass comparison between 1996 and 2019

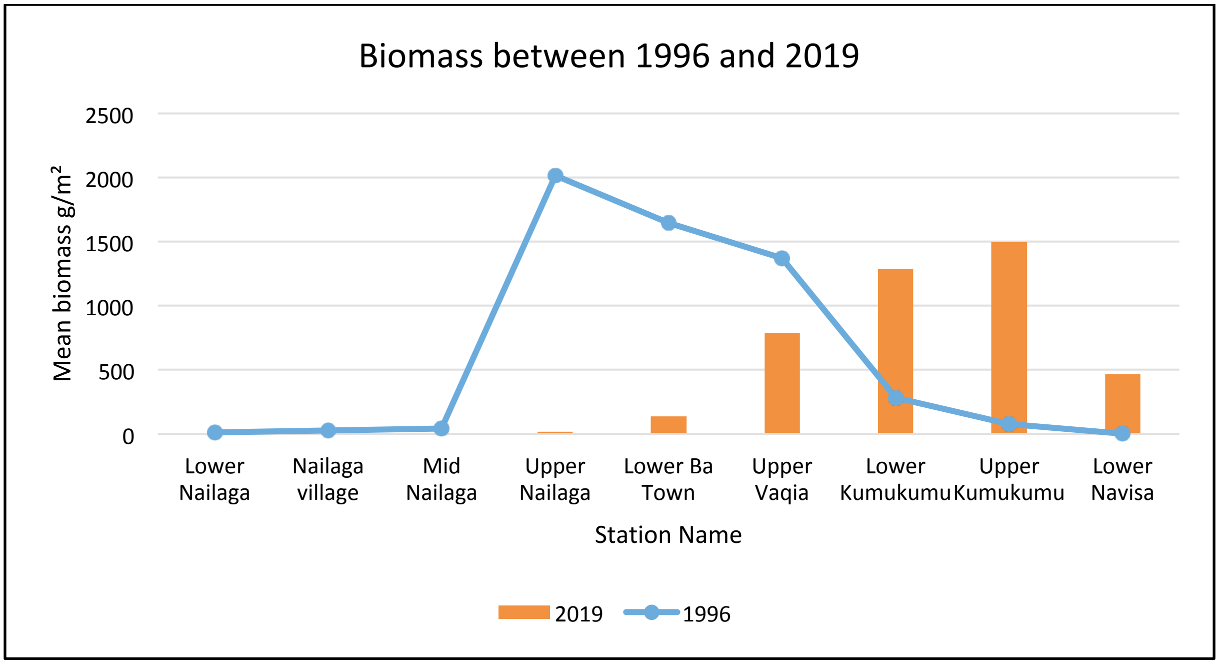

Figure 2: Biomass results between 1996 and 2019 study.

In the 2019 study, kai biomass increased up river with the highest recorded at Lower and Upper Kumukumu (mean kai biomass of 1287.75 g/m^2 and 1495.65 g/m^2 respectively). There was a drop in biomass observed at Upper Nailaga and Lower Ba Town in 2019 compared with the high biomass found during the 1996 study. The current 2019 study shows that Upper Nailaga recorded a kai biomass of 18.41 g/m^2 as compared with 1996 when kai biomass was 2017.39 g/m^2. There was not much difference in biomass at Upper Vaqia between the years. Lower and Upper Kumukumu recorded high biomass, mean kai biomass of 1287.75 g/m^2 and 1495.65 g/m^2 respectively, as compared with the 1996 study (Lower Kumukumu – kai mean biomass of 279.72 g/m^2 and Upper Kumukumu – 78.75 g/m^2). Kai were also noted at Lower Navisa in 2019 with a mean biomass of 468.17 g/m^2.

Correlation between water salinity vs kai abundance

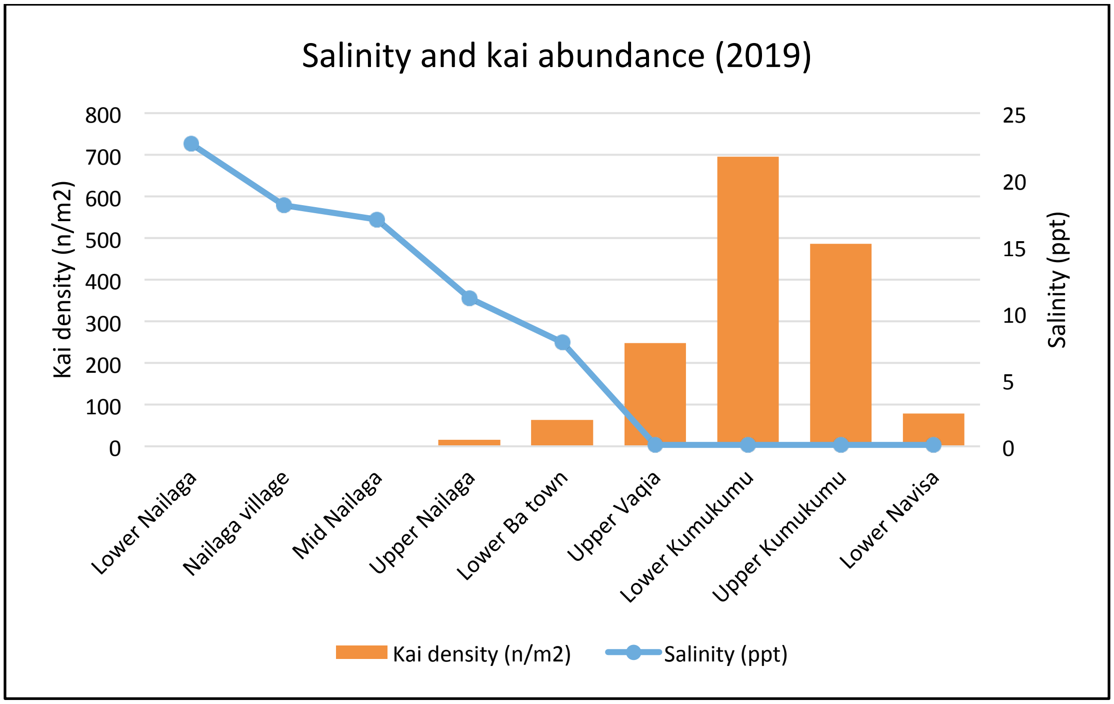

Figure 7: Relationship of Kai density and salinity in the Ba River

Salinity was higher at Lower Nailaga (closer to river mouth) and decreased as it moved further up the river to Lower Navisa. In places where there is no kai, salinity ranged from 17 – 23 ppt. Kai individuals exist only at salinity ranging from 0.1 – 11 ppt. Results showed that kai abundance decreased at high salinities but increased at very low salinities. For example, at salinity of 0.1 ppt, kai abundance ranged from 79 – 695 individuals. Lower Navisa located the furthest inland had salinity recordings of 0.1 ppt.

Frequency of Kai Shell length in the Ba River

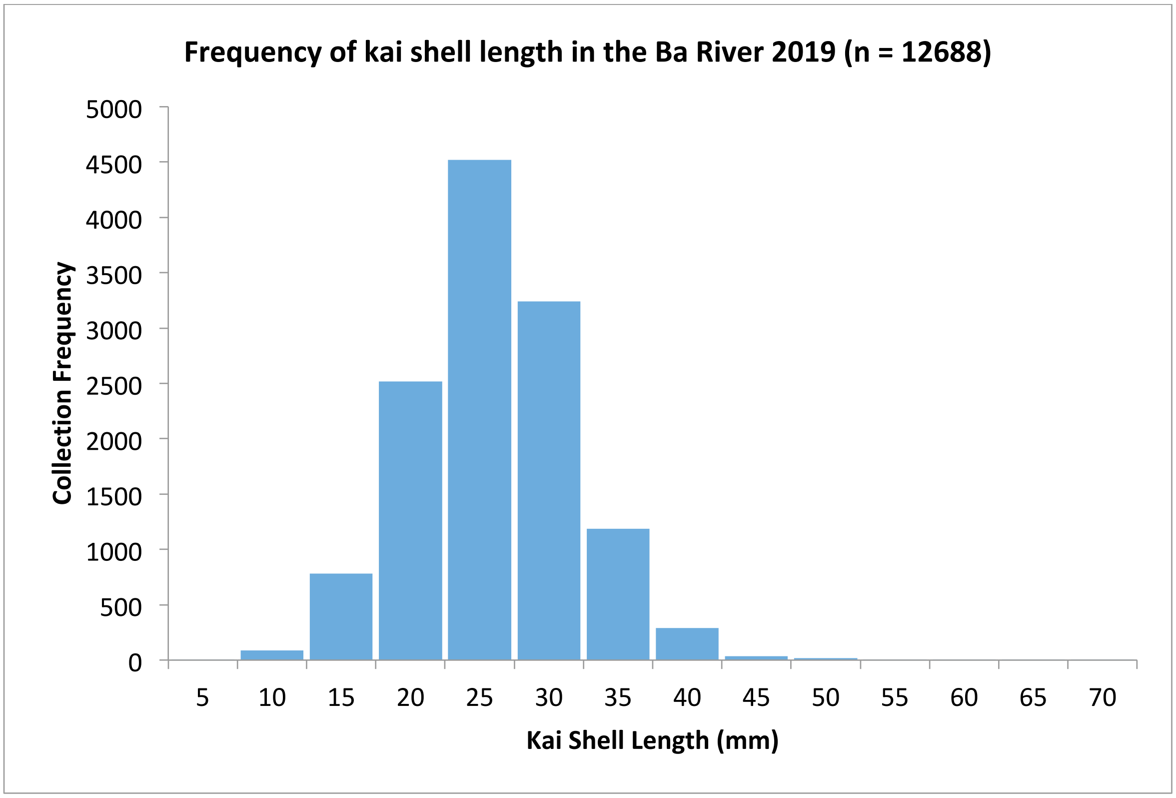

Figure 8: The kai shell length frequency in the Ba River was measured at intervals of 5 mm.

Approximately 38% of the kai population in the 2019 survey falls within the marketable size range (>25mm).

Kai size ranged from 4.76 – 68.33 mm in shell length with a mean of 23.52 mm. The highest frequency of kai shell length occurs at 25 mm (Figure 8) with a total of 4520 kai individuals. The second highest frequency was recorded at the length of 30 mm with 3239 individuals of kai. The largest kai shell length recorded measured at 68.33 mm. Kai individuals >40 mm and <15 mm shell length were in very low numbers.

Discussions

Status of kai bed location in the Ba River

In looking at kai bed locations, the abundance results suggest changes occurred on the lower and upper limits between the two study periods. The 2019 results highlighted that kai populations on the lower limit had moved further up-river, specifically from Lower Nailaga (based on 1996 data) to Upper Nailaga (2019 data). A qualitative study conducted by WWF 2018 supported this result in which the changes in kai fishing areas for communities was reported.

The changes in kai bed locations can be attributed to the extensive dredging development that was carried out in the area from 2012 to 2017. River dredging can substantially change river bed structure and increase water flow within the river channel. Studies by Rasheed and Balchand (2001) and Erftemeijer and Roy (2006) discuss the detrimental impacts that bathymetry and bed configuration can have on inlet stability and estuarine embanks which ultimately impacts upon benthic fauna.

Saltwater inundation is another possible contributing factor to the changing kai range. Gravelle and Mimura (2008) found that the majority of the coastline areas in Viti Levu, Fiji is vulnerable to climate change effects with a high degree of inundation.

Status of Distribution, Abundance and Biomass of kai in the Ba River in 2019

The 2019 study showed that kai populations were distributed along river beds between Upper Nailaga to Lower Navisa. The distribution pattern showed that kai individuals increased as it moved up river and decreased as it reaches Upper Kumukumu. The distribution pattern of kai species were not only reflected on the changes of kai bed but the abundance and biomass results as well.

Substrate composition were observed and therefore suspected to be the regulating factor of kai distribution in the Ba River. During the survey, it was observed that kai individuals were more abundant at places with sandy and firm bluish black mud substrate with small to medium gravel mixture including places with filamentous algae. Kai populations were low in numbers in areas dominated by loose sandy bottom and soft mud which is mostly evident in the lower part of Ba River.

Influence of environmental parameters (salinity) on both density and biomass

The influence of physio-chemical factors of water to population densities and biomass vary among geographical areas (Tanyaros and Tongnunui, 2011). The present results show that both kai abundance and biomass increases as salinity decreases. In the areas from Lower-Nailaga to Mid-Nailaga, salinity ranges from 17 – 23 ppt, with corresponding absence of kai. Kai were found to be abundant in areas with salinity ranges between 0.1 – 11 ppt. The following results strongly suggest that kai thrive better in freshwater although it can survive in mesohaline and oligohaline environments. Kai therefore is not strictly a freshwater species.

Conclusion

The following can be concluded from the study.

Kai bed limit changes

1. There were no kai species identified at Lower Nailaga – Mid Nailaga although the 1996 survey had them present. The change in location of kai presence meant that the lower limit of kai bed had been shifted upstream from Lower Nailaga now to Upper Nailaga at a distance of approximately 4.68 km. The same was noted on the upper river where kai had moved up to a new location (Lower Navisa) from where it was sighted (Upper Kumukumu) during the 1996 study. The upriver movement was estimated to be at the distance of approximately 1 kilometer since 1996.
2. The total distance of the Ba River kai zone has been reduced by 3.64 km. The 1996 study kai zone was estimated to be 17.62 km whereas the 2019 study is approximately 13.98 km.

Kai abundance and biomass changes

3. The total number of kai sampled in this study was 12,688 individuals compared to 17,304 individuals sampled in the 1996 study. Kai density ranged from 0.13 – 1002.38 n/m^2 in 1996 to 0 – 694.75 n/m^2 in 2019 study. The biomass ranged from 10.92 – 2017.39 g/m^2 in 1996 to 0 – 1495.65 g/m^2 in 2019.

Kai population distribution changes

4. In the 1996 study, kai abundance was notably higher at mid-river (Upper Nailaga – Upper Vaqia). But that has changed in this present study where kai individuals dominate in terms of its abundance in the upper river (Upper Vaqia – Lower Navisa).
5. The population dynamics of kai in the Ba River has been reduced and is suspected to be due to the following factors; river dredging for flood alleviation that was focused only on the lower Ba River (where kai was most abundant during the 1996 study); overharvesting; saltwater inundation and unrestricted harvesting of juvenile kai.

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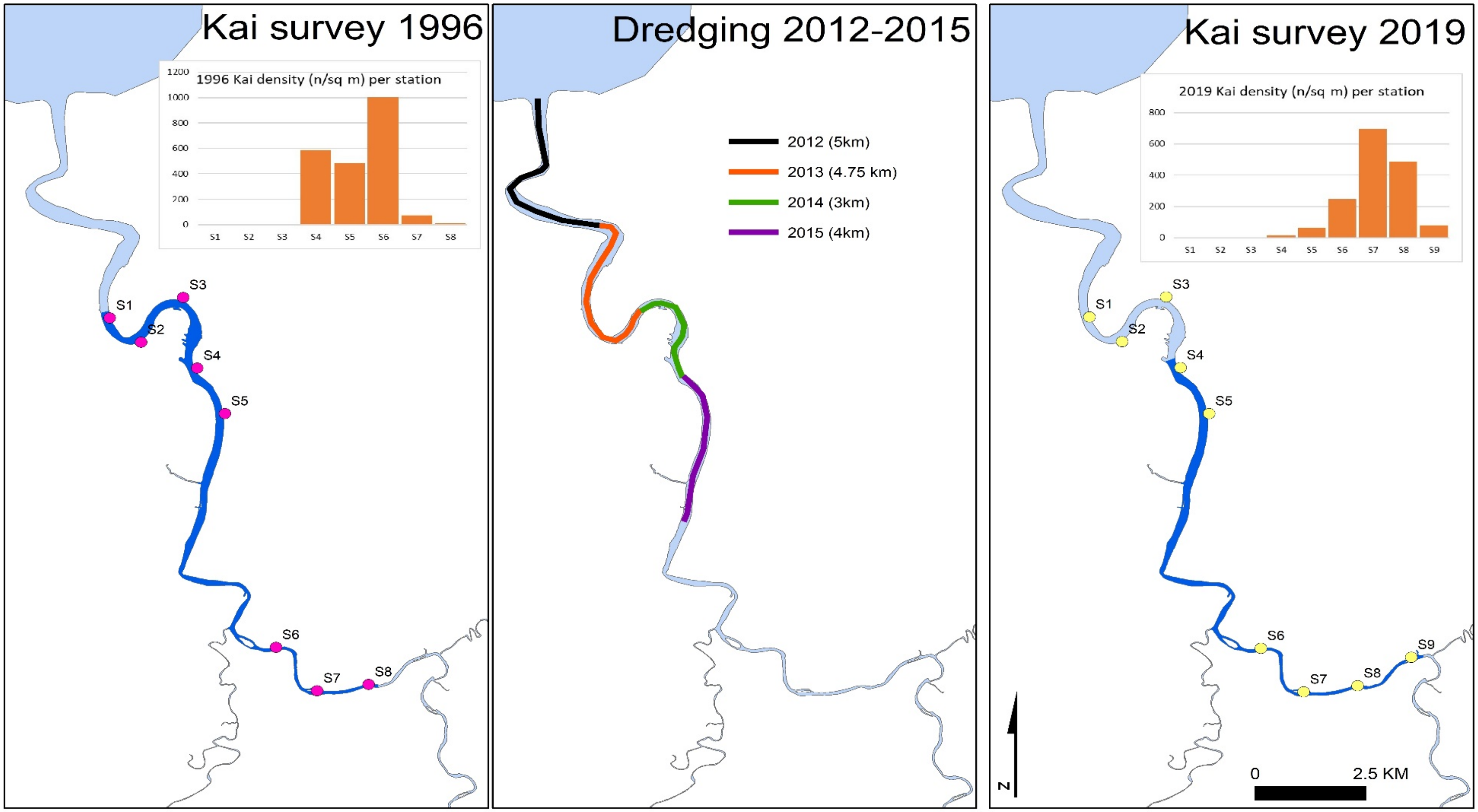
Annex 1:



Kai survey results (kai bed limit, abundance and dredging extent) in the Ba River

Figure 11: Kai bed between 1996 and 2019 study results compared with the dredging results adopted from the Ministry of Waterways and Environment

database. **Note: The dark blue shade (1996 & 2019 studies) signifies kai bed in the Ba river system while the light colour shows the no kai area. The different colour coding (black – 2012, Orange – 2013, Green – 2014, and Purple – 2015) on the dredging results showed the extent of dredging development that was carried out from 2012 – 2015.**