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1 Acknowledgments

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2 Executive summary

Rural communities in the Pacific region often rely on fishing as a source of protein and income. However, high population growth rates are placing increasing stress on local fish stocks, and so it is important to develop alternative livelihood strategies. In Papua New Guinea (PNG), locally based sportfisheries have the potential to provide stable alternative livelihoods for coastal villagers, and build community resilience to impacts such as climate change and fluctuations in commodity prices. The Niugini Black Bass is one of the world's premier sportfish, attracting anglers from around the globe to PNG. In some areas, Black Bass forms the basis of a growing sportfishery, able to benefit local communities' economies while maintaining traditional ways of life and promoting environmental stewardship. However, management is hindered by fundamental scientific knowledge gaps, putting the future of the fisheries at risk.

The objective of this project was to provide NFA with the necessary biological, ecological, socio-cultural and economic understanding needed to develop and manage a sustainable and resilient locally based sportfishery able to provide stable alternative livelihoods for PNG's coastal villages. Work was based in the communities around the villages of Baia, Somalani and Vesse, in the West New Britain Province and focused on Black Bass. Since Spot-tail Bass is also a major drawcard for sportfishing tourists in the region and occurs in similar habits to Black Bass, this species was also included in this study.

Results show that the sportfishery relies mainly on mature fish. However, size is a poor indication of age, meaning it is not possible to assume recruitment to the fishery based on presence of small fish. Since it is important to monitor the age structure to confirm ongoing recruitment and ensure sustainable fisheries, a non-lethal method of ageing was developed, which can be used by NFA to monitor population structure into the future. Results also show that Black Bass use a range of habitats throughout their life cycle, and that snags and other complex structures are particularly important habitats. Although it was not possible to identify exact spawning locations, data suggest that spawning occurs at the interface between salt and freshwaters, and that eggs are then washed out to the sea. After a marine larval stage, juveniles migrate into rivers, where they occur along shallow grassy edges of the lower freshwater reaches. Larger juveniles and adults then move to more downstream habitats as they grow, but make regular migrations throughout the seascape, often associated with the new moon. These lunar movements coincide with the cycle of migration of juvenile gobies ('whitebait') from marine to freshwater. Black Bass feed extensively on these gobies, and therefore the maintenance of these whitebait populations is crucial for the resilience of Bass populations. Overall, results stress that, for the sustainability of this fishery, it is important to maintain (1) connectivity between the coastal and freshwater habitats, (2) good water quality along the river systems and (3) healthy riparian zones that provide structure, shading and food. However, over the course of the project, degradation of river habitats due to logging was evident, and this can negatively affect the Black Bass fishery. Economic and socio-cultural analyses showed that sportfishing operations can have significant economic benefits for local communities and that, in general, people associate the industry with improvements in their quality of life. The socio-cultural analysis indicates that these communities are well placed with the capacity to further capitalise and benefit from ongoing sportfishing or similar livelihood diversification opportunities. There were however potential conflicts in communities where people also gained economic benefits from extractive industries with the potential to impact on sustainable sportfishing.

The multidisciplinary information obtained led to the drafting of a best-practice catch-and-release guideline and a Management Plan for the Black Bass sportfishery. These can be used by NFA as a basis for managing Black Bass and their critical habitats, ensuring the long-term sustainability of Black Bass stocks and the industry. This is of particular importance because coastal and freshwater ecosystems are under increasing threat from burgeoning development of mining, logging and plantation agriculture.

3 Background

Rapid population growth is placing increasing pressure on PNG's coastal, estuarine and freshwater resources (Sabetian & Foale 2006), which often provide the principal source of protein for the largely subsistence population (Koczberski et al. 2006). In addition, local people are increasingly turning to small-scale commercialisation of local fish stocks, which are often the highest contributors to incomes in isolated villages (Koczberski et al. 2006). The joint pressures for increasing extraction of fish as a key subsistence resource and small-scale commercialism set the scene for a looming food security crisis, as fish stocks are rapidly depleted. Resolving this problem requires a complex mix of initiatives, with one key component being the development of alternative ways of utilising fish stocks that both preserve them and provide new income streams to rural communities.

Locally based sportfisheries (i.e. the recreational catch-and-release of iconic game fish) have the potential to diversify rural livelihoods, build resilience to external impacts such as climate change and fluctuations in world commodity prices, and could generate significant environmental benefits by creating incentives to conserve the target species' key habitats. Nature-based tourism such as sportfishing is often regarded as a panacea for creating sustainable livelihoods in developing countries because it creates value from biodiversity, thus generating an inducement to preserve and manage natural assets. This 'biodiversity-linkage' alternative livelihoods model was tested by Salafsky and Wollenberg (2000) across South-East Asia and Melanesia in the 1990s, where it was shown that ecotourism provided the strongest 'win–win' linkages and enterprise longevity compared to harvest-based initiatives. However, there has been limited development of sportfishing as a livelihood alternative in PNG, despite substantial sportfish resources headlined by unique, world-renowned sportfish.

The Niugini Black Bass (*Lutjanus goldiei*) and Spot-tail Bass (*Lutjanus fuscescens*) are the two largest tropical snappers that inhabit estuarine and freshwater habitats. The Black Bass is endemic to New Guinea and surrounding islands, and is one of the world's premier sport fish (Kreh 2012). Its uniqueness, large size and hard-fighting behaviour makes it a highly prized fish that attracts anglers from around the globe to PNG. The Black Bass has been identified by the Tourism Promotion Authority (TPA) as a valuable target for the next wave of ecotourism development in PNG. Along the north-coast of the mainland and the island provinces to the northeast, the Spot-tail is also a major drawcard for sportfishing tourists, so this study also targeted this species.

While experience from other parts of the world has shown that remote indigenous communities can derive livelihood benefits from sportfisheries, context-specific potential limitations and costs need to be taken into account. These include, for example training, lack of experience in business commercialisation, fluctuating tourism markets, social networks and inter-community friction, and territoriality. Concrete socio-economic goals need to be identified, and site-specific market analysis and research on the linkages between goals and community actions and incentives conducted. At a more fundamental level, the ecology and biology of the fish and the fisheries involved also need to be well understood, so that the resources on which commercial success depends can be appropriately managed. However, there is a lack of adequate policies and management strategies for the sportfishing industry in PNG, due to the deficient knowledge of the livelihood costs, benefits and potential impacts of sportfishing, and of the key biological and ecological data required to underpin management strategies and policy decisions. Therefore, through consultation and collaboration between key PNG government departments, namely the National Fisheries Authority (NFA) and the Tourism Promotion Authority (TPA) and a multidisciplinary team formed by James Cook University (JCU) and NFA researchers, the "**Black Bass Project"** was born.

4 Objectives

The overall objective of the project was to empower the NFA, TPA, and business and community groups with the tools needed to sustainably develop, grow and manage an expanded sportfishery in PNG. These tools should be based on the scientific understanding of key biological, ecological, social, economic, resource management and environmental issues, which need to be considered to allow for a sustainable and resilient sportfishing industry. The project therefore addressed two key research questions:

1. What are the key parameters of Black and Spot-tail Bass ecology and biology relevant to ensuring long-term resource sustainability and resilience, and how can these needs be managed most effectively?
2. What are the major socio-economic and commercialisation issues that need to be considered in the development of sustainable sportfisheries, and what are the most effective options and needs for addressing them?

Specific objectives:

Objective 1. *Develop an understanding of relevant aspects of the ecology and biology of Black Bass sportfish resources of PNG, to determine:*

Activity 1a. habitat requirements, home ranges and patterns of habitat occupancy and across life history (e.g. nursery habitats, spawning habitats), life-history migration patterns;

Activity 1b. population structure, growth rates and reproductive periods and locations;

Activity 1c. sources of nutrition and prey resources;

Activity 1d. patterns of abundance of prey species.

Objective 2. *Devise protocols for the appropriate conduct of a sportfishery in a PNG context to maximise its resilience and long-term viability, by:*

Activity 2a. evaluating current sportfishing operations within PNG;

Activity 2b. collecting data on the different fisheries practices used in the Black Bass fishery;

Activity 2c. reviewing best-practice sportfishing practices used in similar sportfisheries in other parts of the world;

Activity 2d. developing best-practice guidelines for sportfishing activities in PNG.

Objective 3. *Develop an understanding of potential livelihood costs and benefits, and how to manage them, by:*

Activity 3a. investigating the social structures and cultural norms related to commercial use of local fish resources;

Activity 3b. investigating how to optimise livelihood costs and benefits in PNG's cultural context, by minimising adverse outcomes and social problems, and ensuring equitable division of benefits;

Activity 3c. identifying issues involved with integrating local people into an appropriate business framework, and methods for addressing those issues.

Objective 4. *Work with NFA to draft a Management Plan for sustainable sportfisheries in PNG.*

Activity 4a. Using the sportfishing operations in Baia as a case study, drafting a *Niugini Black Bass Management Plan* that relates to the conduct and management of the sportfishing industry targeting Niugini Black Bass and associated sportfish.

5 Methodology

5.1 Methods overview

Work comprised four linked phases corresponding to the objectives (Figure 1). All phases involved substantial capacity building.

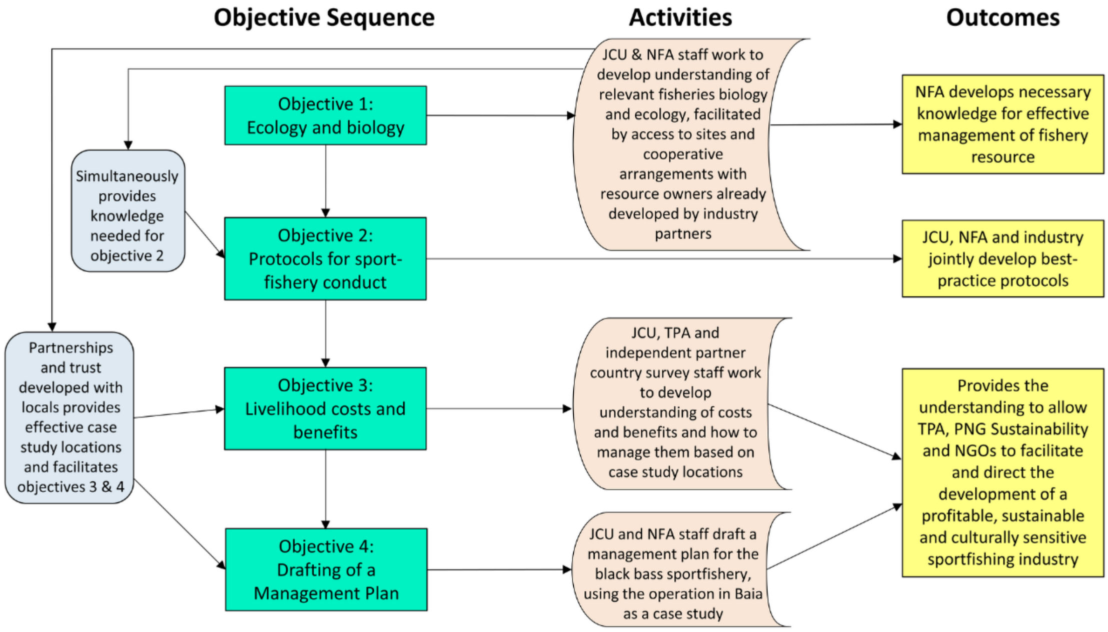


Figure 1. Diagram detailing the project's objectives, activities and expected outcomes.

Objective 1: *Develop an understanding of relevant aspects of the ecology and biology of Black Bass sportfish resources of PNG*

A range of methods was used to address the key knowledge gaps in Black and Spot-tail Bass biology and ecology. For **Activity 1a**, methods included interviews with sportfishing operators to determine their understanding of the extent of areas used by Black Bass; sidescan sonar surveys to identify the variety and distribution of sub-tidal habitats; underwater video surveys in areas surrounding those identified by sportfishers to identify additional areas used (e.g. nurseries); video and net sampling to determine habitat requirements over the Black Bass life-history; acoustic tracking and otolith microchemistry studies to study movements, habitat use and life-history migration; and spatially explicit collections of adult fish to identify spawning areas. For **Activity 1b**, methods included collections of fish from sportfish catches and net collections in cooperation with villagers to provide samples for size structure, age and growth, longevity and reproductive studies. In **Activity 1c**, diet and sources of nutrition were studied using stomach content and stable isotope analysis, based on samples from sportfish catches and net/rod and line collections. **Activity 1d:** underwater video surveys and habitat-specific cast-net sampling provided information on abundance of prey resources.

Objective 2: ***Devise protocols for the appropriate conduct of a sportfishery in a PNG context to maximise its resilience and long-term viability***

Fieldwork for this objective was conducted in parallel with work for Objective 1, using the contacts developed there. **Activity 2a** was based on a literature review to evaluate the current sportfishing operations in PNG. For **Activity 2b,** we conducted field studies to evaluate current sportfishing operations, including gears used and methods of handling and releasing captured fish, and **Activity 2c** was addressed by a literature review on the current best-practice sportfishing practices in other similar fisheries around the world. This work culminated in the development of best-practice sportfishing guidelines (**Activity 2d**).

Objective 3: ***Develop an understanding of potential livelihood costs and benefits, and how to manage them***

Work for this objective was facilitated by the partnerships and contacts developed in Objective 1 and followed on from published work from ACIAR project FIS/2011/071. It involved close cooperation between NFA, TPA and JCU's social scientists. However, unlike objectives 1 and 2 that utilised NFA staff for on-ground work, the social science studies needed to be independent of stakeholders such as NFA and the sportfishing industry, so work was conducted by independent staff. Work was based on household level surveys and participatory mapping exercises, where we worked with local communities to (1) develop an understanding of the key social and cultural aspects of relevance to commercial use of local fish resources (**Activity 3a**); (2) to develop an understanding of how to optimise livelihood costs and benefits in PNG's cultural context, by minimising adverse outcomes and social problems, and ensuring equitable division of benefits, including the economics assessment component, with data collected during joint socio-economic household surveys and economic tourist surveys (**Activity 3b**); and (3) to identify issues involved with integrating local people into an appropriate business framework, and methods for addressing those issues (**Activity 3c**).

Objective 4: ***Work with NFA to draft a Management Plan for sustainable sportfisheries in PNG***

Using the sportfishing operations in Baia as a case study, and coupled with the information collected throughout this project, a "*Niugini Black Bass Management Plan"* was drafted by JCU researchers in consultation with NFA, and for the approval of NFA. This Management Plan relates to the conduct and management of the sportfishing industry targeting Niugini Black Bass and associated sportfish.

More details on methodology are provided in the following sections.

5.2 Objective 1 - Biology and ecology

The biology and ecology of Black and Spot-tail Bass were studied to address **Objective 1:** to *develop an understanding of relevant aspects of the ecology and biology of Black Bass sportfish resources of PNG.*

5.2.1 Study area

This part of the project was conducted in river systems and coastal habitats in the Baia region of Open Bay, West New Britain (Figure 2). This area was chosen due to 1) the presence of a thriving sportfishing venture that involves local communities (Baia Sportfishing Lodge), 2) the strong support from the operators of Baia Sportfishing Lodge, and 3) the high interest of local people in helping and learning from our project. An initial scoping trip was conducted in May 2013 to collect site-specific information and basic ecology samples. More intensive and targeted sampling occurred between June 2015 and September 2018. Due to the difficulty in accessing the sampling areas during the wet season (January-March), field trips were only conducted between April and December. The main (larger) river systems considered were the Pandi, Langa Langa, Sei and Toriu Rivers (Figure 2). Smaller creeks included the Palè, and the Tagio. See Baker et al. (2018a) for site-specific details. Field sites also included coastal areas adjacent to river systems, coastal coral reefs and fringing mangroves (Figure 2).

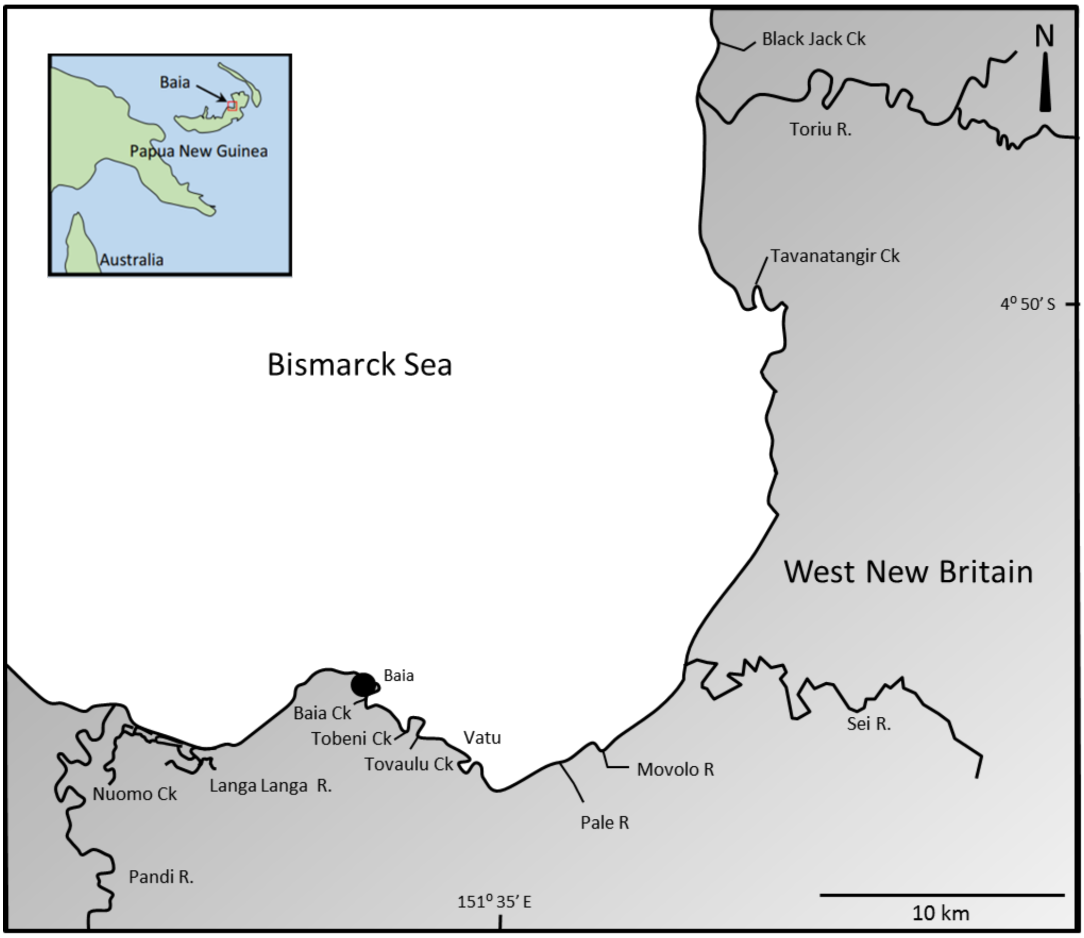


Figure 2. Map showing the main study sites around Baia Village in West New Britain, Papua New Guinea.

5.2.2 Biology (Activity 1b)

Factors such as growth rates, age at first maturity, reproductive cycle and population age structure regulate the resilience of fish populations to fishing pressure, and need to be carefully considered for a sustainable management of fisheries. For example, fast-growing species that breed young can generally sustain heavier fishing pressure than slow-growing, late-breeding, species. On the other hand, the age structure of a population is an indicator of mortality and recruitment success over the previous years, and can be used to assess the health of fish populations and to predict future population size, including the possibility of collapse. Therefore, these biological parameters were estimated for the Black Bass and Spot-tail Bass populations from the main study sites (Pandi, Langa Langa, Toriu and Sei Rivers) (Activity 1b).

Eighty Black Bass and 96 Spot-tail Bass were captured using rod and reel and cast nets (for smaller fish). Animals were measured (total length (TL), in cm), weighed, aged, sexed and had their maturity stage determined (mature *vs.* immature). In a first analysis, the ***length-weight relationship*** was determined for each species. This relationship is important for fisheries assessments, as it can be used for example to describe growth patterns and as a measure of fish condition (Froese 2006).

Sex and ***maturity*** were determined based on the macroscopic examination of gonads. Size at maturity was estimated by identifying the sizes at which Black and Spot-tail Bass first breed, i.e. the smaller sizes where mature fish could be encountered. To describe the ***gonad maturation cycle*** and any possible seasonality in reproduction, gonad tissues of dissected individuals were removed, weighed and the gonosomatic index (GSI) was calculated. GSI is often used in fish as an index of gonadal activity, and corresponds to gonad weight as percentage of body weight, so that GSI = gonad weight/fish weight ×100. The seasonal trend in GSI was analysed for Black/Spot-tail Bass males and females separately.

Ages were estimated by counting apparent growth increments (annuli) in sectioned otoliths (ear bones) as described in Baker et al. (2018b) (Figure 3). ***Size-at-age*** was then plotted for each species to determine if size can be used as an indication of age. Because removing otoliths requires that fish be killed, this method is not ideal to be used in species of conservation concern or species supporting catch-and-release sportfisheries such as the Niugini Black Bass. Therefore, we ***tested a non-lethal method for deriving age estimates***, based on the analysis of annual growth increments in dorsal spines (see Figure 3). Unlike with otoliths, dorsal spines can be quickly and easily removed from fish, and fish can be released into the water almost immediately. Briefly, the second dorsal spine was removed from a subsample of 46 Black Bass and 30 Spot-tail Bass by clipping with wire-cutters at the point of insertion. To determine where longitudinally along the dorsal spine provides the most reliable age estimates, a subsample of dorsal spines was also aged by counting the annual growth increments in sections of the base, mid and tip of the second dorsal spines. The relationships between ages estimated based on otoliths and based on dorsal spine sections were then analysed to determine if 1) dorsal spines can effectively be used for aging, and 2) the part of the dorsal spine that provides the most reliable age estimates. Base sections provided the most similar age estimates to otoliths (Baker et al. 2018b), so the remainder spines were aged at that position.

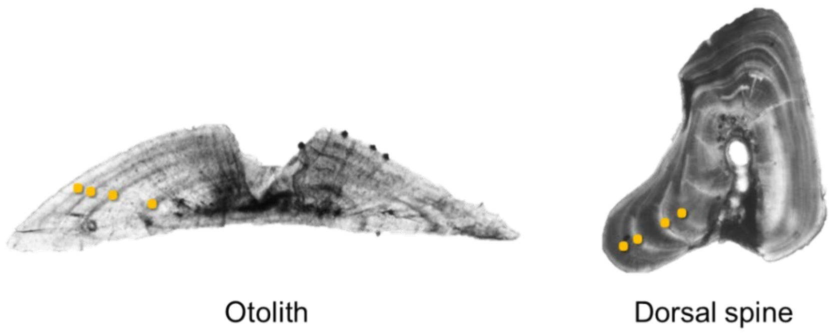


Figure 3. Sectioned otolith and dorsal spine from a four-year-old mangrove jack (*Lutjanus argentimaculatus*), showing the clear annual growth increments in each structure (yellow dots). Photos by R. Baker.

5.2.3 Ecology

Diet and sources of nutrition (Activities 1c and 1d)

Information on diet and sources of nutrition that support fish populations is crucial for the appropriate management of both the fishery species and the habitats they depend on. To study Black and Spot-tail Bass diets, the ***stomach contents*** of 99 Black Bass and 108 Spot-tail Bass were removed and the contents were analysed visually and under a dissecting microscope (Activity 1c). Prey were identified to the lowest taxonomic level possible. The presence of each prey type in each stomach was recorded and data were analysed based on the frequency of occurrence of each prey type in the total number of stomachs analysed (Baker et al. 2014).

To ***assess the diversity and relative availability of prey*** (Activity 1d), underwater video surveys were conducted at each process zone (freshwater, estuary and coast). See "movement and habitat use" section below for details on the underwater video survey methodology. Catch per unit of effort (CPUE) was calculated for each family of fish prey as the sum of the maximum number observed for each process zone divided by the number of samples per process zone.

Stable isotope analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) (Fact Sheet 10) were also used to identify the ultimate sources of nutrition (marine, estuarine vs freshwater/terrestrial origin) fuelling the food webs that support Black and Spot-tail Bass populations (Activity 1c). This allowed us to understand the importance of the different habitats in supporting these fishery species. Standard ellipse areas (SEAs) (Jackson et al. 2011) and Bayesian mixing models (Parnell et al. 2013) were also used to quantify diet niche sizes (SEA sizes), to estimate the potential diet overlap (a proxy for competition) between the two species (SEA overlaps), and to estimate the importance of different habitats for small Black Bass juveniles (mixing models). Sampling for stable isotope analysis is a quick and easy process, that involves the removal of a small muscle sample with a biopsy punch. Fish are returned to the water immediately after sampling. Primary producers and prey from the different habitats were also sampled from each of the main study sites (Langa-Langa, Pandi, Sei and Toriu Rivers).

Movement and habitat use (Activity 1a)

Most fish species use a mosaic of interconnected habitats throughout their lives (Nagelkerken et al. 2015b). These habitats are used at various times and for different functions (e.g. feeding, refuge, reproduction). To ensure continuing healthy populations and sustainable fish stocks, it is important to identify and protect the crucial habitats and resources used throughout the fish's life-history. However, before this project, the extent of movement of Black Bass individuals among the different components of the coastal seascape, the location of juvenile nursery habitats, adult spawning sites, and critical connectivities was unknown (Sheaves et al 2016). We therefore used a range of methods to study Black Bass movement and habitat use throughout their life-cycle, including underwater video surveys, sidescan sonar, acoustic tracking and otolith microchemistry analysis.

Underwater video surveys

Underwater video surveys were used to identify the habitats used by the different life stages of Black Bass and Spot-tail Bass, as well as the distribution and habitat use of the overall fish community (including prey) that live in the rivers and coastal habitats where Black Bass occurs. Fifteen minute video surveys were conducted across a range of freshwater, estuarine, and coastal habitats over three trips between September 2015 and November 2016, following the methodology described in Bradley et al. (2017). Surveys targeted structured habitats including rock, coral, macroalgae, seagrass, mangrove edge, submerged riparian vegetation and woody debris, since the vast majority of lutjanid occurrences are in structured habitats (Bradley, unpubl. data). A total of 412 replicate video samples were collected across these habitats in fresh (n = 86), estuarine (n = 169), and coastal (n = 157) waters. Surface and bottom salinity and temperature data were collected with each riverine replicate, and each replicate was then defined as being freshwater or estuarine based on these readings. If either reading showed salinity >0, the replicate was considered estuarine.

Sidescan sonar

Sidescan sonar imagery was collected using a Humminbird sidescan sonar to survey and map the subtidal habitats available to Black Bass. See Fact Sheet 11 for methodology details. Briefly, as the boat moves through the water, the sidescan sonar projects a sonar pulse to each side of the boat multiple times per second. The sonar signal is then reflected off underwater objects and the time the reflected signal takes to return to the sonar receiver is used to measure how far away the object is. The sidescan unit converts the information returned by successive echoes to produce a 2-dimentional 'map' of the underwater seascape and of structures that are on the bottom. Snags and rocks could be identified down to about 1 m in length. Habitat variables were recorded per 100 m section and included for example density/number of small/large snags, number of snag clusters, snag length, proportion of area dominated by snags, proportion of area dominated by rock, etc. Sidescan sonar interpretations were ground-truthed against structures visible from the boat. This approach was very important as the presence of crocodiles in the study sites makes it unsafe to enter the water.

Sidescan sonar survey was viable in seven waterways: Pandi, Langa Langa, Toriu and Sei Rivers, and Black Jack and Tavanatangir Creeks. The extent of navigable water was too limited for useful sidescan survey in some small systems (Movolo and Pale Rivers, Tobeni, Tovaulu and Baia Creeks) while water depth were too shallow (<1 m) along the coastal mangrove fringe of the Vatu coast. These sites were included in the larger study because of their potential to provide Black Bass habitats and coastal connection pathways between rivers and lagoons. The bulk of the coastline consisted of sandy beaches and was not surveyed because it provided little structurally complex habitat that Black Bass could use.

Acoustic tracking

Acoustic tracking of aquatic animals can be used to gain long-term information on animal movements and habitat use. In this study, 50 Black Bass and 23 Spot-tail Bass from the Pandi, Langa Langa and Toriu Rivers were tagged with acoustic transmitters (tags) (see Fact Sheet 13). Fish were captured with rod and reel and immediately placed into an aerated holding tank with diluted anaesthetic, where they were held until loss of equilibrium indicated effective anaesthesia (~5 min). Once anaesthetised, fish were brought into the boat, and acoustic transmitters were surgically implanted into the body cavity (Figure 4). This procedure took <5 minutes during which time ambient water was continuously flushed across the gills. After surgery, fish were transferred to a recovery pen attached to the side of the boat and allowed to regain equilibrium and rest for a few minutes before release (Figure 4). All fish tagged were adults or sub-adults (Black Bass: 40-85 cm TL; Spot-tail Bass: 34-55). Each of the tags used transmit a unique number every 1-2 minutes for up to three years.

Figure 4. Acoustic tracking: a) an acoustic receiver and a transmitters used in the present project; b) surgically implanting an acoustic tag into the body cavity of an anaesthetised Bass, and c) a fish recovering in a cage beside the boat after surgery. Fish were released back into the water as soon as possible after recovery. Photos by A. Barnett and R. Baker.

To *listen* for the tags, a network of acoustic receivers (**Figure 4**a) was deployed between June 2015 and September 2018 throughout the three rivers (Figure 5). Receiver locations were in part dictated by depth of the river, i.e. many places were too shallow. In each system, receivers were placed in the estuarine and lower freshwater reaches of the river, to a maximum of 9 km upstream from the river mouth (in the Toriu). Receivers were also placed in the coastal waters outside the river mouths (Figure 5) to detect tagged fish moving out of the rivers. When a tagged fish passes within the range of a receiver, the receiver records the time and individual tag number. Range testing indicated reliable detection of transmitters at 200 m distance within the rivers. Since the widest section in these rivers did not exceed 170 m (and mostly much narrower), individual receivers effectively gated sections of the rivers. Receivers were removed from the rivers for the wet seasons (December to April) to avoid receiver loss during the heavy wet season flows. Coastal receivers were left in place throughout the wet seasons.

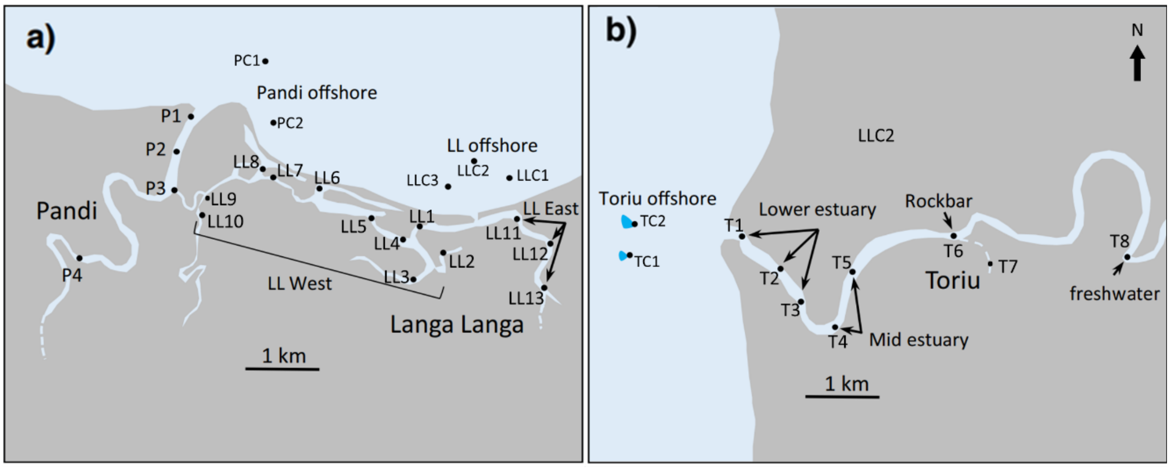


Figure 5. Location of acoustic receivers at 1) the Pandi (P receivers) and Langa Langa (LL receivers) rivers, and b) the Toriu River (T receivers). Black dots represent acoustic receivers. To visually interpret movements of acoustically tagged fish, receivers were grouped to represent seascape zones, and the groupings are indicated. Figure based on Baker et al. (2018a).

Movement patterns

To interpret Black Bass and Spot-tail Bass movement patterns, receivers were grouped based on their positions and on salinity profiling data to represent relevant zones of the coastal-estuarine-freshwater seascape (see Figure 5). The Langa Langa receivers were grouped into east- and west-branch receivers, with the west-branch including 10 receivers through the brackish/saline mangrove portion of the system between the mouth and the Pandi River, and the east-branch including three receivers up the eastern arm of the system (Figure 5a). The four Pandi receivers (P1-P4) were considered individually (Figure 5a). For the Toriu, receivers T1-T3 were grouped to represent the lower estuary, receivers T4 and T5 were grouped to represent the mid-estuary, the receiver at a rockbar at the top of the estuary (T6) represents the upstream boundary of brackish water, and receiver (T8) was placed in the only accessible deep pool in the freshwater portion of the river, 9 km upstream from the mouth and 4 km above the rockbar (Figure 5b).

To study movement patterns, the days each fish was detected at each receiver group were plotted on a timeline. For Black Bass, to further identify preferred habitats, the mean amount of time Black Bass spent around each receiver ('residency time') was calculated, and results interpreted taking into account the habitat characteristics of the area around each receiver.

Otolith microchemistry analysis

While acoustic tags track detailed movements of individual fish while they are tagged, the fish's ear bones, or otoliths, store a record of the areas used throughout the fish's life. Otolith microchemical analysis (OMA) measures the chemical composition of the otoliths, giving a time-integrated record of the movements between waters of different chemistry throughout the fish's life (Elsdon et al. 2008). This is because as fish (and their otoliths) grow, some chemical elements are taken in from the water they live in, so that the chemical profile of an otolith matches that of the environment water. Since different waters often have different chemistry, e.g. freshwater vs. saltwater, muddy estuary vs. clear reef, the analysis of the longitudinal pattern in otolith microchemistry can be used to identify movement between habitats throughout a fish's life (Elsdon et al. 2008, Walther & Limburg 2012).

Therefore, to identify life-history movements among different salinity zones in the coastal seascape, we compared otolith microchemical profiles of Black Bass, Spot-tail Bass and also of mangrove jack (*Lutjanus argentimaculatus*) to those obtained from eight reference reef-resident and two freshwater-resident reference species (Walther & Limburg 2012). Fish were collected over six sampling trips between May 2013 and November 2015. Most were sampled from the estuaries and lower freshwater reaches (<8 km from mouth) of rivers around Baia Village (Figure 2). Marine- and freshwater-resident species were collected from inshore coral reefs and from freshwater reaches, respectively.

For this analysis, fish were killed and one otolith from each individual removed. In the laboratory, otoliths were cut transversely through the centre and vaporised with a laser, following a track from the centre (made when the fish was very young), to the edge of the otolith (made just before the fish was captured). OMA focused on strontium (Sr), barium (Br) and calcium (Ca), as these elements typically provide the greatest resolution to detect movements across the freshwater-estuarine-marine seascape where sharp gradients in salinity and sediment load occur (Gillanders 2005, Elsdon et al. 2008, Walther & Limburg 2012). For each fish, the Sr:Ca, Ba:Ca, and Sr:Ba profiles were plotted to identify major transitions through the coastal seascape. Sr:Ca and Sr:Ba profiles were overlayed with the boundaries defining saline and freshwater residence derived from the reference fish profiles. See Briefing Report 6 for details.

Each individual was classified into one of five life-history movement categories, based on its microchemical profile (excluding the otolith core, for which all fish reflected an offshore larval phase). The categories were: *Freshwater Resident (FWR)* – profiles that entirely overlap with those of the freshwater reference fish; *Freshwater-Brackish Transient (FBT)* – profiles that span both freshwater endmember values and values intermediate between freshwater and marine endmembers, providing evidence of transition between freshwater and brackish waters, or occupation of intermediate waters which could indicate residence in areas of fluctuating but low salinity; *Seascape Migrant (SM)* – transition between and occupation of different seascape components indicated by stepped profiles, or by profiles ranging from FW to saline extremes; *Saline-Brackish Transient (SBT)* – evidence of transition between brackish and saline waters, or occupation of intermediate waters that could reflect residence in a single area of fluctuating but high salinity; *Saline Resident (SR)* – profiles overlapping those of the reef-resident reference fish.

Fish were also aged by counting annuli (described above) to estimate the approximate timing of any substantial life-history seascape movements indicated by otolith microchemistry profiles.

5.3 Objective 2 – Developing best-practice guidelines for Black Bass sportfishing

To devise protocols for the appropriate conduct of a Black Bass sportfishery with maximised resilience and long-term viability, we conducted a literature review to evaluate the current sportfishing operations in PNG against world best-practice (Activity 2a). Data on the different sportfishing practices, including fish handling and gears used (line sizes, hook types, landing net types) was also collected using direct observations in the field, interviews, and analysis of online images (photos). This information was then used to evaluate the fish handling practices currently used in the PNG Bass fishery (Activity 2b). Finally, based on the information obtained in Activities 2a and 2b, and on a literature review on the best-practice sportfishing practices used in similar sportfisheries around the world (Activity 2c), a best-practice guideline for the Black Bass sportfishery was developed (Activity 2d).

5.4 Objective 3 - Livelihood costs and benefits

5.4.1 Social science surveys and focus groups

For the social science component of this project, an initial scoping visit was conducted in June 2015 to (a) introduce the research team and project to potential study communities, including the specific areas of interest, the researchers, and the roles of other members of the field team, (b) to invite communities to participate in the research and (c) to build relationships with local leaders and other stakeholders. The focus was on three communities associated with the activities of Baia Sportfishing Lodge: Baia (inclusive of two settlements to the West of the main village called Silaleve and Loiloi), Vesse, and Somalani. These villages are located in the vicinity of two sportfishing lodges: one at Baia and one on an island called Uluai, which is close to Vesse (3 minutes by boat) and Somalani (30 minutes by boat) (Figure 6). Subsequently, household-level survey interviews were carried out in August 2015 in these three communities. We interviewed one person from almost every household (98%) in participating villages, resulting in a final sample of 157 households across the three villages.

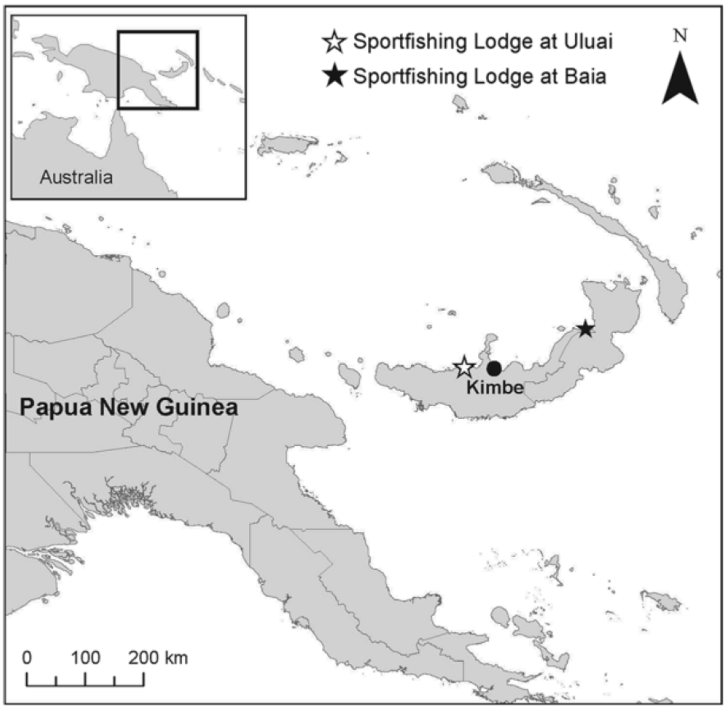


Figure 6. Location of the sportfishing lodges neighbouring the study villages in West New Britain, Papua New Guinea. Vesse and Somalani are associated with the lodge at Uluai and Baia is associated with the lodge to the east of Kimbe, the main commercial centre in the province. Map from Diedricht et al. (2018).

The household-level survey was designed to capture community and individual level characteristics and perceptions related to the potential costs and benefits of sportfishing and other forms of development. These included factors that reflect current impacts on the community, both positive and negative, and factors that may influence future outcomes of sportfishing and other forms of development, specifically (a) perceptions of quality of life and the factors influencing quality of life, (b) perceptions of change (past and anticipated), (c) livelihoods (with an emphasis on fishing), (d) social capital, (e) perceptions of fisheries resources and the impacts upon them, and (f) perceptions of tourism.

The first draft of the survey was adapted to ensure cultural and local relevance on the basis of feedback from PNG nationals and following our scoping visit to Western New Britain in June 2015. Once the survey questions were finalised, the survey was translated into Tok Pisin by the research team using a back-translation method (see Appendix 7 for survey questions in both languages) and was piloted on Tok Pisin speaking students at JCU. Data collection was conducted in August - September 2015 by two members of the team that are bilingual in Tok Pisin and English. Local assistants from each village were also involved in facilitating the survey questionnaires. Surveys were implemented face-to-face with one member of each household over the age of 18. Responses were recorded in English, entered into a database and analysed using qualitative and quantitative statistical methods.

In August 2016, we returned to the three communities to conduct a series of focus groups to:

1. gather spatially explicit information related to the use of aquatic resources, markets and infrastructure in the communities; and
2. capture the communities' desires, goals and needs associated with sportfishing tourism and other forms of development in the community.

The town councillor of each village was asked to gather two groups of six individuals (one male group and one female group) representative of different sectors (e.g. fishing, farming, tourism) and different age groups (e.g. elders, youths) to engage in a focus group interview and mapping exercise. The mapping exercises were carried out using laminated aerial views of the villages and surrounding environment obtained from Apple Maps. Men and women were not separated for this exercise. Firstly, they were asked to map the areas where they fish or glean for food. Information about species, seasons, and gear used was also collected. Secondly, participants were asked where they take the sportfishers to catch fish and whether there had been any conflict or overlap with respect to fishing locations. Finally, they were asked about village infrastructure (locations of schools, access to roads, medical facilities) and markets (distance, cost, procedure). Once the mapping exercise was complete, men and women were separated and asked to discuss the five changes they would most like to see in their communities in the next 10 years. Once consensus was reached, they were asked to present the results back to the project team members.

5.4.2 Economic assessment

A team of economists joined the project team in 2015. The economic assessment focuses on: (a) the potential long-term financial viability of sportfishing ventures, (b) the potential benefits of these ventures for local communities, and (c) local perceptions of environmental change and (local perceptions) of the environmental impact of those ventures. This assessment was undertaken using data from three sources: (1) the international literature; (2) data collected in the household-level survey described above (Appendix 7); and (3) data collected from sportfishers. Information from the literature and surveys were combined, providing insights into the way in which sportfishing generates economic benefits for those in local villages, regional centres and PNG more broadly. Economic surveys and assessment were undertaken by JCU with the assistants of NFA, TPA, and Riccard Riemann and the staff of Baia Sportfishing Lodge.

6 Achievements against activities and outputs

6.1 Achievements against activities

Objective 1: To develop an understanding of relevant aspects of the ecology and biology of Black Bass sportfish resources of PNG

No.	Activity	Achievements/Outputs
1a	**Habitat requirements**: determine habitat requirements, home ranges and patterns of habitat occupancy and across life history, as well as life-history migration patterns	- Based on the knowledge obtained through this study (see Fact Sheets (Appendix 1) and Briefing Reports (Appendix 2)), detailed fish-habitat matrices were constructed for Black Bass and Spot-tail Bass (Appendix 3). These matrices provide a good understanding of the habitat requirements for the life cycle of these species. The only aspect there is still uncertainty about is the exact spawning locations. However, data seems to suggest spawning takes place at the convergence of fresh and marine water. - Scientific publication: Sheaves et al. (2016) The conservation status of Niugini Black Bass: can the world's toughest sports fish thrive in a time of rapid change in Papua New Guinea? *Fisheries Management and Ecology* 23: 243-252 - Scientific publication: Baker et al. (2018) Contrasting seascape use by a coastal fish assemblage: a multi-methods approach. *Estuaries and Coasts.* - Further publications are currently being prepared for publication, including one on diet and sources of nutrition, one on movements and one on the importance of riparian habitats.
1b	**Population structure, growth and reproduction:** determine growth rates and reproductive periods and locations.	- Important information on sex ratios, age, growth and reproduction was obtained. However, as mentioned above, there is still uncertainty about exact spawning locations. - Scientific publication: Baker et al. (2018) Non-lethal aging of tropical catch-and-release sportfishery species. *Fisheries Research* 207: 110-117 - A second manuscript on growth and reproduction is in advanced stage of preparation (see Briefing Report 3 for a summary).
1c	**Food resources:** determine sources of nutrition and prey resources.	- Stomach content and stable isotope analyses were useful to address this activity – see Briefing Reports 4 and 5. - Recruiting sicydiine gobies (*Sicyopterus lagocephalus*), or 'whitebait' were identified as important prey resource for Black Bass (see Fact Sheet 9). - A manuscript on this aspect is being prepared for publication.
1d	**Prey requirements:** determine patterns of abundance and resource needs of prey species	- Underwater video surveys were used to obtain data on the relative abundance of the main taxonomic groups of fish in the different habitats (Briefing Report 4). - Whitebait was found to be important for Black Bass diets (Fact Sheet 9). Since these fish need good water quality (e.g. clear waters with low turbidity) to complete their life-cycle, anthropogenic activities that impact water quality can greatly impact the food webs supporting the Bass populations. - One manuscript on this topic is being prepared for publication.

Objective 2: To devise protocols for the appropriate conduct of a sportfishery in PNG to maximise its resilience and long-term viability

No.	Activity	Achievements/Outputs
2a	Evaluate current sportfishing operations within PNG	- Publication: Wood et al. (2013) Sportfisheries: Opportunities and challenges for diversifying coastal livelihoods in the Pacific. *Marine Policy* 42: 305-314 - A report on the current sportfishing operations within PNG was produced (see Appendix 4).
2b	Collect data on effects of different fishing practices	- Publication: Barnett et al. (2016) Sportfisheries, conservation and sustainable livelihoods: a multidisciplinary guide to developing best practice. *Fish & Fisheries* 17: 696-713 - Data on sportfishing practices used was collected using direct observations, interviews, and analysis of online data (images) to evaluate the fish handling practices used in the Black Bass fishery (Appendix 4).
2c	Review best-practice sportfishing practices used in similar sportfisheries in other parts of the world.	- Publication: Barnett et al. (2016) Sportfisheries, conservation and sustainable livelihoods: a multidisciplinary guide to developing best practice. *Fish & Fisheries* 17: 696-713 - Contributes to producing 2d.
2d	Best-practice guidelines: Develop best-practice guidelines for sportfishing activities in PNG	- The best-practice catch and release guidelines for the Black Bass fishery was developed (Appendix 5).

Objective 3: To develop an understanding of potential livelihood costs and benefits, and how to manage them

No.	Activity	Achievements/Outputs
3a	Investigate the social structures and cultural norms related to commercial use of local fish resources	- Report: Diedrich et al, (2016) Sustainable Management of Communities in Papua New Guinea: Report on Western New Britain Survey Results for the Socio-cultural Component, ACIAR Project Report, Project FIS/2013/015 - Community Summary Sheets reflecting data collected for Activities 3a and 3b and delivered to communities during August 2016 field visit (Appendix 8).
3b	Investigate how to optimise livelihood benefits in PNG's cultural context while minimising adverse outcomes and social problems, and ensuring equitable division of benefits.	Outputs above (3a), along with: - Report: Farr et al. (2016) Sustainable management of sportfisheries and communities in Papua New Guinea: Economic aspects. ACIAR Activity Report, Project FIS/2013/015 - Economic survey facts sheets (Appendix 9) and briefing report on the based on joint socio-economics household surveys at case-study villages in West New Britain (see Appendix 7).
3c	Identify and address local perceptions, needs, and barriers associated with developing sustainable livelihood pathways, for WNB communities	Outputs above (3a and 3b), along with: - Report: Diedrich & Pandihau (2017) Focus group report (Appendix 6). - Publication: Diedrich, A, Benham, C, Pandihau, L, Sheaves, M. 2018. Social capital plays a central role in transitions to sportfishing tourism in small-scale fishing communities in Papua New Guinea. *Ambio*. doi.org/10.1007/s13280-018-1081-4 - Identification of the villagers' perspectives on livelihoods and sportfishing (Briefing Report 7). - Conference presentation: Diedrich, A., Benham, C, Pandihau, L, Sheaves, M. (2018) Social Capital plays a central role in transitions to sportfishing tourism in PNG. 3rd World Small-Scale Fisheries Congress, Chiang Mai, Thailand, October 22-26 (Appendix 10).

Objective 4: To provide NFA with the information and analysis needed to draft a Management Plan for sustainable recreational fishing in PNG.

No.	Activity	Achievements/Outputs
4a	Work with NFA to draft a management plan for sustainable sportfishing in PNG	The *Niugini Black Bass Management Plan* was drafted – see Appendix 11.

6.2 List of outputs from the Black Bass Project

Publications

1. Baker R, Barnett A, Bradley M, Abrantes K, Sheaves M (2018) Contrasting seascape use by a coastal fish assemblage: a multi-methods approach. *Estuaries and Coasts*. 10.1007/s12237-018-0455-y
2. Baker R, Bradley M, Freddi S, Abrantes K, Barnett A, Sheaves M (2018) Non-lethal aging of tropical catch-and-release sport fishery species. *Fisheries Research* 207: 110-117
3. Diedrich, A, Benham, C, Pandihau, L, Sheaves, M. (*2018*). Social capital plays a central role in transitions to sportfishing tourism in small-scale fishing communities in Papua New Guinea. *Ambio*. doi.org/10.1007/s13280-018-1081-4
4. Sheaves M, Johnston R, Miller K, Nelson P N (2018) Impact of oil palm development on the integrity or riparian vegetation of a tropical coastal landscape. *Agriculture, Ecosystems and Environment*. 262: 1-10
5. Barnett A, Abrantes K, Baker R, Diedrich A, Kuilboer A, Mahony T, McLeod I, Moscardo G, Prideaux M, van Luyn A, Sheaves M (2016) Sportfisheries, conservation, and sustainable livelihoods: A multidisciplinary assessment of best practice. *Fish and Fisheries* 17: 696-713
6. Sheaves M, Baker R, McLeod I, Abrantes A, Wani J, Barnett A (2016) The conservation status of Niugini Black Bass: a world-renowned sport fish with an uncertain future. *Fisheries Management and Ecology* 23: 243-252
7. Wood AL, Butler JRA, Sheaves M, Wani J (2013) Sport fisheries: Opportunities and challenges for diversifying coastal livelihoods in the Pacific. *Marine Policy* 42: 305-314

Reports

1. Diedrich A, Farr M, Stoeckl N, Larson S, Pandiahu L, Prideaux M, Kuilber A, & Moscardo G (2016) Sustainable Management of Communities in Papua New Guinea: Report on Western New Britain Survey Results for the Socio-cultural Component. ACIAR Activity Report, Project FIS/2013/015
2. Farr M, Stoeckl N, Larson S, Diedrich A, Prideaux M, Kuilber A, Moscardo G (2016) Sustainable management of sportfisheries and communities in Papua New Guinea: Economic aspects. ACIAR Activity Report, Project FIS/2013/015

Other outputs

1. Focus group report (Diedricht & Pandi 2017)
2. Community data factsheets
3. Economic surveys factsheets
4. Fact Sheets (17) on key biology, ecology and socio-economic aspects
5. Briefing Reports (8) on key biology, ecology and socio-economic aspects
6. Fish-habitat matrices for Black and Spot-tail Bass.
7. A report evaluating current fish handling practices in PNG
8. A best-practice guideline for the Black Bass fishery
9. A Draft Management Plan for the Black Bass fishery in PNG
10. Conference Presentation: Diedrich A, Benham C, Pandihau L, Sheaves M (2018) Social Capital plays a central role in transitions to sportfishing tourism in PNG. 3rd World Small-Scale Fisheries Congress, Chiang Mai, Thailand, October 22-26.

7 Key results and discussion

7.1 PNG sportfisheries: A focus on Black Bass

Although the Black Bass sportfishing industry has the potential to provide long lasting benefits to local communities, management is hindered by fundamental scientific knowledge gaps. Therefore, for the first part of this project, we assessed the current status of knowledge and threats to Black Bass, and identified key areas for research needed to support the sustainable development of the Black Bass sportfishing industry while fostering positive conservation outcomes. This work was published in Sheaves et al. (2016a) (see Published Output Brief 1 for a summary).

Our work confirmed the distribution of Black Bass around the islands of New Guinea, New Britain and New Ireland, and acknowledged unconfirmed reports from Borneo (Figure 7). Until recently, Black Bass was considered to be almost exclusively a freshwater fish (Allen 2004), but our review confirmed that individuals from small juveniles to large adults also occur in the brackish and saline parts of estuaries. Key knowledge gaps were also identified, with limited information about most aspects of the biology and ecology of Black Bass. Current threats include development, including plantation agriculture, logging and mining that impact habitat quality, and overfishing that results from human population increases. This initial work gave the current project a starting point for collecting data to fill the knowledge gaps.

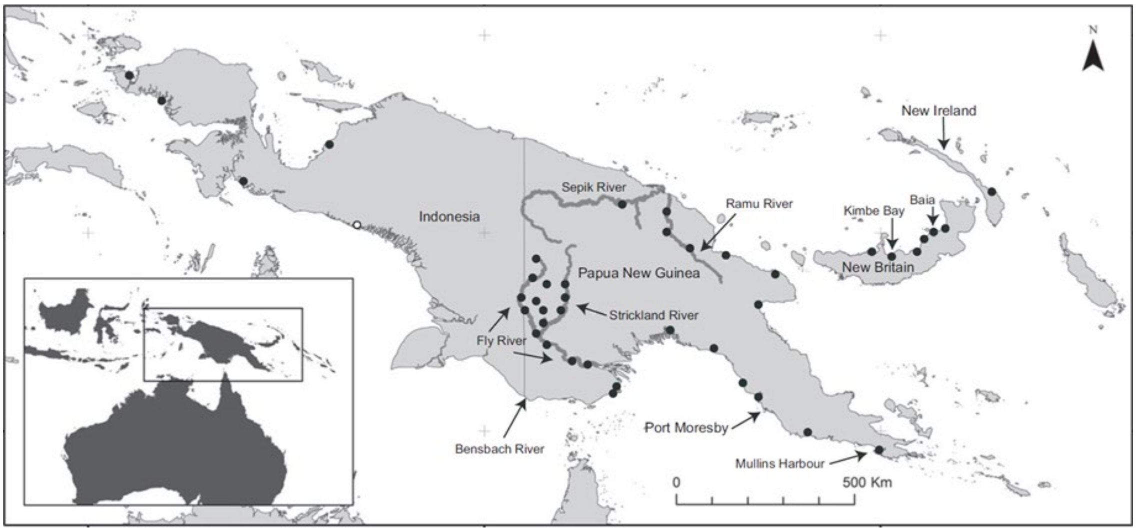


Figure 7. Geographic distribution of Black Bass. Filled circles indicate reliable records (Source: Sheaves et al. (2016a)).

7.2 Best practice guidelines for sportfisheries

We developed a set of multidisciplinary best-practice guidelines to be applied in sportfisheries in developing countries, with the aim to enhance livelihood sustainability without compromising the traditional ways of life. These guidelines have been published in Barnett et al. (2016) (see Published Output Brief 2 for a summary). Briefly, based the three pillars of sustainability (sociocultural, environmental and economic) framework, a sustainable sportfishery should:

Sociocultural pillar

- Understand and respect the cultural values of local communities;
- Inform, consult and involve local communities and leaders on decision;
- Provide location-specific guidelines for tourists.

Environmental pillar

- Develop a detailed understanding of the biology and ecology of target species and align research with sportfishing development;
- Identify and minimize threats to the target species and their natural habitat;
- Develop best handling practice.

Economic pillar

- Employ local people whenever possible;
- Negotiate offsets before impacts occur if negative side effects are unavoidable;
- Implement a sustainable livelihood approach (i.e. short-term coping mechanisms and long-term capacity building).

In addition, a best-practice catch-and-release manual was developed, detailing the techniques that should be used to ensure optimal outcomes for released. This manual can be seen in Appendix 5. If followed, these guidelines will greatly increase the likelihood of the long-term success of the Black Bass sportfishery.

7.3 Bass biology & ecology

7.3.1 Biology

Age and growth

Eighty-seven Black Bass (47 females, 33 males and 7 immature) and 96 Spot-tail Bass (38 females, 36 males and 22 immature) were measured, weighed, aged and had their maturity status determined. The largest measured Black Bass was 82 cm and weighed 10.2 kg, while the largest Spot-tail Bass was only 61 cm long and 3.5 kg. The length-weight relationships for these species can be found in Figure 8.

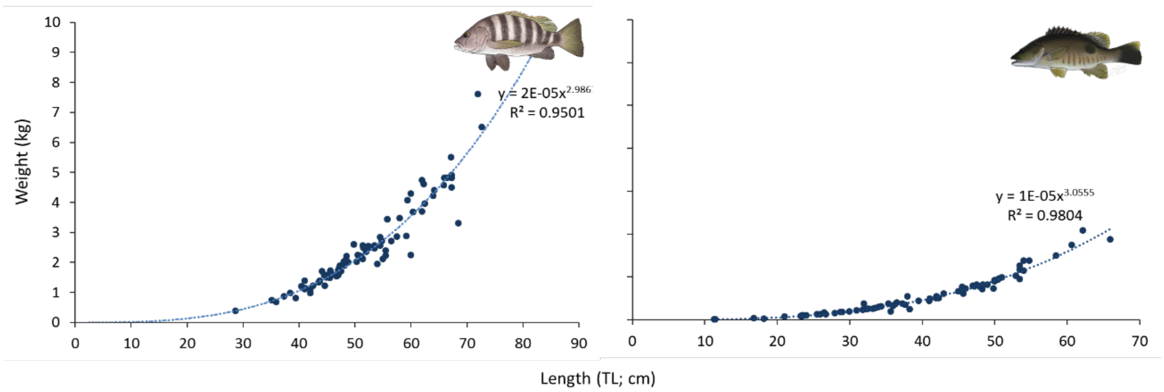


Figure 8. Length-weight relationship for Black Bass (left) and Spot-tail Bass (right) from rivers around Baia.

Mature Black Bass ranged from 35 to 82 cm, while immature individuals ranged from 2.5 to 45 cm (Figure 9). Results suggests that Black Bass start maturing at around 35 cm in length, and that most fish are mature by ~45 cm (Figure 9). Approximately 45 cm is also the minimum size typically caught in the fishery. Spot-tail Bass mature at smaller sizes than Black Bass, and all fish larger than 33 cm were mature (Figure 9).

Although there was a clear pattern for Black and Spot-tail Bass size-at-maturity (Figure 9), the same cannot be said about *size-at-age* or *maturity-at-age* (Figure 10) (see Briefing Report 3). Indeed, and as for other lutjanid species (e.g. Sheaves 1995, Heupel et al. 2010), **size is a poor indication of age**. For example, the smallest Black Bass captured in the sportfishery are ~45 cm long, and among our samples fish this size ranged from 3 to 12 years old (Figure 10). Similarly, for Spot-tail Bass, fish ~30 cm long ranged from 4 to 11 years old. The largest Black Bass examined was a 82 cm female estimated to be 11 years old, while the oldest individual was a 77 cm fish estimated to be 18 years old (Figure 10). This means that small fish are not necessarily young fish, and that the presence of small fish in the fishery does not confirm successful recruitment of young fish to the population. The size-at-age plots (Figure 10) also indicate that our sample does not include the asymptote of the growth curve for either species, i.e. it does not include the largest, oldest, individuals of the population.

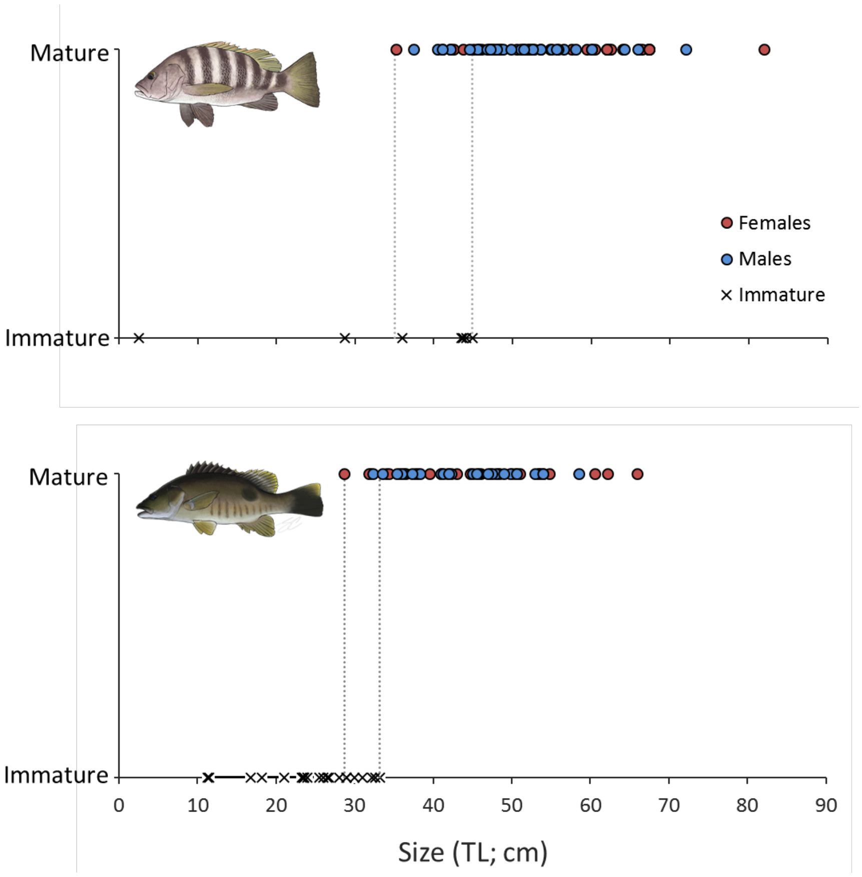


Figure 9. Size at maturity for Black (top) and Spot-tail (bottom) Bass from rivers around Baia.

Black Bass reach maturity at ~35-45 cm in length and 6-7 years old (Figure 10, Figure 10). Spot-tails mature earlier, at 4-6 years old and only ~30-35 cm in length. However, both species showed a wide range in maturity-at-age (Figure 10, Figure 11). For example, the youngest mature Black Bass were 6 years old, while the oldest immature individual was 10 years old, and for Spot-tail Bass the youngest mature individual was only 4 year old, and the oldest immature fish was 9 years old (Figure 10). The smallest mature Spot-tail was a 29 cm, 7 year old female, and the smallest mature male was a 32 cm, 10 year old fish (Figure 10).

Implications for fisheries management

As seen above, although there was a clear relationship between size and maturity for both male and female Black and Spot-tail Bass (Figure 9), both species varied widely in size-at-age (Figure 10). For example, fish at 46-47 cm in length ranged in age from 3 to 12 years old (Figure 10, Figure 11). These are amongst the smallest Black Bass captured in the sportfishery. This means that a small fish is not necessarily a young fish, and that the presence of small fish might not indicate successful recruitment of young fish into the population. Because small fish can be relatively old, recruitment failure could go unnoticed for a decade before the lack of small fish became apparent. This new understanding of Bass size at age highlights the importance of monitoring population age structure to ensure that a successful recruitment of young fish is continuing. A decrease in numbers of younger fish would indicate an impact on the population that could lead to future collapse if left unchecked.

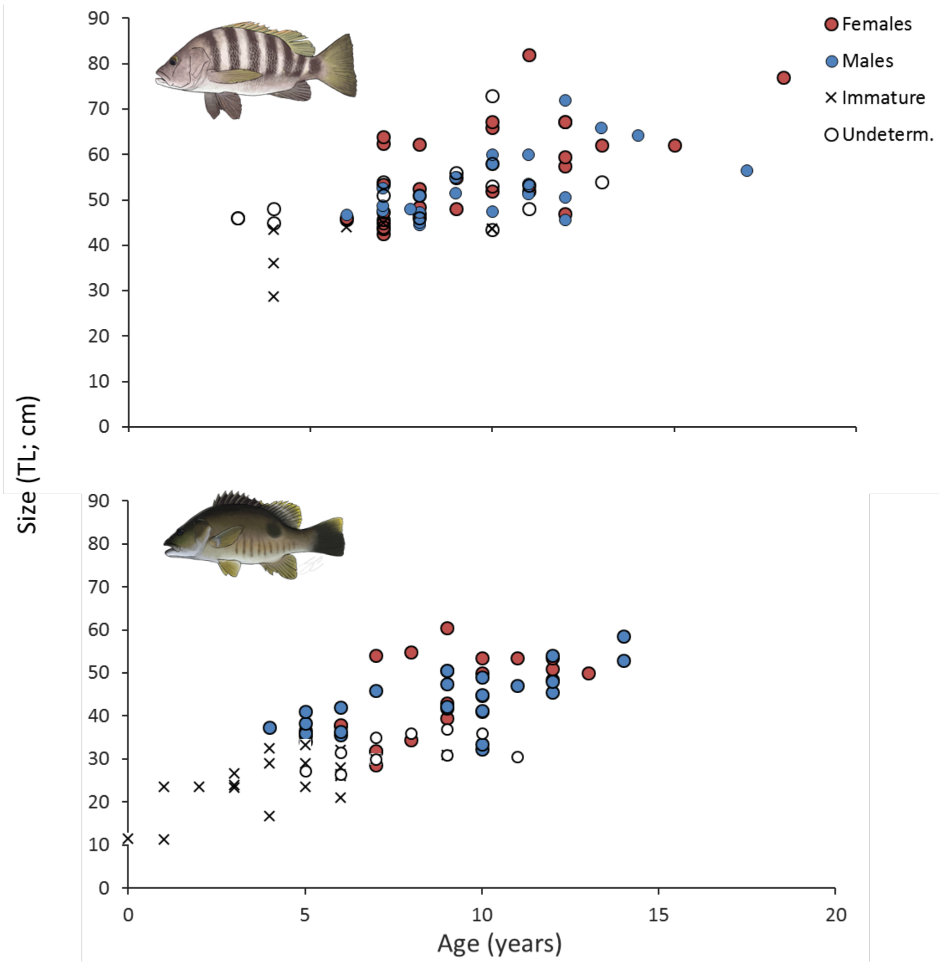


Figure 10. Size-at-age plots for Black Bass (top panel; n = 76) and Spot-tail Bass (bottom panel; n = 79) from the rivers around Baia. Fish ages are based on counts of yearly rings (annuli) in sectioned sagittal otoliths.

Figure 11. This 46 cm Black Bass was 12 years old. Few Black Bass smaller than this are captured in the sportfishery, meaning even the smallest fish can be quite old. Photo by R. Baker.

Non-lethal aging of Bass

To develop and validate a non-lethal method of aging Black Bass, we estimated the age of 44 Black Bass and 30 Spot-tail Bass individuals based on the count of annual growth increments in otoliths and in dorsal spines, and analysed the relationships between the two measurements. For both Black Bass and Spot-tail Bass, the base of the dorsal spines provided the most precise age estimates than the mid and tip sections (Baker et al. 2018b), with estimates comparable to those based on otoliths (Figure 12; Briefing Report 3). Although the age estimates based on dorsal spines were not as accurate, they were close enough to distinguish a young (e.g. <5 year old) from an old (e.g. >10 years old) fish, which often have similar size (Figure 10). This means that aging using dorsal spines provides a simple, cheap and effective means of monitoring age structure and recruitment to the fishery, while minimising impacts on populations that support a catch-and-release fishery.

Because dorsal spines can be easily clipped from live fish before release, and because storage of spine samples does not require any specialised training or facilities, there is great potential for the anglers and tour operators to provide local or national fisheries authorities with samples of dorsal spines from each region. This approach also has the advantage of engaging anglers and members of the remote communities to participate in the management of this fishery, an important factor that helps maximise the likelihood of positive outcomes for all stakeholders (Barnett et al. 2016).

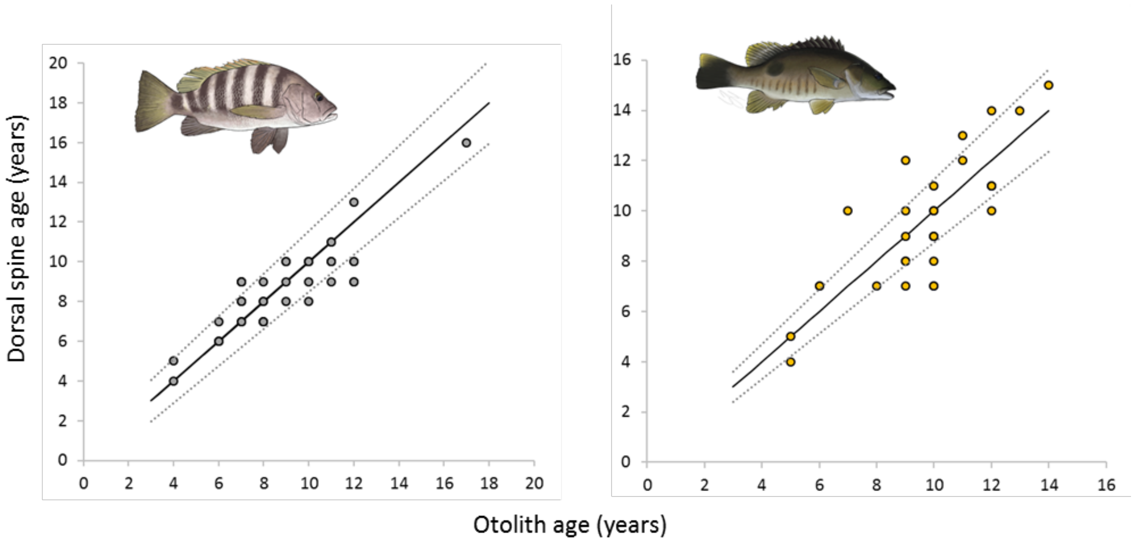


Figure 12. Comparison of otolith and dorsal spine base-section age estimates for Black Bass (top), and Spot-tail Bass (bottom). Dashed lines correspond to the 95% confidence intervals around the 1:1 lines. See Baker et al. (2018b) for details.

Reproductive cycle

Since the field sites are not accessible during the wet season (January-March), it was only possible to collect samples between April and December. Visual analysis of the reproductive system (e.g. Figure 13) show that at least some Black Bass individuals were close to spawning condition throughout most of the sampled months. There was however a clear seasonal trend in the GSI of females, as it was highest in fish collected in April, and declined throughout the year to a low in September-November (Figure 14). This suggests that the Black Bass peak spawning period is some time during the wet season or at the end of the wet season in April, perhaps extending into July.

Figure 13. Dissected female Black Bass, showing the well-developed gonads. Photo: K. Abrantes.

Spot-tail Bass appear to have the peak in reproductive activity earlier in spring, around October (Figure 14). High GSIs were observed in April and October-December, while minimum gonad sizes were observed in the cooler months (Figure 14). This suggests that, as with Black Bass, Spot-tail Bass may have a peak spawning season in the warmer summer months. During this period, large aggregations (100s) of mature-sized Spot-tail Bass were observed on structured habitats in the mixing zone between salt and freshwaters, and these fish showed no interest in feeding. Although we were unable to assess the reproductive status of fish at these aggregations, the timing and information on GSI seasonality (Figure 14) suggests that they are related to spawning. The location of Black Bass spawning remains uncertain, but acoustically tagged fish have been recorded moving to similar areas of the estuary on the new moon, which could be related to spawning. Interpretations of reproductive seasonality must however be treated with caution as no fish were collected between January and March (the warmer months) in any year, and no Black Bass were captured in December. Nevertheless, given the consistent trends seen from year to year, with gonad size increasing towards summer and declining from observed maxima in April through to winter/late dry season, it is likely that both species have a peak spawning period through the summer/late wet season period.

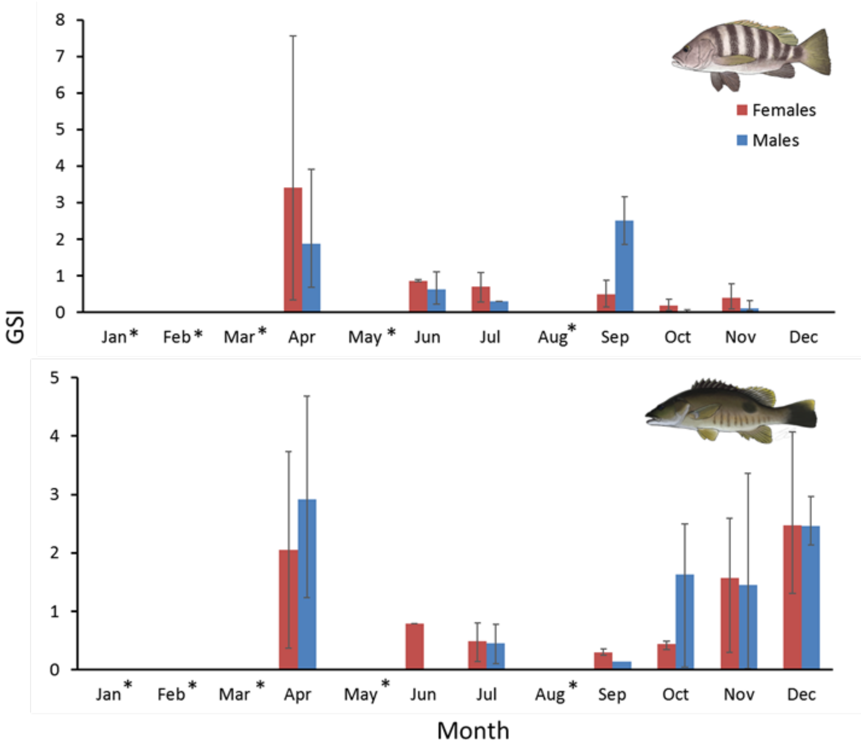


Figure 14. Mean monthly gonadosomatic index (GSI, an indicator of fish reproductive stage) in Black Bass (top panel; *n* = 73) and Spot-tail Bass (bottom panel; *n* = 72). Monthly data were combined when the same month was sampled in different years. Whiskers represent the range in GSI; numbers above bars indicate sample sizes. * - months for which no data were collected.

Key findings on the biology of Black Bass

- Black Bass mature at small sizes relative to size of fish caught in the fishery.
- The fishery is based mainly on mature individuals.
- Any impacts/mortality from fishing are unlikely to affect the overall populations, but may impact the numbers of large/old trophy fish.
- Trophy fish are likely to be relatively old (~20 years or more).
- Black Bass has similar growth rates to other lutjanids and, like others, size is poor indication of age.
- Since even relatively small fish can be quite old, it is not possible to assume recruitment to fishery based on presence of small fish.
- It is important to monitor the Black Bass age structure to confirm ongoing recruitment and ensure continuing profitable fisheries.
- Black Bass has a long reproductive season, but the peak appears to be during the wet season
- The reproductive peak seems to occur during a time when anglers are not targeting the fish due to the inaccessibility to fishing areas (wet season)
- Although this is a catch-and-release fishery, it could have important impacts if fishing targets spawning aggregations. Given the timing of fishery in relation to the peak of the reproductive season, this is unlikely to be an issue.

7.3.2 Ecology

Diet and sources of nutrition

Stomach content analysis

The stomach contents of 99 Black Bass and 82 Spot-tail Bass collected from five systems (Sei, Toriu, Langa-Langa, Pandi and Barema Rivers) were analysed. Forty-six Black Bass (46.5%) and 57 Spot-tail Bass (70%) stomachs contained food (Figure 15, Figure 16a). As for other tropical snappers (Sheaves et al. 2016), the diets of both species were dominated by crustaceans and fish (Figure 16b). Crabs were mostly sesarmids and hermit crabs, while shrimps/prawns included alpheid and palaemonid shrimps and penaeid prawns. Fish included gobies (Eleotridae and Gobiidae, including recruiting post-larval sicydiine gobies (‘whitebait’)), mullet (Mugilidae), ponyfish (*Gazza* sp.) and glassfish (*Ambassis* sp.).

The prey composition and proportion of the different types of prey differed between the two species. While Black Bass fed only on fish and crustaceans, Spot-tail Bass stomachs also contained terrestrial invertebrates and some plant material (Figure 16b). Moreover, fish and crabs were more important for Black Bass diets, while shrimp/prawns were more important for Spot-tail Bass (Figure 16b).

Figure 15. Examples of prey found in Black Bass stomachs.

There was also evidence of ontogenetic variation in diet for both species. For Black Bass, smaller individuals (35-45 cm TL) feed mostly on crabs and shrimp/prawns, while for larger individuals fish become increasingly important and the occurrence of crabs decreases (Figure 16b). For Spot-tail Bass, smaller individuals (<25 cm TL) feed mostly on crustaceans such as shrimps, prawns and crabs, whereas larger individuals (>25 cm TL) also feed on fish (~20%). Other foods such as terrestrial insects and plant material were also consumed only by larger individuals (>35 cm TL) (Figure 16b). Note however that our understanding of Black Bass diets is limited to medium-large fish, as only two Black Bass individuals smaller than 35 cm were analysed for stomach contents.

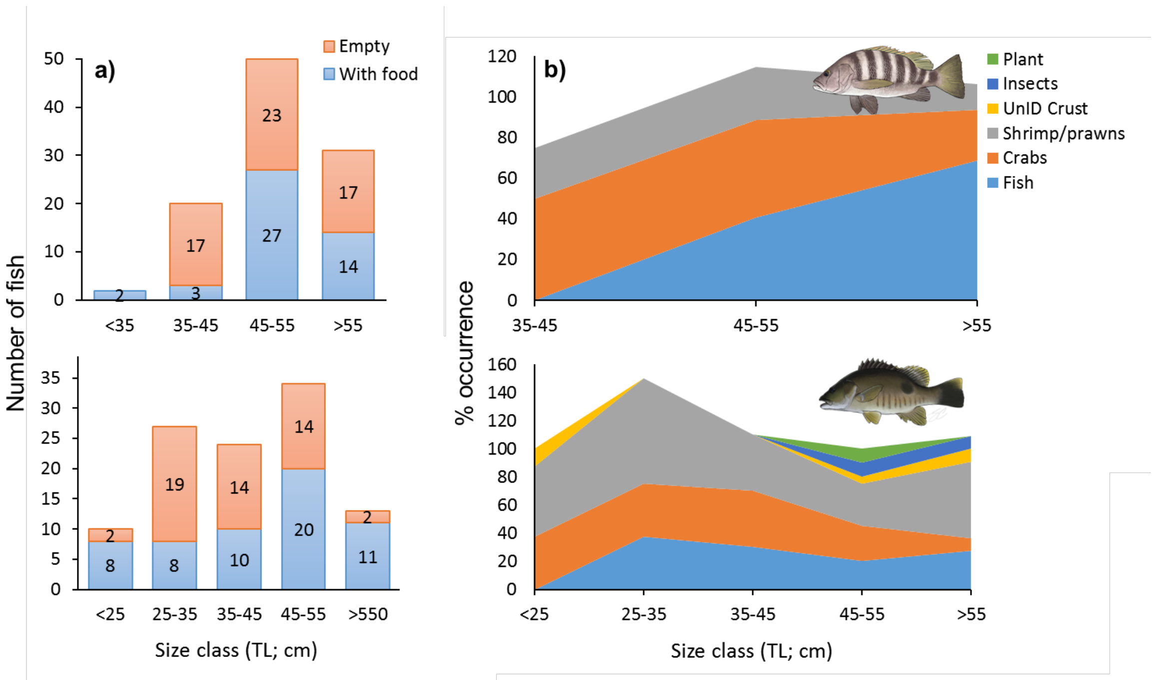


Figure 16. a) Size-structure of Black Bass (top) and Spot-tail Bass (bottom) examined for stomach contents, showing that a large proportion of fish had empty stomachs. **b)** Black Bass (top) and Spot-tail (bottom) diet composition per size class. Data are % occurrence, i.e. the proportion of stomachs containing each prey type as a percentage of total stomachs containing at least some food.

Whitebait

Although post-larval sicydiine gobies, or 'whitebait', could only be positively identified in three Black Bass and two Spot-tail Bass stomachs, these gobies are of great importance for Black and Spot-tail Bass diets (see Fact Sheet 9). Sicydiine gobies spend their planktonic larval phase in the marine environment, and post-larvae recruit through estuaries into freshwaters where the adults live and spawn (Keith et al. 2015). In the days prior to most new moons, millions of these ~3 cm long post-larvae aggregate just outside the river mouths, moving into the rivers on the new moon. See here a video of one of these aggregations.

Black Bass feed heavily on whitebait at the mouth of the rivers around the new moons. However, the limited period of time this recruiting events take place, coupled with the relatively fast rate of digestion of fish tissues in Bass stomachs (Baker et al. 2014), means that it was difficult to positively identify whitebait amongst the partially digested material found in stomachs. Nevertheless, the observed regular and heavy feeding on whitebait means that these gobies represent the transport of massive amounts of nutrients from the marine environment into estuaries and river systems. This demonstrates the importance of whitebait not only for supporting Bass populations, but also for the overall ecology of these rivers.

Stable isotope analysis

The stable isotope composition of Black and Spot-tail Bass was measured, along with primary consumers and fish and invertebrate prey. For all systems with the exception of the Sei River, Black Bass showed a wide variability in stable isotope composition, indicating broad dietary niches (Figure 17). This indicates that different Black Bass individuals specialise to feed on different prey or in different habitats. Spot-tail Bass had smaller isotopic niches, suggesting a less varied diet and/or a more specific range of habitats used.

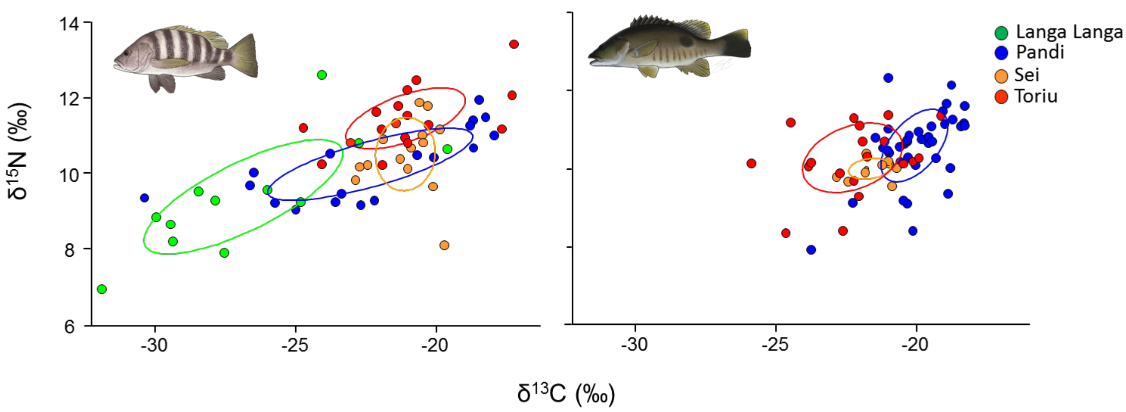


Figure 17. Stable isotope composition (data points) and standard ellipses of Black Bass and Spot-tail Bass found at the four main study systems. Standard ellipses, containing ~40% of the data, represent the isotopic niche widths, a proxy for dietary niche sizes, i.e. for dietary variability. Since different habitats can be characterised by different stable isotope composition, isotopic niches can also be used as indicative of the variability in habitats used by the different individuals within a population.

When stable isotope data were compared between the two species, there was only a small overlap between Black and Spot-tail Bass (Figure 18), indicating limited diet/habitat overlap. At the Toriu and Sei Rivers, Black Bass tended to have higher $\delta^{15}N$ than Spot-tail

Bass, likely a result of a higher trophic level. This is in agreement with the stomach content study which showed that Black Bass feed more on fish (which tend to be of higher trophic levels) and less on shrimp/prawns (which typically are of lower trophic levels) than Spot-tail Bass (see Figure 16). However, the differences in $\delta^{13}C$ between the two groups suggest that the small overlap between the two species is mostly due to differences in the main habitats used, e.g. freshwater vs. estuarine reaches.

The Pandi and Langa Langa Rivers provided the best conditions for identification of the habitats used by Black Bass for feeding. These were the only systems where there were strong enough differences in $\delta^{13}C$ between prey from the different habitats (freshwater/lagoonal/estuarine) to allow the identification of the main feeding environments (freshwater, estuarine and marine environments for the Pandi; lagoonal habitat, mouth of the estuary and marine habitats for the Langa Langa). At both these sites, different Black Bass individuals had different $\delta^{13}C$, from values that indicate feeding mostly in more upstream habitats to values that suggest feeding primarily in the estuary mouth, including values in-between, which suggest that fish feed on a mixture of prey from the two separate habitats (Figure 19). For the Pandi River, despite the relatively narrow estuarine area, over half of the Black Bass analysed had $\delta^{13}C$ that suggest feeding almost exclusively on estuarine prey.

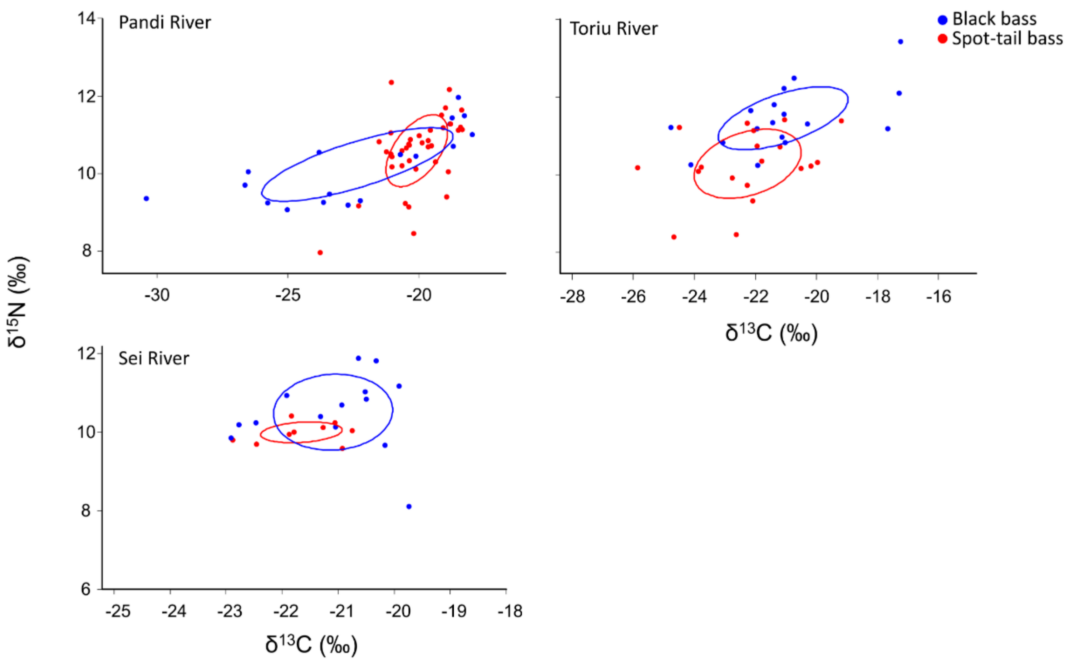


Figure 18. Stable isotope composition (data points) and standard ellipses (ellipses) of Black Bass and Spot-tail Bass found at the thee study systems where enough individuals of both species were collected, showing the isotopic niche overlap between Black and Spot-tail Bass.

Interestingly, smaller Black Bass tended to have lower $\delta^{13}C$ than larger individuals (Figure 20), suggesting that, as they grow larger, Black Bass tend to become more associated to estuarine habitats. Note however that a limited range in Black Bass sizes was analysed at this site (48-66 cm). For Spot-tail Bass, there was no relationship between fish size and $\delta^{13}C$ (Figure 20) or $\delta^{15}N$ (see Briefing Report 5), despite that a wider range in sizes was analysed, suggesting that a more limited range of prey/habitats is used throughout this species' life. Indeed, at most sites, Spot-tail Bass had less variable stable isotope composition than Black Bass (Figure 17, Figure 18).

Additionally, despite that Spot-tail Bass occur mostly on freshwater reaches of fast-flowing rivers, fish from the Pandi River had stable isotope values that suggest feeding mostly on estuarine prey (Figure 20). It is however possible that those values resulted from feeding on a combination of the sampled freshwater prey and of prey that feed on pit-pit grass (which had $\delta^{13}C$ of -13‰), but those prey were not sampled.

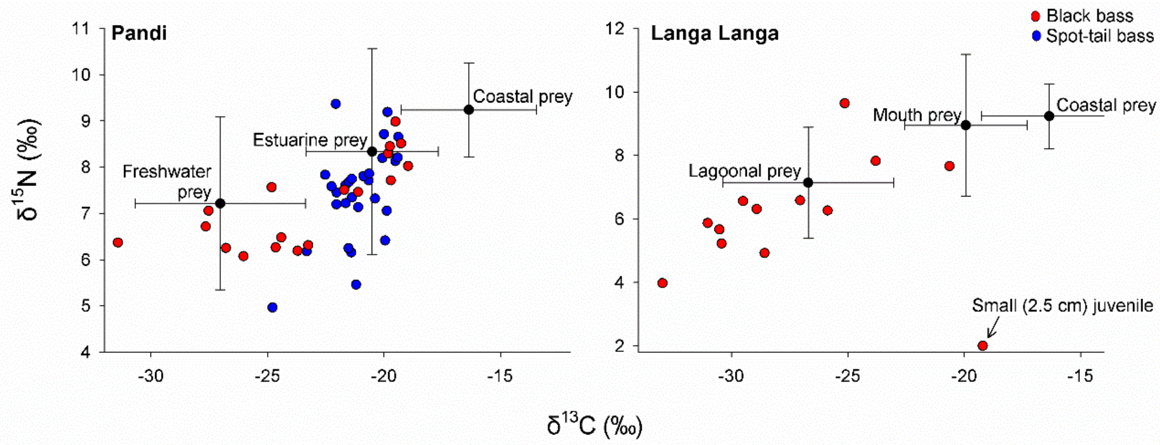


Figure 19. Stable isotope composition ($\delta^{13}C$ and; corrected for trophic fractionation: +1) of Black and Spot-tail Bass individuals captured at the Pandi and Langa Langa Rivers. $\delta^{13}C$ values of potential prey groups found at each main habitat are also indicated (mean (±SD), calculated based on the average values of the different potential prey species.

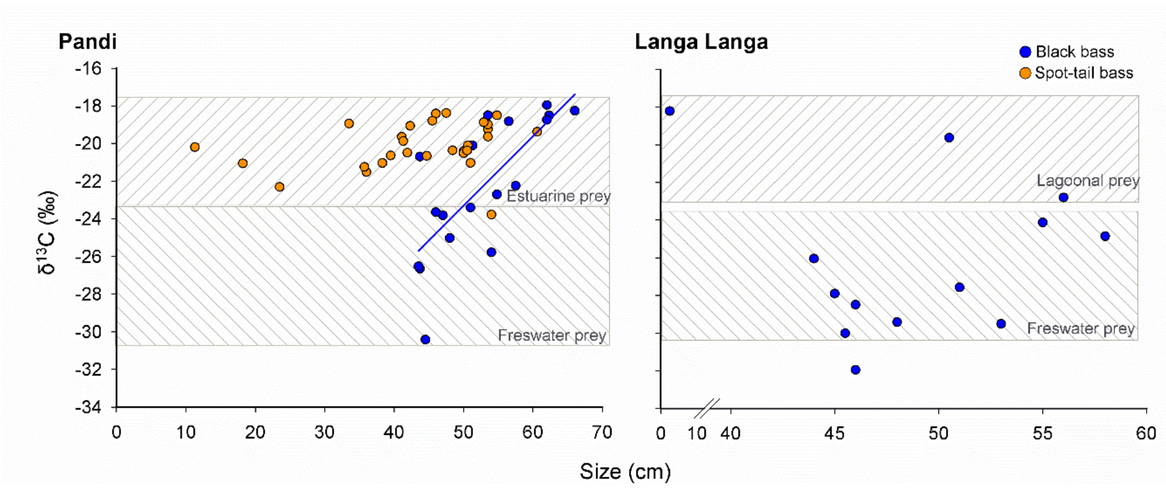


Figure 20. Relationships between fish size and $\delta^{13}C$ for Black and Spot-tail Bass found at the Pandi River. $\delta^{13}C$ values of potential prey groups found at each main habitat are also indicated by grey dashed boxes (representing ±1 SD around the mean). Solid blue line represents a significant relationship ($p < 0.05$).

Small Black Bass juveniles

Only two small (2.5 and 2.7 cm) Black Bass juveniles were captured and analysed for stable isotopes, one from the Langa Langa and one from the Sei River (both captured in November 2016). Those two fish had very similar stable isotope composition ($\delta^{13}C$: -18.2‰ and -18.3‰; $\delta^{15}N$: 5.0 and 4.5‰). Whitebait had $\delta^{15}N$ values (9.1‰) much higher than those Black Bass, suggesting that Black Bass that size not do not share the same food sources with whitebait, i.e. that small juveniles do not rely on marine plankton.

Bayesian mixing models were run to estimate the contribution of the different types of primary producers to small juveniles. Here, juveniles were considered to be of trophic level 3 and trophic discrimination factors of +1.1 for $\delta^{13}C$ and +2.8 for $\delta^{15}N$ (McCutchan et al. 2003) were used. Results suggest that grasses that use the C4 photosynthetic pathway (C4 grasses) such as pit-pit are the most important sources of nutrition for this size juveniles, and that riparian vegetation such as forest trees, mangroves and *Nypa* also have some importance. This stresses the importance of healthy riparian vegetation for the resilience and conservation of Black Bass populations.

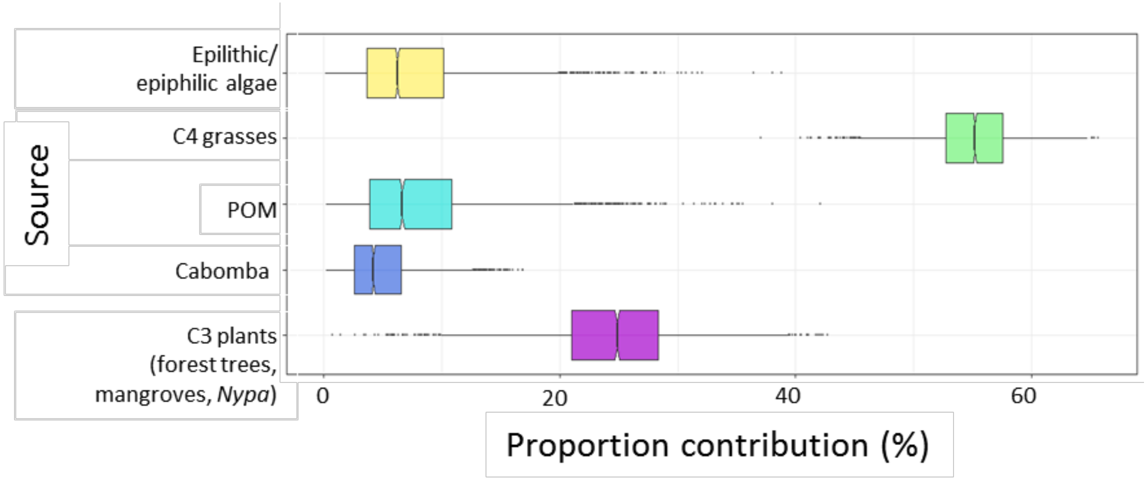


Figure 21. Mixing model results on the contribution of the different sources of nutrition to small Black Bass juveniles, showing that C4 grasses (such as pit-pit grass) have the greatest importance, followed by riparian plants such as forest and mangrove trees.

Movement and habitat use

Sidescan sonar, underwater video surveys and direct observations revealed that a range of structurally complex habitats are available to Black and Spot-tail Bass throughout the river systems around Baia (Figure 22). Sidescan data shows that submerged snags were common across almost all waterways and reaches (see Fact Sheet 1), and occurred at densities of up to >20 snags per 100 m. While in most cases snags were naturally derived forest trees, in Tavanatangir Bay these were mostly mill logs likely lost while loading logging ships. In contrast to snags, substantial areas of rock only occurred in the Toriu River where there were four substantial rock bars (Fact Sheet 1).

Underwater video surveys

A summary of the habitats available at each system can be found in Fact Sheet 1. Underwater video surveys identified previously unknown Bass juvenile habitats (Fact Sheets 2, 3 and 4). ***Black Bass*** occur in both fresh and estuarine waters, and there was evidence of downstream ontogenetic movements when the early juvenile and late juvenile/adult distributions were compared. Young juveniles (~10 cm; 0-1 years old) were not found in the same habitats used by adults, and our data shows that they have specialized nursery ground requirements (Fact Sheet 3, Briefing Report 2). Indeed, young juveniles were only found in shallow (<0.5 m) slower flowing freshwater locations, such as along the shallow edges and side arms of the rivers, in the lower freshwater reaches. In these areas, they occur exclusively in and around aquatic and partially submerged riparian vegetation. Key habitats include: stretches of bank dominated by tall grasses with floating root mats such as pit-pit grass (*Saccharum edule* and *Miscanthus floridulus*), areas dominated by floating mats of kangkong (*Ipomoea aquatica*), banks with tree roots and over-hanging riparian vegetation, and areas with large beds or mats of submerged aquatic vegetation (Fact Sheet 3). Older juveniles use a broad variety of habitats including the same areas as used by young juveniles as well as deeper bank habitats in rivers. They also move into estuaries, where they use a range of adult habitats. Note however that rivers were not surveyed extensively further than ~5 km upstream of the mouths. It is likely juvenile Black Bass occur further upstream, and although the exact nature of the habitats they use in these areas is still unknown, it is likely similar to what was found further downstream.

Figure 22. Range of habitats available to Black and Spot-tail Bass in the rivers around Baia.

Spot-tail Bass were found almost exclusively in freshwater, where both early juveniles and larger individuals were widespread (Fact Sheet 4). Unlike Black Bass, juveniles do not seem to have specialised nursery requirements. They are widely distributed through freshwaters, occupying the same snag habitats as adults and also using woody debris in shallower water, outside the depth range favoured by adults.

Video surveys also show that adult Black and Spot-tail Bass use different parts of the aquatic landscape, but the two species commonly use very specific and very similar structurally complex habitats. Indeed, for both species, floating rafts of debris, debris still attached to the bank and bamboo, all form important overhanging structured habitat, while submerged rock bars, mangrove forests, log jams and entire trees, often with intact branches and root balls, form important submerged structured habitat. See Briefing Report 2 for details.

Life-cycle movements - Otolith microchemistry analysis

Otolith microchemistry (Sr:Ca and Sr:Ba) profiles of freshwater and marine resident species were well separated and were useful as references to identify the habitats used by Bass throughout their lives (see Briefing Report 6) (Baker et al. 2018a). Otolith microchemistry analysis (OMA) indicate that both Black Bass and Spot-tail Bass have marine larval phases, similar to all other known members of the Lutjanidae (Allen 1985). This suggests that, from wherever they are spawned, Bass are quickly washed into ocean waters. At the end of their larval phase, both species migrate into coastal rivers.

Spot-tail Bass. Almost half of the Spot-tail Bass analysed resided in freshwater after recruiting to the rivers, a quarter showed evidence of residence in the upper brackish reaches of the estuaries, while another quarter (the 'seascape migrants') showed wider-ranging movements throughout the seascape throughout their lives (Table 1). Seascape migrants tended to be older fish (average age: 10 years old; range: 6–14 yr), while the freshwater resident and freshwater-brackish fish were younger (average 7 yr; range: 0+ to 12 yr). Among seascape migrants, there were consistent life-history movement patterns: fish spent most of their initial time in fresh or low-salinity waters, after which they moved downstream into more saline waters.

Table 1. Life-history movement classifications of Black and Spot-tail Bass, based on otolith microchemistry profiles. Movement categories are defined in the Methods. Values represent the percentage of individuals classified into each category. Boxed values indicate the general distribution of each species.

Species	Freshwater resident	Fresh-brackish transient	Seascape migrant	Saline-brackish transient	Saline resident	Total
Black Bass	0	7	63	30	0	57
Spot-tail Bass	46	24	26	4	0	54

For 10 seascape migrants that had otolith increments (age) overlayed onto the microchemical profiles, this downstream movement from fresh to more saline waters occurred at between 3 and 10 years of age (see Figure 23 for an example). Therefore, results suggest that recruiting Spot-tail Bass move directly into freshwaters, where they stay until around the age of maturity (4–6 years). Many fish then move downstream to the upper limits of salt intrusion. This trend of downstream lifecycle movements could be related to moving closer to the spawning areas. As mentioned above in the reproduction section, large aggregations of mature Spot-tail Bass were observed in the upper reaches of estuaries, and those fish had no interest in feeding. Although we were not able to assess reproductive status at these aggregations, our data on reproductive seasonality (Figure 14) suggests this was within the time of year when they are reproductively active, so these could be spawning aggregations.

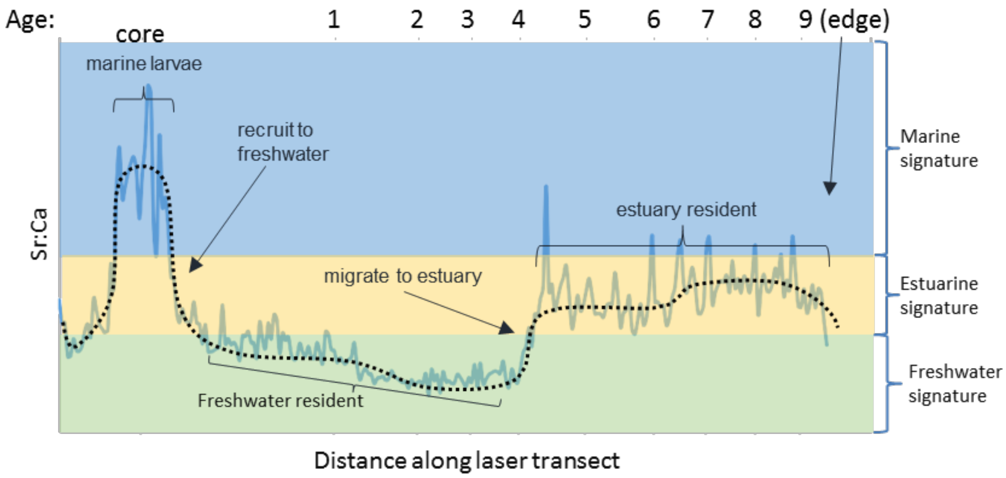


Figure 23. Example of an OMA profile showing the life-cycle movements of a 61 cm Spot-tail Bass from the Pandi River. This fish had a marine larval phase, indicated by high Sr:Ca ratio in the otolith core. It recruited into the river, moving rapidly into freshwater where it remained resident until ~4 years of age. It then migrated into the brackish part of the river, where it resided until capture.

Black Bass. OMA shows that Black Bass have a different distribution to Spot-tail Bass (Table 1), and that early juvenile habitat ranges from low salinity to freshwater areas (Baker et al. 2018a). There is also a high variability in seascape use within the species, with different individuals occupying different seascape components throughout their lives, from freshwater to saline extremes (Table 1). Indeed, while about two-thirds of the examined fish appeared to have made wide-ranging movements across the seascape during their lives, being classified as seascape migrants (see Figure 24 for an example), about one third spent most of their lives in the brackish parts of estuaries, and a few spend several years in freshwater environments (Table 1). The saltwater migrants spent most of their time in brackish waters, and while no individuals spent their entire lives post-settlement in either fresh or fully saline waters (i.e. none classified as either as freshwater resident or saltwater resident), some of the seascape migrants spent at least part of their lives occupying both these areas. Only four individuals (7%) were classified as fresh/brackish transient. However, these results must be interpreted with caution as these were younger fish (average age 6 years old), while the seascape migrants and saline-brackish transient tended to be older (average 9 years old). Therefore, there seems to be a general trend for the centre of the home range of larger individuals to shift from more upstream reaches downstream into brackish/saline waters.

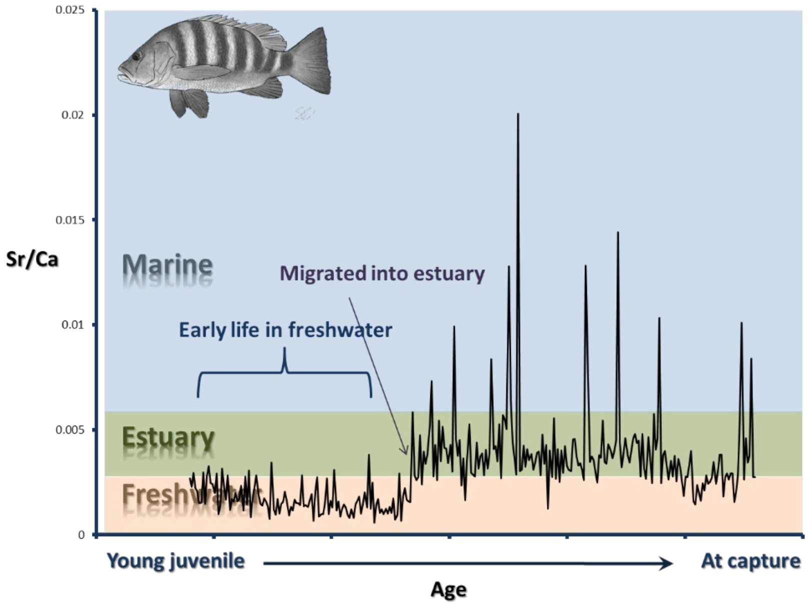


Figure 24. Example of an OMA profile showing the life-cycle movements of a 77 cm Black Bass from the Sei River. This fish had a marine larval phase, indicated by high Sr:Ca ratio in the otolith core. It recruited into the river, moving rapidly into freshwater where it remained resident until ~3 years of age. It then migrated into the brackish part of the river, making occasional movements in to coastal marine waters and freshwater until its capture.

Acoustic tracking

In general, Black Bass were centred in the brackish estuarine reaches of the rivers and spend most of the time near river mouths, but also make wide-ranging seascape movements extending into saline coastal waters and to the most upstream receiver locations, up to ~9 km away (see Figure 25 for examples).

Black Bass

Toriu River. At the Toriu River, a large proportion of Black Bass moved from the lower estuary to the upstream rockbar at the head of the estuary (in the dry season) around the new moon before returning downriver the same day or on subsequent days (e.g. Figure 25a) (average time spent at rock bar per visit was 4:14 h). The timing and regularity of these movements suggest two potential drivers: feeding or spawning. Some estuarine-resident sparids make regular spawning migrations to estuary mouths to spawn at night on peak ebb tides (Garratt 1993, Sheaves et al. 1999). During the dry season, the upstream extent of saline intrusion is typically at the rockbar. So, Black Bass could be moving to structured habitat at the interface of salt and freshwater to spawn in their preferred salinity, and eggs and larvae are dispersed offshore during the ebb-tide (Sheaves et al. 1999). However, collected information on the reproductive cycle (see above) suggests that the main period for spawning for Black Bass is likely during the wet season. During moderate river flows, we observed freshwater plumes extending over the coral reefs where the coastal receivers were deployed, and presume this would occur during much of the wet season. Five of our tagged Black Bass were detected on offshore coral reefs (~1km from the river mouth) around the new moon during the wet season (Figure 25b), again suggesting that Black Bass spawn at the interface of salt and freshwater.

The alternative hypothesis is related to fish feeding on post-larval sicydiine gobies, or ‘whitebait’. Recruiting whitebait aggregate in large numbers just outside the river mouths in the days prior to the new moon, and move into the rivers on the new moon. Black Bass were observed feeding heavily on whitebait at the mouth of the rivers around the new moon. The movements of Black Bass around the new moons from the river mouth upstream to the rockbar and further into freshwaters (Figure 25a) could reflect fish tracking recruitment pulses of these gobies to maximise feeding on them during their migration. Similarly, Black Bass moving offshore prior to new moon in the wet season (but not on the dry season) (Figure 25b) could be moving to feed on whitebait that, due to higher freshwater flow at this time, aggregates further offshore. 'Whitebait' runs can however be highly variable: we observed recruitment events with an estimated number of millions of fish, while on other new moons no whitebait was observed.

Figure 25. Timeline showing a) the detections of a representative subset of Black Bass tagged in the Toriu River, showing that individual fish moved from the lower estuary (receivers T1-T3) through the mid-estuary (receivers T4 and T5), the rock bar (receiver T6) and into freshwater (receivers T7 and T8) and back multiple times. Note the high residency periods at the lower estuary, and the short residency periods at the rockbar around the new moon. Numbers are tag IDs. b) Timeline showing the detections of tagged Black Bass at the receivers placed outside the Toriu River mouth. See Figure 5 for receiver locations.

Pandi and Langa Langa Rivers. The Pandi and Langa Langa are connected by a small channel ~1 km upstream from the mouth of the Pandi River (Figure 5). Black Bass moved between the two rivers (e.g. Figure 26, Figure 27) through this channel, and so the two systems are treated as one. This movement between systems demonstrates that apparent different systems can function as one unit even when only minor connections exist. This type of information is important to determine if fish from different rivers should be managed as one interconnected population or as separate, relatively isolated populations. In contrast to the Pandi/Langa Langa complex, large scale movements between Toriu, Sei and Pandi/Langa Langa complex did not occur, suggesting connectivity between river systems spread over relatively large distances is unlikely, or at least uncommon. A genetics study to quantify level of connectivity between these populations is underway.

The pattern of Black Bass habitat use in the Pandi and Langa Langa Rivers was not as clear as in the Toriu River. Individual differences were evident: while most fish moved between the Pandi and Langa Langa, others were only detected in one of the rivers or spent the majority of time in a single river (Figure 27) (Baker et al. 2018a). Given the complexity of the Pandi-Langa langa system (that includes two contrasting river, the fast running Pandi and calm brackish swamp-like Langa Langa), differences in Black Bass movement behaviour between the Pandi-Langa Langa and the Toriu systems were not unexpected. For the Pandi, the obvious pattern was that Black Bass mainly use the lower estuary region, and rarely move to the receiver further upstream in freshwater (receiver P4). The high use of the lower estuary by tagged individuals coincides with the salt wedge under dry season flow conditions reaching up only to receiver P3, only ~1.2 km upstream from the river mouth. This would suggest that if spawning occurs at the interface between salt and freshwaters, the lower section of the Pandi would likely be the spawning location.

Figure 26. Example of a Black Bass moving from its tagging location in the east arm of the Langa Langa River to the mouth of the Pandi River. Nineteen of the 27 Black Bass tagged in the Pandi or Langa Langa Rivers moved between these two systems. Only one of the six Spot-tails tagged in the Pandi moved between rivers.

We initially thought that Black Bass spawn offshore, similar to their mangrove jack relatives (Sheaves 1995). However, for the Pandi/Langa Langa complex, the pattern of movement offshore suggests that spawning does not occur off the coast. The three receivers deployed on the structure (reefs) closest to the Pandi/Langa Langa Rivers detected no fish. Only receivers in coastal waters just outside the river mouths (Figure 5) detected Black Bass, and no pattern was evident to suggest spawning behaviour for this system. Indeed, individual use of coastal habitats was variable, with some fish spending considerable time on the coast, while others made movements associated with the last quarter to new moon phase, but remained outside the rivers for longer periods than those likely to be associated with spawning movements (Figure 28). Given that reproductive data suggests that the main spawning period is in the wet season (December to March), the few movements to offshore receivers during this period (Figure 28) also suggests that spawning is not occurring offshore.

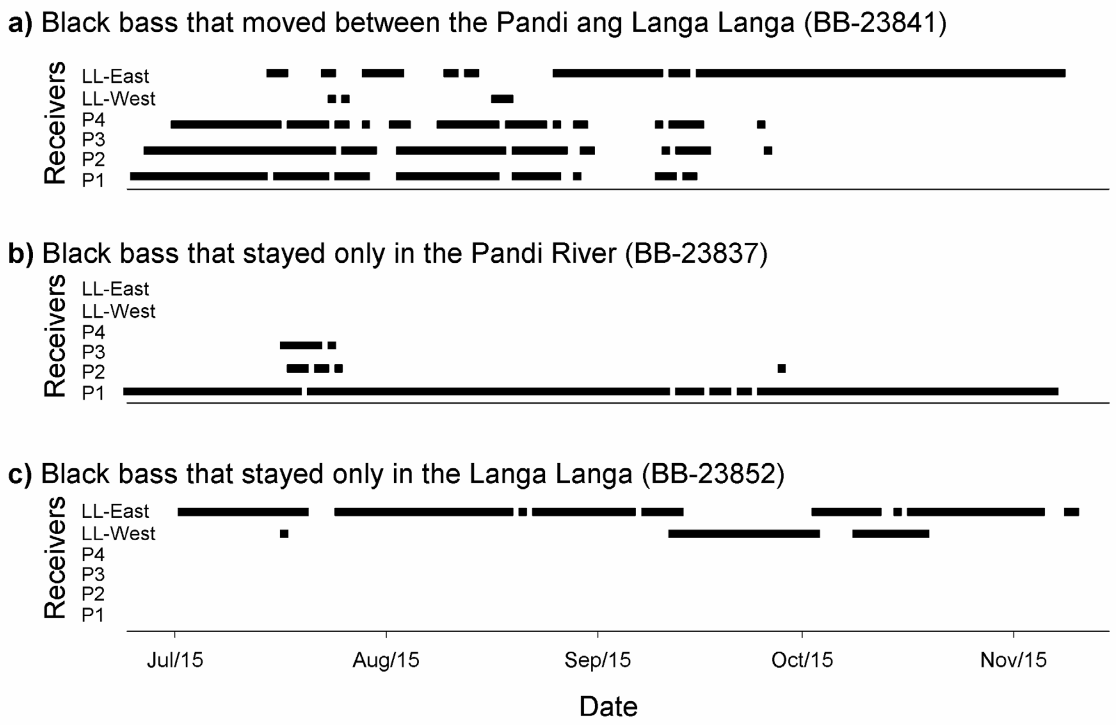


Figure 27. Timelines showing detections of selected Black Bass individuals from the Pandi-Langa Langa complex. See Baker et al. (2018a) for the timelines of all tagged fish.

When the depth use of the ten Black Bass tagged with depth tags was analysed, it was possible to see that Black Bass predominately use depths < 6 m, with most detections occurring between 0-2 m (Figure 29). Only one fish was detected as deep as 18 m (Figure 29). This suggests that Black Bass remain close to the coast when moving outside the rivers.

The lack of a distinct movement pattern linked to the days around the new moon (Figure 28) also suggests that movement offshore is not linked to whitebait runs. Indeed, we collected data on the occurrence of whitebait runs from September 2016 to September 2018, and again no pattern was evident to suggest that whitebait runs were driving coastal detections. During that period, fish occurred offshore regardless if a whitebait run occurred or not, and sometimes when they did occur, only a single fish was detected (Figure 28).

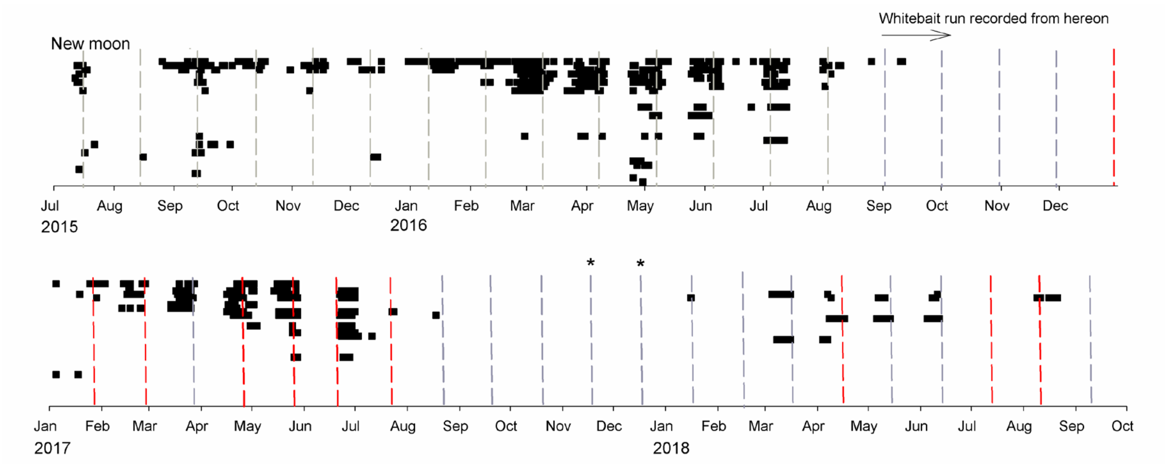


Figure 28. Timeline of Black Bass detections on receivers outside the Pandi/Langa Langa Rivers. Each line is an individual fish, dashed lines are new moon, red dashed lines are when whitebait runs occurred. The absence or occurrence of whitebait runs were recorded from September 2019 onwards. Asterisk indicates that whitebait run was not monitored for those months.

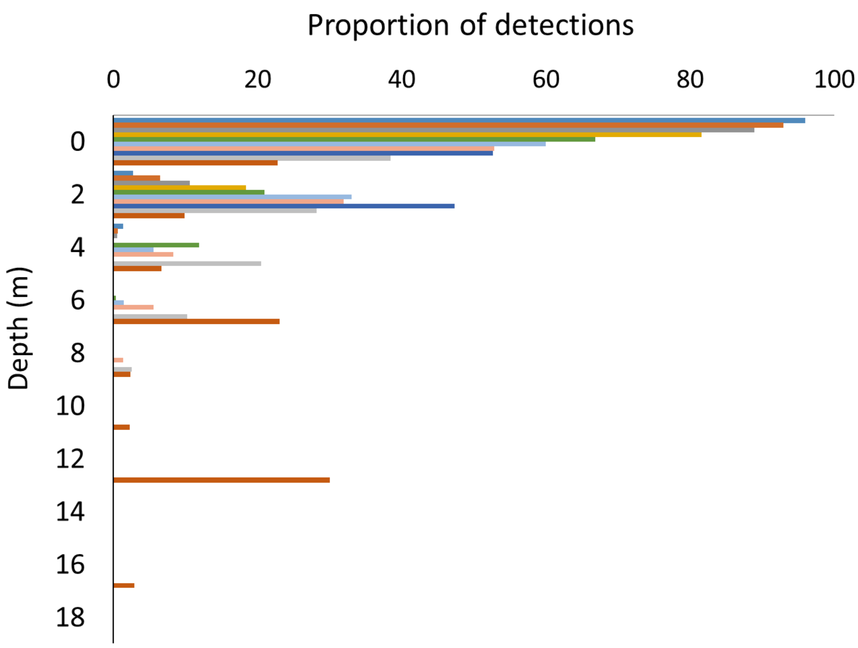


Figure 29. Black Bass depth use when using the coastal area outside the Pandi River, as the proportion of depth records for each depth range, for each of the 10 Black Bass that moved out of the Pandi River. Each colour represents one individual.

Spot-tail Bass

In contrast to Black Bass, acoustic tracked Spot-tails tend to spend most of their time in freshwater, but also move into estuarine waters at times. In the Toriu River, Spot-tails spent most of time at the upriver receiver (~9 km upriver) (e.g. Figure 30a). Under normal river flow, conditions, the rockbar receiver (~4.5 km upriver) is located at the interface between fresh and saltwater, and this location was the downriver limit that many of the Spot-tails were detected. A single Spot-tail moved ~9 km from the Toriu most upstream receiver to the mouth of the river, before returning upstream (Figure 30b). See Baker et al. (2018a) for details of all fish tracked.

Spot-tails from the Pandi spent longer periods of time in the downstream section of the river (Figure 30c). This coincides with the fresh/saltwater interface being much closer to the mouth of the Pandi River. Spot-tail Bass rarely moved into the Langa Langa. The sportfishing operators and guides believe Spot-tails prefer faster running rivers.

Importance of riparian zones

When residency time around was analysed (Pandi and Langa Langa only), it was possible to see that, in general, Black Bass spent more time around the receivers at the Pandi River than around the receivers at the Langa Langa (Figure 31). This is most likely related to differences in habitat (snag) complexity between these systems, as snag complexity in the Pandi was much higher than at the Langa Langa (Figure 32). Accordingly, in the Langa Langa, higher residency times were around receivers placed in areas with more snags or with in-water structure such as bamboo stands (Figure 31), stressing the importance of structure for Black Bass.

Differences in structure availability and complexity between the two systems result from differences in topography and hydrology. The Pandi River has high flow rates and flows steeply to the coast. It is surrounded by forest trees (Figure 33) that work as a source of woody debris due to lateral bank migration and erosion. The steepness and fast flow also mean that snags (often large trees, many >40 m in length) generated upstream are carried downstream during high flow events, further contributing to increased snag habitat complexity. Consequently, the Pandi has high densities and complexities of in-water snag structure (see Fact Sheet 1; Figure 32). Unlike, the Pandi, the Langa Langa is slow flowing and consists of a complex of mangrove-lined channels dominated by the *Nypa* palm (Figure 32), so snag generation and snag transport from upstream environments is limited and snag density/complexity at this system is much lower than at the Pandi River (Fact Sheet 1).

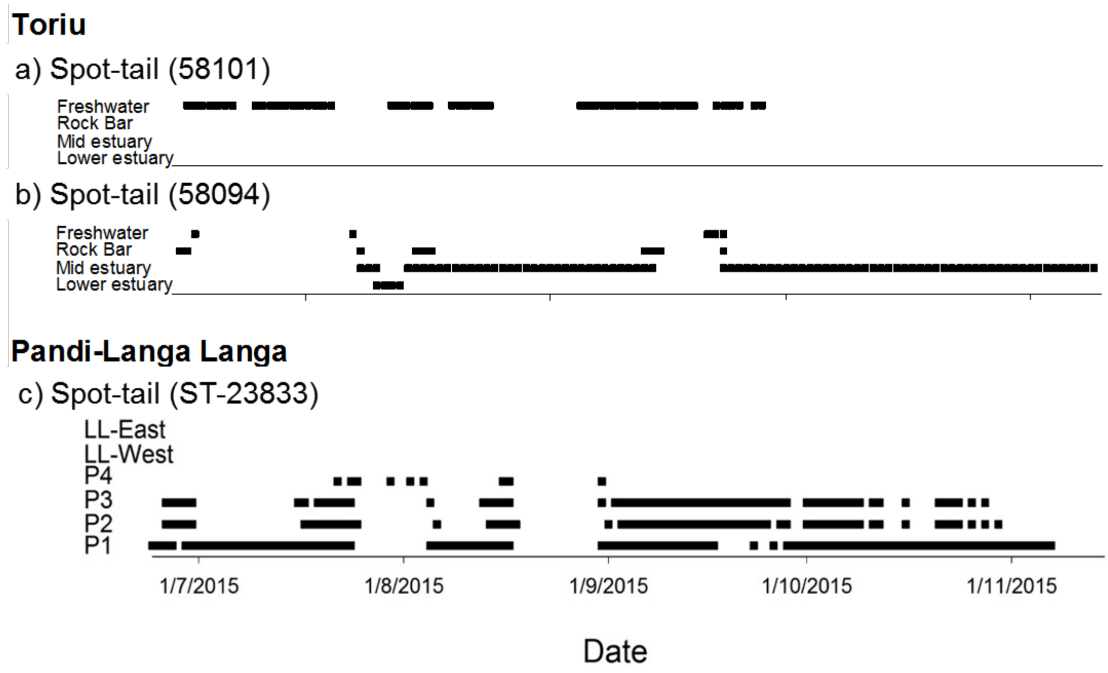


Figure 30. Timelines showing detections of three representative Spot-tail Bass individuals, showing a) an individual tagged in the Toriu River that was only detected in the upstream receivers above the rockbar (T7 and T8), b) an individual that moved from the freshwater reaches of the Toriu River to the lower estuary and back, and c) an individual tagged in the Pandi River, showing the high residence time in the downstream section of this river. See Figure 5 for receiver positioning details.

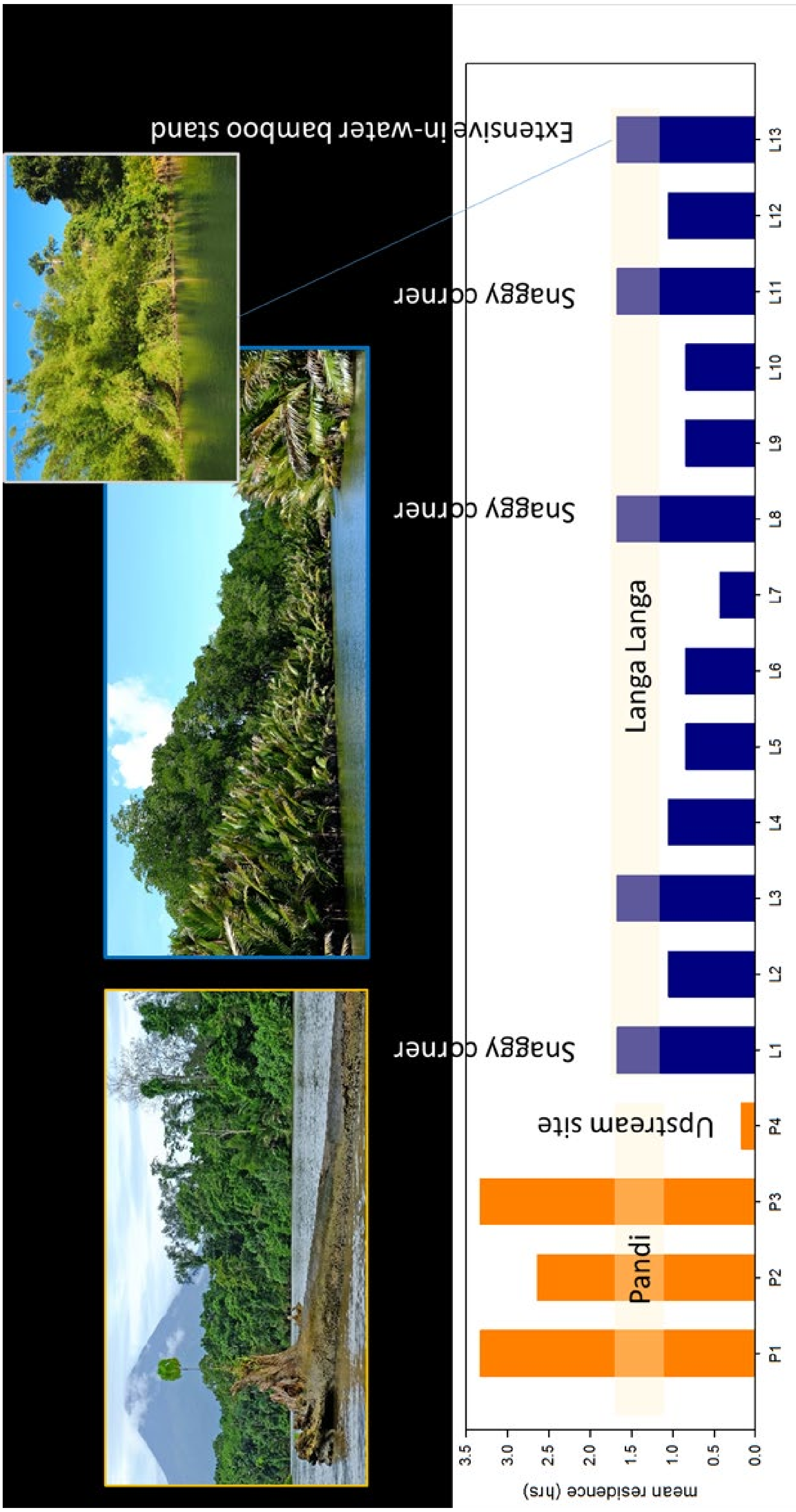


Figure 31. Mean residency time (hours) tagged black bass spent at each receiver.

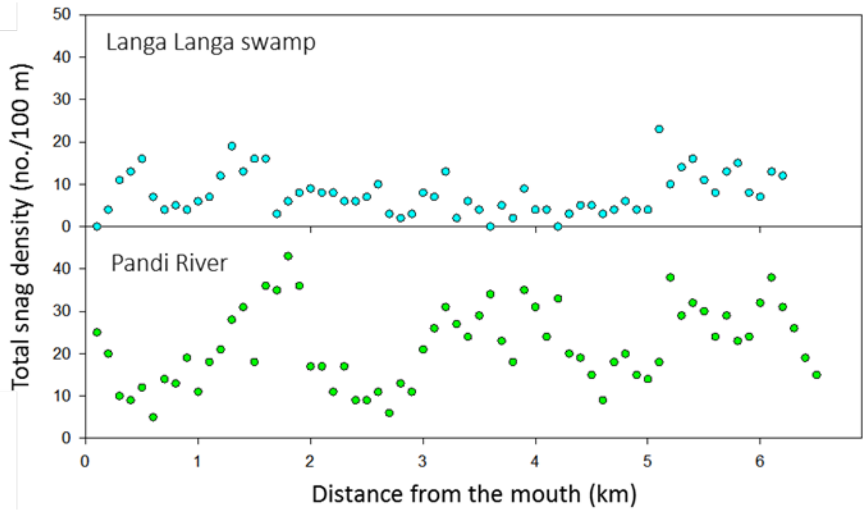


Figure 32. Snag density along the Langa Langa and Pandi systems, showing a higher density at the Pandi River, reaching up to >40 snags/100 m.

Figure 33. Photographs of the Pandi (top) and Langa Langa (bottom) Rivers, showing the differences in riparian vegetation. Photos by M. Sheaves.

Life cycle of Black and Spot-tail Bass

Despite Black Bass having a wide intraspecific variability in movement patterns, the use of a range of methodologies (OMA, acoustic tracking, underwater video surveys and stable isotope analysis) allowed us to greatly improve our understanding of the life-cycle of Black and Spot-tail Bass (Figure 34). However, the exact spawning locations are still not known. The lack of evidence of a temporal pattern of offshore/coastal movements, particularly during the wet season when these species are more reproductively active, means that it is unlikely that Bass spawn offshore or outside the river mouths. The high use of the lower estuary/river mouth areas and/or locations where salt and freshwaters consistently meet, suggests that these interface areas are the most likely to be the spawning locations for both Black and Spot-tail Bass.

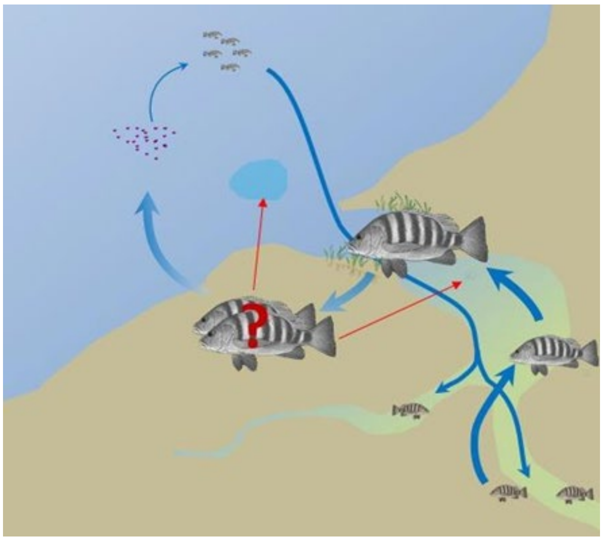


Figure 34. Life-cycle movements of Black Bass, showing the offshore larval phase, recruitment of juveniles to freshwaters, and staged migration downstream to estuarine areas where many adults live. Red question mark ('?') and red arrows indicate that the exact mating/spawning location remains uncertain.

Fish-habitat matrices

Using the data obtained by the different methods used throughout this study, fish-habitat matrices were constructed (see Sheaves et al. (2016b) for details). These matrices summarise the combinations of *macro-habitats* in particular *process zones* that are important for different life-history stages as well as key migration pathways, providing an easy to interpret representation of the mosaic of habitats and connectivities required by each species to complete its life history. The habitat-requirements, including critical knowledge gaps are summarised into fish-habitat matrices that can be seen in Appendix 3.

7.3.3 Implications for management

The outcomes of this project present a range of implications for fisheries management. These can be organised into five categories of issues and actions:

1. Large numbers of fish: The success, resilience and longevity of the Black and Spot-tail Bass sport fishery relies on the continued availability of large numbers of large fish. Consequently, careful management is needed to ensure the continuity of stocks with these characteristics. This will require: (a) That the management of both local extraction and the sportfishery concentrates on minimising extraction, particularly of large fish. This is particularly important in the face of increasing human populations (e.g. workers moving in to new oil palm areas), increased access to more efficient fishing technologies, and the continued use of destructive fishing practices such as poison and explosive fishing. (b) Detailed and effective monitoring of the fishery, fish stocks and particularly recruitment success. (c) Education and monitoring of participants in the industry to ensure that best practice handling and catch-and release processes are understood and observed.

2. Riparian protection: As with other tropical snappers (Sheaves 1992) adults of both Black and Spot-tail Bass are closely associated with a range of structurally complex habitats that provide the necessary shelter, feeding and resting sites. The abundance and quality of these habitats therefore determine the sustainability of Black Bass populations and, consequently, the sustainability of their fisheries. This means it is critical to maintain the quality and snag-generating potential of vegetated riparian zones. The potential threats to the long-term viability of such structure are well understood around the world. In PNG, plantation agriculture, mining and logging are expanding in many catchments occupied by Black and Spot-tail Bass (e.g. Figure 35), creating the potential for these industries to impact on Black Bass and the environments they rely on (Sheaves et al. 2016). Effective management of these habitats will require extensive collaboration between multiple government departments, particularly fisheries, forestry, agriculture and environment.

Figure 35. Riparian damage in the Pandi River (left) and oil palm plantation at the margins of the Dagi River (right). Photos by M. Sheaves.

3. Connectivity: The wide-ranging seascape movements of Black Bass and Spot-tail Bass, and particularly their requirement for life-history migration, highlights the importance of maintaining effective connectivity between marine, estuarine, and freshwaters to maintain ecosystem function (Nagelkerken et al. 2015a) and support sustainable sportfisheries (Barnett et al. 2016). Maintaining connectivity has even greater import when the importance of whitebait as prey supporting Bass populations is considered, and the critical life-history migration requirements of whitebait. Even though barriers, such as dams and weirs, are rare in most of PNG's coastal streams at present they are common in nearby regions (Sheaves et al. 2008) and can have devastating impacts on connectivity. Consequently, the connectivity needs of diadromous species need to be considered when any future river infrastructure development is planned.

4. Water Quality: Ensuring access to critical resources extends beyond the maintenance of physical connectivity; it also includes ensuring high quality in-stream habitat throughout their range, good water quality, and access to required resources (Sheaves et al. 2015). For instance, extensive logging actives in the catchments of river systems inhabited by these snappers, can substantially disrupt the water quality, via increased turbidity and sedimentation, as well as the upstream snag generations, which these species are known to rely on. Additionally, while Black Bass can utilise a range of habitats including fast-flowing, snag-rich systems (e.g. Pandi and Sei Rivers) and low salinity, slow coastal mangrove swamps (e.g. Langa Langa complex), Spot-tail Bass only use fast-flowing, snag rich (mainly freshwater) streams, making them particularly vulnerable to the developing environmental challenges facing PNG. Clear water is the natural condition for many of PNG's Black and Spot-tail Bass streams, and prey such as whitebait are dependent on such conditions, further emphasising the importance of maintaining high water quality. Experience from Australia's Great Barrier Reef makes it clear that ensuring the maintenance of water quality requires whole-of-system management. Thus, there is a vital need for the rapid development of cooperative, whole-of-catchment management that includes the full range of government and non-government actors who manage and utilise PNG's coastal catchments. One key component of this is the development of baselines and implementation of effective monitoring (Sheaves et al. 2016c).

5. Managing the sportfishery for people and operators: The success of Black and Spot-tail Bass sportfisheries as livelihood ventures relies on the continuity, health and resilience of sportfishing businesses. Consequently, a key role of management is to develop comprehensive guidelines and management plans that support and protect sportfishing operations as well as the fish and fisheries themselves. Management arrangements for the Black Bass sportfishery need to be aimed at simultaneously (i) controlling overall harvest to ensure the sustainability of both the high-value sportfishing resource and continued, sustainable, harvest by local people; (ii) ensuring protection of key habitats and resources that the fishery relies on; (iii) regulating the number of operators in any one area to ensure fishery and business sustainability; (iv) ensuring sustainable conduct of the fishery, and (v) ensuring operators have appropriate training to conduct operations sustainably in accordance with the requirements of the industry (see Appendix 11: Draft Niugini Black Bass Management Plan).

It is however important to note that the present study was conducted in only one part of the broader distribution of these species, and in other parts of their ranges the nature and spatial extent of the coastal seascape can vary considerably. For example, Black Bass also occur in the Gulf of Papua along the southern coast of mainland PNG (Allen 2004). They have been recorded around 1000 km upstream in the Fly River (Swales et al. 2000), and there are anecdotal reports of them on oil infrastructure over 25 km offshore in the Gulf of Papua. This means that, while many of the lessons from this study will be broadly applicable that is not necessarily the case. Consequently, it is important to obtain system-specific information when setting up new sportfishing ventures or developing location specific management plans.

7.4 Understanding potential livelihood costs and benefits

7.4.1 Sportfisheries: Opportunities and challenges for diversifying livelihoods

For this part of the project, we identified the opportunities that sportfishing offers for diversifying livelihoods in the Pacific. Unlike other industries, sportfishing can provide income for locals while protecting the ecosystem. This work resulted in a scientific publication (Wood et al. 2013), where five main principles for the success of sportfishery enterprises are suggested (see Published Output Brief 3 for a summary):

1. Adequate local capacity must be available to manage a tourism business and facilities.
2. Appropriate governance arrangements must be in place to ensure the equitable dispersal of benefits to all members of the community, and manage conflict resolution.
3. resource-ownership boundaries and rights must be clearly delineated before the enterprise begins in order to minimise the potential for future conflict.

4. Social, biodiversity and ecosystem service co-benefits should result from the enterprise. These should include improvements in income, health, education, food security, the status of the target and non-target species and their habitat and non-fishery ecosystem services.
5. Monitoring and evaluation of these principles is required within an adaptive co-management framework which takes a social-ecological systems approach and includes all stakeholders in social learning and power-sharing.

7.4.2 Household-level surveys

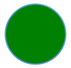
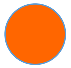
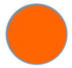
The results of the household surveys showed relatively high potential for benefits from sportfishing tourism (SFT) in all the communities studied, and suggest this potential is slightly higher in Baia than in the other villages. This conclusion is based on the results presented in Table 2, which shows the main results for key variables explored in this study (e.g. quality of life, perceptions of change) and presents a scoring system, where each village is scored on the basis of its potential for receiving local benefits from SFT (i.e. potential benefits score: PBS). The proposed relationship between each variable and PBS is explained in the table, including the logic behind the allocation of the score for each village. Suggestions are also made regarding important aspects to be considered or actions to be taken with regards to future SFT development. It is important to note that, since the survey was completed, there has been significant logging activity in the areas surrounding Baia, which is likely to have detrimental impacts on the habitat of the Black Bass and, hence, on the potential for SFT to develop.

Although understanding the local context is key to determining the likely impacts of development activities (hence, the results of this study are presented at the community level), a number of trends were relevant across communities. First, all villages perceived, on average, that there had been an improvement in overall QOL, much of this attributed to development such as improvement in health and education. In Baia, positive change was associated with SFT. There was some emphasis in the other villages on improvements resulting from potentially unsustainable use of natural resources (e.g. logging and oil palm), which is an aspect that needs further attention as it could conflict with the objectives of sustainable SFT.

The villages were largely dependent on aquatic resources, which were considered to be decreasing by a significant proportion of the respondents. Although this is an issue of concern for livelihoods, it does present a good foundation for the promotion of alternative livelihoods in the community from a non-extractive activity such as SFT. The high level of adaptability of livelihoods displayed across the villages is also favourable to villagers becoming more involved in SFT. However, relatively low levels of wealth (indicated by crowded households and material style of life scores) and high dependence on natural resources at the subsistence level across the villages does present a significant challenge. Coupled with the fact that many villagers recognised a need for capacity building and education to support their future involvement in tourism, these results demonstrate a need for investments to build infrastructure and capacity to maximise potential for SFT benefits. In Diedrich et al. (2018), we used the survey data to model the influence of social and other capital assets on people’s perceptions of how easy it would be to become involved in sportfishing tourism. We found that social capital has a stronger influence relative to other forms of capital, with perceptions of reciprocity and satisfaction with leadership being the most influential aspects.

Table 2. Summary of results and their implications for potential benefits of sportfishing development in the study communities. Potential Benefits Score (PBS) indicates if the conditions are favourable for generating local benefits from sportfishing tourism (SFT) in relation to each variable. Red dot indicates conditions are not favourable, and actions may be needed to create these conditions. Orange dot indicates conditions are somewhat favourable, but that there is potential for negative repercussions. Thus, outcomes specific to these domains should be closely monitored or explored in more depth. Green dot indicates conditions are favourable. This does not negate the need for monitoring, but suggests there is a lower likelihood of negative repercussions (from Diedrich et al. (2016)).

Variable	**Baia**		**Somalani**		**Vesse**		**Explanation of potential benefit score (PBS)**
	Key Result	**PBS**	**Key Result**	**PBS**	**Key Result**	**PBS**	
Quality of Life (QOL)	• Mean 9 (10 highest) • Highest QOL of study villages • Overall improvement in QOL in the last 10 years most pronounced • Two distinct groups emerged QOL; the larger one are people who were very satisfied, and the smaller group who expressed more neutral levels of satisfaction • Social capital most important factor for improving QOL	🟠	• Mean 7 (10 highest) • Overall improvement in QOL in the last 10 years • Broad distribution of perceptions of QOL of life with close to 50% being neutral or below • Income most important factor for improving QOL	🟠	• Mean 7 (10 highest) • Overall improvement in QOL in the last 10 years • Broad distribution of perceptions of QOL of life with close to 50% being neutral or below • Income most important factor for improving QOL	🟠	If people are generally satisfied with their QOL then this indicates that their basic needs are being met. These conditions will be favourable to them becoming involved in new development opportunities in the village. However, the presence of distinct groups of people who are satisfied and unsatisfied creates the potential for benefits of SFT to be unequally distributed (or perceived to be that way), which can lead to conflict in the community. The focus on social capital for improving QOL in Baia indicates that they value this aspect of village life, which is favourable to ensuring equitable benefits. However, the fact that they are focusing on this dimension could be an indicator that they feel it is in danger of breaking down; an aspect that should be looked into in more detail. The presence of two distinct groups of highly satisfied and less satisfied individuals should also be taken into account. The value placed on income for improving QOL in Vesse and Somalani means they would be predisposed to diversifying activities to support tourism development (this is also reflected elsewhere in the results). However, a focus on income over other aspects of QOL such as health, education and social capital has the potential to provoke development that does not benefit the whole community.

Variable	Baia		Somalani		Vesse		Explanation of potential benefit score (PBS)
	Key Result	**PBS**	**Key Result**	**PBS**	**Key Result**	**PBS**	
Perceptions of change	• Mostly positive perceptions of past change • Most frequent positive changes were better school and education, better health services and a new church. • Most attributed positive changes to sportfishing tourism and to the Provincial Government • Expect mostly positive changes for the future including better health services, modern houses, and better schools.		• Mostly positive perceptions of past change • Main benefits were modern houses, better transportation and better telecommunication services. • Most of the benefits due to the hard work of individuals, educated family members, and the timber logging company. Expect mostly positive changes for the future • Expect mostly positive changes for future, in particular more modern houses and further increase in income and transportation links.		• Mostly positive perceptions of past change • Main benefits were due to the presence of the oil palm company, the timber logging company and sportfishing tourism; and a consequent ability to sell fish and products. • Main benefits associated with an increase in income and other monetary benefits, better transportation and better education services. • More than a quarter of respondents reported no perceived change in the last 10 years. • Oil palm and logging industries were also perceived by some respondents as bringing negative changes such as population pressure and deterioration of the natural environment. • Expect mainly positive changes, such as better houses, transportation, education services, water supply and increase in income and other monetary benefits.		How people perceive change and what their expectations are for the future is a good indicator of (a) how they might respond to different types of changes in the community, and (b) the factors that are impacting on the community. In Baia, people had very positive perceptions of change, citing development of benefits to the entire community (e.g. health, education). They also attributed a large proportion of these changes to SFD, which is a clear indicator of benefit potential. The other communities also report positive change, but these are associated with activities that could be unfavourable to SFT, as this requires a healthy natural environment. Particularly, the division over perceptions of oil palm and logging in Vesse could create conflict around engaging in more environmentally sustainable activities in the village.

Variable	Baia		Somalani		Vesse		Explanation of potential benefit score (PBS)
	Key Result	PBS	Key Result	PBS	Key Result	PBS	
Main Livelihoods	• Growing crops and fishing first and second most important • Sale of fish then sago most important for making money • Baia residents may sell proportionately less fish/crops than the other villages • Main target species red emperor • Do not target Black Bass		• Growing crops and fishing most important, followed by 'other' (included making mats, sago, baskets, selling shell money) • Results indicate that activities that make money (outside of selling crops and fish) are more important in Somalani than in other villages. • Salaried employment reported by a higher proportion of men than women than in other villages • Sale of fish then sago most important for making money • Main target species red emperor • Do not target Black Bass		• Fishing and collecting aquatic species first and second most important • More dependent on aquatic resources than other villages • Significant proportion of women engaged in mat making • Sale of fish then mat making most important for making money • Main target species red emperor • Do not target Black Bass		In communities that depend largely on extractive use of natural resources for subsistence and income, their relative dependence on these resources is an important consideration for nature-based tourism, such as SFT. Highly subsistance lifestyles or complete dependence on the same resources (i.e. aquatic resources) could create potential for conflict. All of the communiteis are highly dependent on aquatic resources for subsistence of income purposes. Although they do not target Black Bass specifically, there is potential for overlap of fishing grounds, an aspect that will be explored in detail in the focus group exercise (see Section 4). Further, red emperor is a fish commonly favoured by sportfishers so the potential for conflicing use of this resource should be evaluated in more detail.
Occupational Multiplicity	• On average, one distinctive activity per member of the household		• On average, one distinctive activity per member of the household • A slightly broader distribution than in other villages		• On average, one distinctive activity per member of the household		If housholds diversify their activiites, they are less vulnerable to sudden changes in natural resource or market conditions as they have other activities to fall back on. Also, diversified households are better suited to capitalise on multiple opportunities associated with tourism devleopment. All of the villages showed relatively high levels of occupational multiplicity. Some Somalani households showed notably high diversity of activities. Activities such as mat making and shell necklace making (products that could potentially be sold to tourists) could be targeted by small businsess development and capacity building activities.

On average, respondents perceived relatively high levels of social capital in all the villages. However, the distribution of their perceptions also showed that there were many individuals who were less trusting of people in their community or who felt sharing was not common in the village. Some diversity of opinions will always exist; however, understanding the distribution of positive (or negative) aspects of life (e.g. access to social capital, satisfaction with QOL), and wealth is critical to anticipating and monitoring the potential distribution of benefits of development activities such as SFT. Equitable distribution of benefits is essential to avoid potential marginalization of certain groups of individuals (e.g. women, poorer members of the community), and conflict (e.g. from the presence of 'winners' and 'losers' in the community). For this reason, there is a strong emphasis on exploring the distribution patterns of many of the variables in this study and they feature strongly in determining the scores presented in Table 2.

The results of the participatory mapping exercise showed a diversity of fishing grounds and target species for the villages (Appendix 6) (Diedrich et al. 2016, Farr et al. 2016). The main species listed by the focus group participants are reflected in the results of the survey data collected previously, which supports the accuracy of these results (see Farr et al. (2016)). This diversity of grounds and target species, the fact that Black Bass is not a primary target, and confirmation from the villagers that they do not consider there to be any conflicts with SFT, are all positive results with respect to future SFT development. However, there was a significant lack of basic infrastructure across the villages, which could act as an impediment to future tourism development. Access to markets is also limited, particularly in Vesse and Somalani (Appendix 6), which impede the efficiency of fishing for sustainable livelihoods. These villages are highly dependent on fishing (Table 2) (Diedrich et al. 2016), so their ability to maintain this practice in a sustainable way is critical. Improving market access and improving infrastructure, if combined with appropriate training, could contribute to improving the efficiency of fishing and supporting further tourism development.

The future visions of the community members were particularly interesting (Appendix 6). They share similarities in their focus on the need for basic infrastructure and development, but differ quite significantly with respect to sustainable livelihood pathways. For example, Somalani residents expressed a well-articulated and strong desire to develop sustainable tourism, avoid other less sustainable options (e.g. oil palm, logging), and learn how to fish more sustainably. Vesse residents, on the other hand, expressed a desire to fish more, obtain more boats and develop more houses on the island. In Baia, the village leader supported the prospect of establishing a field school in the lodge to bring in more income when SFT is not occurring. Participant observation and informal accounts from villagers suggest that logging practices are severely impacting on their river systems, which will likely impact on their ability to maintain SFT. Identifying alternative livelihood options to extractive industries such as logging is critical for ensuring a sustainable future for the villages.

Detailed analyses of the socio-cultural component of this study can be found in Briefing Report 7, Diedrich et al. (2016) and Diedrich et al. (2018), and analyses of relevant economic aspects in Briefing Report 8 and Farr et al. (2016).

7.5 Provide NFA with the information and analysis needed to draft a Management Plan

A Management Plan for the Black Bass sportfisheries has been drafted and development is ongoing - see Appendix 11 for details.

8 Impacts

8.1 Scientific impacts now and in five years

This project led to a range of scientific advancements with real-life impacts, and will contribute to improve the scientific approaches used in future studies.

Biology and Ecology. One of the most important finding of this project was that Bass size is a poor indication of age or maturity, and that small fish are not necessarily young fish. This means that size structure cannot be used to identify the recruitment of young fish into the population, and that it is important to directly monitor the populations' age structure to ensure that young fish are successfully recruiting into the fishery. This new knowledge will be useful for monitoring fisheries both now and in five years, and will prompt scientists and management in other settings to test for absences in size-age relationships and adjust their monitoring methods accordingly.

Following from this finding, we demonstrated the effectiveness of a non-lethal approach to estimate Bass age, based on the analysis of annual growth increments in dorsal spines. Published in Baker et al. (2018b), this result will have continuing scientific and conservation impacts, as we demonstrated that it is not necessary to kill fish to determine their age. This finding will change the methodological approach used in fisheries monitoring, and is particularly important for species of conservation concern such as Black Bass. Because a dorsal spine can be easily clipped from live fish before release, anglers and tour operators can provide NFA with samples from a number of fish from each river each year, so that NFA can easily monitor the populations.

The multi-methods approach used to study different aspects of Bass life-cycle and habitat use was also novel and will likely be used in future studies. We used a range of different methods that provide complementary information, which helped circumnavigate the limitations of each method in isolation.

Importantly, our paper on best practices guidelines sets the platform for new sportfishing ventures to follow when setting-up a successful, environmental friendly and socially acceptable venture. These guidelines will have a positive impact on the fisheries, on the habitats they depend on and on the livelihoods of local people, and this impact will be both in the immediate future and in the next decades.

Moreover, this project led to an increased understanding in the expanding ecological fields of nursery ground, seascape, connectivity, resource dynamics and predator ecology. Insights developed in the species-rich environment of PNG, a region where these fields of study have not previously been investigated, will likely lead to much better understanding across these new fields of research and allow key principles to be applied to tropical situations in a valid way. In addition, this work was started when the sites were close to pristine, so provides key information on the nature of unaltered systems that will be critical for future work on artisanal fisheries management, coastal ecosystem repair and climate-change adaptation.

Socio-cultural dimension. Growing concerns about pressures of global change on small-scale fishing communities resulted in the emergence of alternative livelihood initiatives, many of them linked to tourism. However, many of these fail to achieve intended outcomes because simply providing opportunities to make money does not necessarily lead to positive outcomes and this is especially true for marginalised groups and isolated communities with limited exposure to western culture and markets. One reason for this is due to unrealistic expectations about how local people will engage with new income earning opportunities and failure to consider the constraints faced by isolated, traditional communities in transitioning to more westernized forms of economic activity. It has been demonstrated that resilience to social change is low in many isolated communities in the Pacific, who may be more equipped to adapt to environmental changes due to past experience of environmental variability than exposure to western culture. Yet, social capital often takes a back seat to other forms of capital (e.g. human capital (education), financial and physical capitals) in development initiatives. Our research demonstrates that social capital plays a central role in people's transitions to sportfishing tourism, indicating the importance of social capital for improving livelihoods outcomes from tourism in PNG. The impact of our publication and conference presentation on this topic is expected to contribute to increased focus on the role of social capital in alternative livelihoods in the future. Given the applied nature of this research, it is anticipated that these findings will influence how donors and development practitioners implement alternative livelihood projects.

Therefore, results of this project will contribute to improve the currently used methodological approaches in sportfisheries science and management.

8.2 Capacity impacts now and in five years

This project used a number of in-country staff that were trained to conduct diverse tasks, contributing to the development of research and operational capacity within PNG. Indeed, NFA staff and local villagers, particularly from Baia, were exposed to and trained in a range of biological, ecological and social science methods. In particular, NFA staff acquired a better understanding of the range of methods that produce the types of data needed to manage similar fisheries in PNG. They also improved their understanding on how to engage with local communities in order to capture their views, capacity needs and, ultimately, encourage their participation in managing a sustainable sportfishery.

NFA and tourism operators and local guides were also trained on how to obtain samples for non-lethal aging of fish using dorsal spines. Operators can now easily collect spines annually (or biannually) and send to NFA for analysis, allowing for an effective monitoring of the fishery at relative low cost. This has an important impact both now and in five years.

The combined exposure of NFA staff, tourism operators and local people to fisheries ecology, social science and economic assessments provides a holistic understanding of starting and managing a successful sportfishery that can ensure sustainable livelihoods into the future. In particular, the exposure of NFA to the concept of social-ecological thinking (e.g. the inherent links between social and ecological systems, and the need to manage and understand people and resources concurrently) provides the knowledge to expand a sportfishery with new operators in new coastal areas if opportunities arise in the future.

Research capacity was also enhanced for Australian participants, including JCU staff and students. For example, project leaders benefited from the collaborative linkages developed from their long-term research involvement. Postdoctoral-level researchers had the opportunity to improve their skills in project management in remote areas, while increasing their publication output. Australian personnel also had the opportunity to gain research skills in new fields of research and in an area of the world with unique challenges and increasing research opportunities. The experience gained in this project provided Australian researchers with the skills and understanding needed to work with Australian Indigenous groups to develop their own sport-fishing operations.

8.3 Community impacts now and in five years

8.3.1 Economic impacts

Although the national and regional financial benefits of sportfishing was found to be minimal, the industry can create a significant change and financial benefit at the local level in the communities where the sportfishing venture operates (see Farr et al. 2016). Current sportfisheries in PNG are small scale but already produce considerable revenue at the village level, with one operation having a value of over US$26,500 per year to villagers in the form of access to waters, wages for guides, wages for camp servicing, tourist artefacts purchased, medical supplies and clothing donations, in addition to US$144,000 per year in business income (J. Yip, pers. comm.).

A well-managed, locally based sportfishing industry can provide a variety of economic benefits (Farr et al. 2016). It directly provides a new source of income for local landowners through resource access payments and jobs for local people. This increase in local wealth means more buying power in the local community, allowing the development of new, diversified commercial opportunities. These are in turn enhanced by the flow of ecotourists through the community as a result of sportfishing operations. Such businesses can include village-based industries and add-on ecotourism enterprises such as bird watching and snorkelling. There can also be long-term economic benefits that accrue from the increased size and resilience of the resource. These result from the increased incentive to conserve the resource that a commercial benefit would engender. Because sportfisheries are based on no-take principles, the financial gains would occur without reduction of the fisheries resource.

Our economic report (Farr et al. 2016) found that planning efforts should concentrate on capacitating and enabling villagers to provide goods and services to the sportfishing ventures, and on stimulating or requiring sportfishing ventures to obtain as many goods and services as possible from the neighbouring villages. Given the small visitor numbers, it is economies of scope (that is, one or few people providing a wide range of different products, i.e. fish, seafood, garden products, fruit, wood carvings, bait, etc.) rather than economies of scale (that is, the whole village growing vegetables for sale to the lodge), that should be promoted at the local level.

8.3.2 Social impacts

Sportfisheries can have substantial positive social impacts in PNG. For example, one venture delivers over 3,000 kina in medicines and clothing (J. Yip, pers. comm.), and provides a frequent and reliable conduit for the delivery of aid to isolated communities that have no access to government services. Increased wealth inevitably brings social change, a result of enhanced buying power, increased access to education and increased awareness of the value of resources (Asafu-Adjaye 2000). Consequently, sportfishing ecotourism in PNG needs to be developed carefully to ensure that social benefits are maximised and potential adverse impacts managed and minimised. Key aspects of this process were identified in Wood et al. (2013).

Through this project, sportfishing operators, NFA and the communities involved now have a better understanding of the Black and Spot-tail Bass biology/ecology, and of the importance of critical habitats. This means that operators and guides are better informed about their product when interacting with clients, that local people have a better understanding about sustainable fishing and of the importance of the ecosystem health to fish stocks, providing incentive to conserve their resource. Importantly, they now understand the impacts of logging on fish habitats and, consequently, on fisheries sustainability, so they can now make better informed decisions about their future livelihood choices.

The communities involved were engaged in all aspects of the social science research, determining important questions, implementing and facilitating the surveys and focus groups. Through this process, and through participating in the surveys and focus groups, villagers gained a greater understanding of how the different facets of their lives have been affected by sportfishing and other changes that have occurred, or may be expected to occur in the future. The focus group exercise also further allowed men and women to reach consensus about their visions for the future. Thus, the social impact of this research initially has been that local people now have an improved understanding amongst each other, not only of how sportfishing tourism has changed their communities, but also of other opportunities and shared visions for beneficial development. The process opened up a dialogue about how other activities such as logging and oil palm affected natural resources, livelihoods and, ultimately, how it impacts on the potential for sportfishing to develop. With these lines of communication being more open, we anticipate that local people will be better equipped to drive development in their communities.

Moreover, the tourism operator, NFA and TPA are now more aware of local views and visions, meaning there is now increased scope for participatory management of sportfishing and associated development opportunities to occur. However, bearing in mind the problems that have arisen in Baia as a result of logging over the course of the project, efforts will be needed to build awareness within the study and surrounding communities of the potential environmental impacts of extractive industries such as logging and oil palm so they can make more informed choices.

8.3.3 Environmental impacts

This project led to substantial environmental benefits, both directly and indirectly. Directly, it generated the knowledge needed to effectively manage a previously poorly understood fishery resource. Indirectly, it helped develop the capacity to implement local-level management, provided the knowledge on which to base sound conservation and management plans, and increased the awareness of the value of key ecological and environmental resources/conditions (e.g. of healthy riparian zones), therefore creating incentives to conserve the target species' key habitats. This will hopefully lead to the appropriate management and conservation of the estuarine, wetland and riparian habitats that support the sportfishery resources, resulting in overall improvements in long-term environmental outcomes extending far beyond the sportfishery (Wood et al. 2013). Note however, that positive impacts will only take place if both the fisheries and the habitats they depend on are managed in a sustainable manner. A draft management plan for Black Bass sportfisheries was provided to NFA (Appendix 11), but it will only lead to positive economic, social and environmental impacts if appropriately implemented.

A key environmental result of this project is related the importance of healthy riparian zones. These zones provide critical habitats, food, and are crucial for maintaining good water quality in the river systems. One unanticipated impact over some of the studied systems was the visible decline of water quality, specifically due to increased sediment loads, over the last four years. This impact in such a short period was due to logging practices in upstream areas, and due to the removal of trees in the lower sections of the rivers, including sections of the riparian zone. The resulting turbid waters and silting of the river systems affected Black Bass catches (pers. obs), and can soon affect tourism and the livelihoods of local villagers. In the long-term, high sediment loads can lead to habitat degradation, which in turn will affect the food webs supporting Black and Spot-tail Bass. For example, on most new moons, millions of juvenile sicydiine gobies, or whitebait, regularly move from the ocean into freshwater habitats. These gobies provide a pulse of food (energy-nutrients) into the river systems, and are likely key components of the food web supporting the larger predator fishery species including Black Bass in the river systems. Discussions with the operator and local guides suggest these migrations are occurring less, likely due to increased turbidity, again stressing the importance of healthy riparian zones for the overall river health.

This project also provided knowledge to ensure that developments in forestry, agriculture and mining are managed to minimise adverse impacts on this important sustainable fisheries resource. This is a particularly important topic at present, due to the recent increasing rate of habitat degradation along rivers and in their catchments. Logging is the greatest threat to sportfishery in the Baia region, and current logging practices are causing major habitat degradation to the rivers and coastal areas in that region (e.g. Figure 36). On our last visit in September 2018, the removal of sections of the Pandi River riparian zone resulted in a loss of critical snag habitats in the lower reach of the river. If this continues, there are grave concerns for the future of these systems, and the people's livelihoods they support. The resulting turbid waters and silting of the river systems in the short-term affect fish catches (and can eventually affect tourism and therefore the livelihoods of local villagers), and in the long-term degrades habitats which will eventually negatively impact populations of Black and Spot-tail Bass, along with other species. Coastal habitats including inshore reefs, important areas for local people to catch fish for consumption are also showing signs of habitat degradation. If logging continues as it is now, the likely impact in five years, will be no healthy sportfishery to support local peoples livelihoods, and a risk of less fish for local people to eat, with possible effects on food security issues. Given that logging can only support the area over a limited number of years, the livelihood impacts in five years could be significant. Compounded on this, these fish constitute an important source of protein for local people, and therefore degraded rivers would mean less fish to catch, and could result in future food security issues.

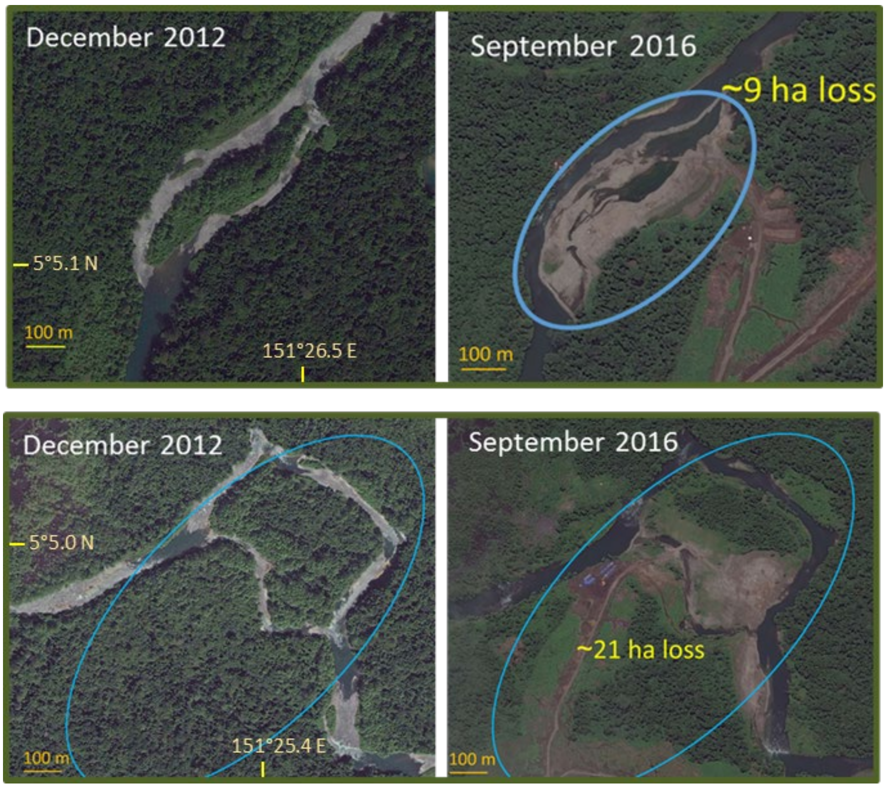


Figure 36. Aerial photos showing the degradation of habitat, including riparian vegetation, in two sections of the Pandi River between 2012 and 2016 (Map data: Google, DigitalGlobe).

8.4 Communication and dissemination activities

At the start of the Project, a website (http://www.niuginiblackbassresearch.com/black-bass/) was constructed to communicate results to tourism operators, management agencies and the public. During the Project, we produced 17 Fact Sheets (Appendix 1) and 8 Briefing Reports and (Appendix 2) that provided NFA, sportfishing operators and guides with important biological and ecological information about the fishery. Additionally, Tourism PNG was provided with information on what locals would like to see to help promote the sportfishing business. This project culminated with the drafting of the *Black Bass Management Plan* (Appendix 11), which was provided to NFA. Two technical reports ((Farr et al. (2016) and Diedrich et al. (2016)) were also produced, with information on the socio-cultural and economic aspects to take into account when implementing and managing sportfisheries in PNG.

Results were also disseminated to the scientific community through a number of peer-reviewed international publications. So far, seven scientific papers have been published and we will continue to publish data collected throughout this project. Given the opportunities for sportsfisheries to support livelihoods in developing countries, the information in the publications should assist future developments in this field. In particular, Barnett et al. (2016) provides guidelines for best practice in developing a sportfishery operation for sustainable livelihoods, and Diedrich et al. (2018) highlights the critical role of social capital relative to other forms of capital in influencing local peoples' transitions to sportfishing tourism.

Furthermore, NFA and JCU are currently developing educational materials to share with villagers and operators (for guides and clients). These include laminated storyboards and Fact Sheets, pamphlets, posters and booklets. These will cover three main themes: 1) the life cycles of Black Bass, 2) critical habitats for Black Bass, and 3) major threats facing Black Bass. There will be different versions for children and for adults, the children version being in cartoon layout and a workbook for school. The aim is to communicate the long-term effects of logging, i.e. to show what happens when environment damaged, so that villagers are better informed before allowing loggers to log their land for the short-term benefits.

9 Conclusions and recommendations

9.1 Conclusions

Sportfishing operations can have significant economic benefits for the communities where they operate, representing important livelihood diversification opportunities. While the communities studied rely heavily on fishery resources for sustenance, and some perceived a decline in local fish stocks over recent times, none attributes these declines to the presence of sportfishing operations. Overall, our socio-cultural analysis found positive perceptions of the sportfishing operations and that people associated the industry with improvements in their quality of life. Importantly, the socio-cultural analysis shows that these communities are generally well placed in terms of their capacity to further capitalise and benefit from ongoing sportfishing. There were however potential conflicts in communities where people also gained economic benefits from extractive industries with the potential to impact on sustainable sportfishing such as logging and mining.

The biological and ecological part of this study was based on the rivers around Baia. An important finding was that Black Bass size is a poor indication of age, so it is important to monitor the age structure to ensure continuing profitable fisheries. We developed and validated a non-lethal method age estimation, based on counts of apparent growth increments in dorsal spines, that can be used by NFA in conjunction with tourism operators to monitor Bass population structure into the future.

Results also show that Black Bass use a range of habitats throughout their life cycle, and that the presence of in-water structure is critical for Bass populations, including shallow grassy edges of the lower freshwater reaches for small juveniles, and snag habitats for larger juveniles and adults. Since one of the main threats to Bass habitats is the loss of snag generating capacity and reduction in riparian services (Sheaves et al. 2018), habitats that provide structure, including riparian vegetation in particular and catchment forests in general, should be carefully considered by management, in a whole-of-system approach.

Black Bass were also found to make regular migrations throughout the seascape, often associated with the new moon. These lunar movements coincide with the cycle of migration of juvenile gobies (‘whitebait’) from marine to freshwater reaches. Black Bass feed extensively on these gobies just outside the estuary mouths on new moons, suggesting that the health of whitebait populations is critical to the resilience of Bass populations. Migrating whitebait transport copious amounts of marine-derived energy and nutrients to the estuaries and freshwater environments, representing an important and regular subsidy of nutrients to river food webs. This means that these whitebait populations are important not only for Bass but also for the overall functioning of river systems. Therefore, management should also implement measures that ensure continuing, healthy, whitebait populations, e.g. by maintaining good water quality.

Overall, results stress that, for the sustainability of this fishery, it is important to maintain (1) adequate connectivity between coastal, estuarine and freshwater habitats, (2) good water quality along the river systems and (3) healthy riparian zones that provide structure, shading and food (and ensure continuing good water quality). However, over the course of the project, degradation of river habitats due to logging was evident, and this can negatively affect the Black Bass fishery and other resources local populations rely on.

9.2 Recommendations

The knowledge gained from this project has important implications not only for the direct management of the Black Bass sportfishery but also for the management of particular habitats, overall rivers and their catchments. The main risks to Black Bass habitats (e.g. degradation of riparian vegetation, decreased water quality), the nature of Bass fisheries and the biology of Bass mean that effective monitoring of population change is imperative. Our results show that monitoring should focus on age, and that sub-lethal aging based on the analysis of growth increments in dorsal spines is appropriate and should be used. Moreover, although data indicate that both Black and Spot-tail Bass have marine larval phases and that larger individuals move out of rivers into coastal waters, the extent of connectivity between populations from the different river systems remains unknown. In a region where traditional land tenure remains strong and local communities maintain control over local rivers, management strategies must consider the implications of the extent of connectivity of fished populations among rivers. For example, if populations are restricted to individual or connected river systems, then management of the populations by individual communities should be effective. Conversely, if populations range widely over a region spanning multiple community tenures, then effective management will require coordination among communities (Sheaves et al. 2016a). Given the knowledge gained, the precautionary approach to should be used, where rivers, or rivers within local areas should be managed as individual units until further genetics information is available.

The use of the marine-estuary-freshwater continuum throughout the Black Bass life-cycle means that it is critical to preserve appropriate ocean-river connectivity. Although high rainfall in PNG means that the pressure to build impoundments is not high, the connectivity needs of freshwater/estuarine fish need to be kept in mind for future planning. While the construction of barriers to movement within rivers in remote areas seems unlikely at present, plantation agriculture, logging and mining are expanding in many catchments, with impacts on habitat, water quality and, therefore, on the overall river and estuarine food webs (Swales et al. 2000, Caddy 2008). For example, areas with high sediment load have the potential to interrupt the migration of sensitive species such as Sicydiine gobies (Jenkins et al. 2010). Since these gobies are important for the overall functioning of river food webs, impacts can extend further than the impacted habitats, affecting the overall food web. Thus, ensuring these species have access to the resources needed to complete their life-cycles extends beyond the maintenance of physical connectivity; it includes ensuring high quality habitat throughout their range, and good water quality to allow access to required habitats and resources (Sheaves et al. 2015).

The multidisciplinary information obtained through this project led to the drafting of a best-practice catch-and-release guideline and a Management Plan for the Black Bass sportfishery. These recommendations should be used by NFA to adequately manage Black Bass and their critical habitats, ensuring the long-term sustainability of the industry. This is of particular importance as coastal and freshwater ecosystems are under increasing threat. Note however that the present study was conducted in only one part of the broader distribution of these species, and in other parts of their range the nature and spatial extent of the coastal seascape can vary considerably. This means it is important to consider system-specific settings when planning to set up similar sportfishing ventures.

Therefore, with this project, the key ecological, biological and social information necessary for the sustainable management of the Black Bass sportfishery was obtained. This includes understanding almost the complete life cycle of Black and Spot-tail Bass, and the identification of the key habitats that need to be preserved to ensure a healthy and sustainable fishery, able to support local livelihoods into the future. Moreover, there is now a good understanding of local opportunities and constraints for improving livelihoods as a result of sportfishing. Information gained provides a strong foundation for future sport-fishing development to support food security and livelihood diversification throughout the Pacific. However, the long-term impacts of this project will only come to fruition if the suggestions, guidelines and management plan produced in this study are translated into real, on-ground, management of this fishery and of the habitats it relies on, in a whole-of-ecosystem management approach.

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11 Appendices

Appendices Contents

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Appendix 6: Diedrich A and Pandihau L (2017) *Sustainable Management of Sportfishing Communities in PNG: Further insight into Fishing, Infrastructure and 'Future Visions' of Communities in Western New Britain*. Focus Group Report, June 2017.

Appendix 7: Household level survey questions

Appendix 8: Community data factsheets - Community Data Summary Sheets – summaries of socio-cultural community surveys.

Appendix 9: Economic survey factsheets

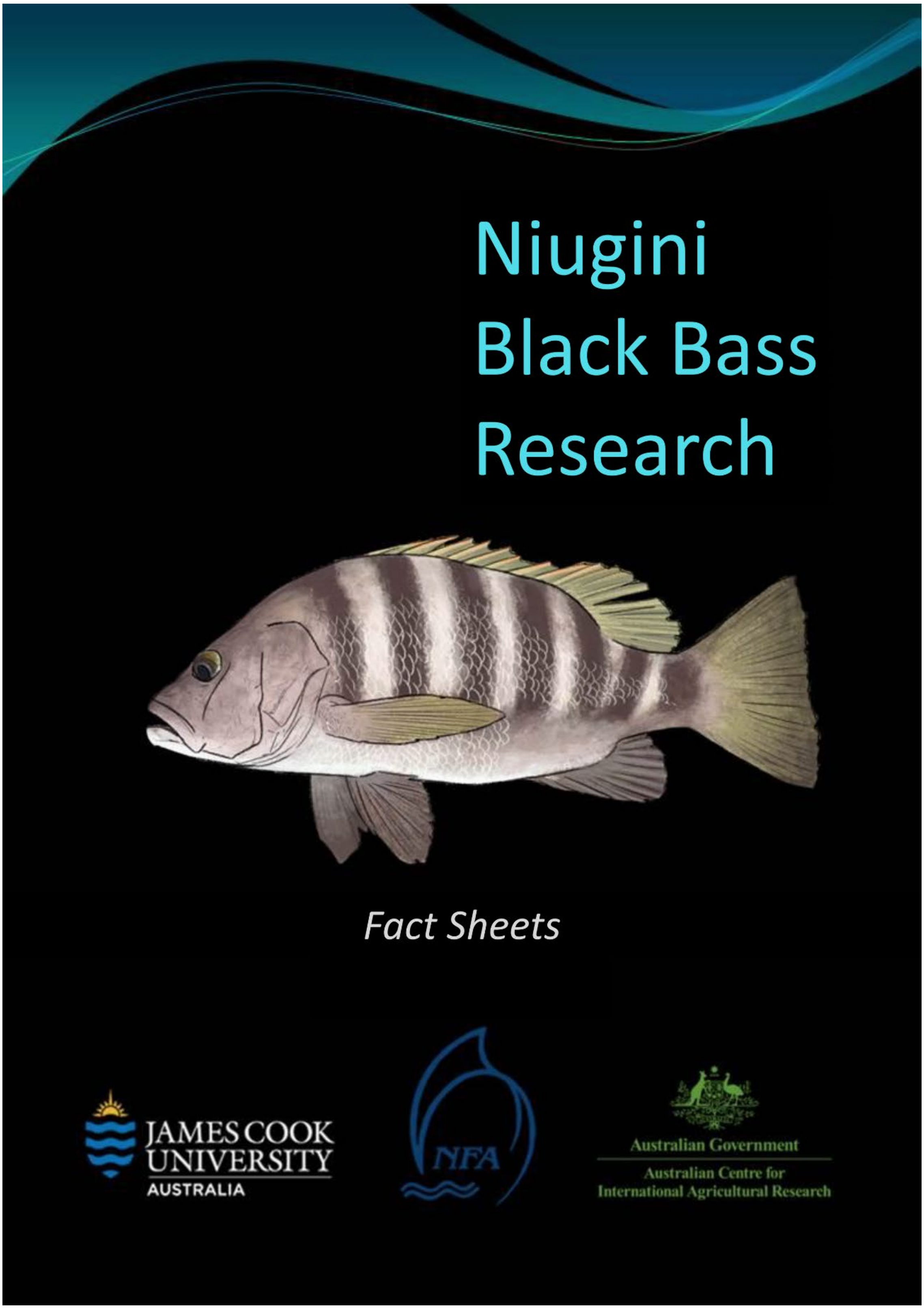
Appendix 10: Role of social capital in transitions to sportfishing tourism in PNG (slides from conference presentation)

Appendix 11: Draft Niugini Black Bass Management Plan

Appendix 12: Published output briefs

> Published Output Brief 1: Sheaves et al. (2016) The conservation status of Niugini Black Bass: a world-renowned sport fish with an uncertain future. Fisheries Management and Ecology 23:243-252.
>
> Published Output Brief 2: Barnett et al. (2016) Sportfisheries, conservation and sustainable livelihoods: a multidisciplinary guide to developing best practice. Fish and Fisheries 17:696-713
>
> Published Output Brief 3: Wood et al. (2013) Sport fisheries: opportunities and challenges for diversifying coastal livelihoods in the Pacific. Marine Policy 42:305-314

11.1 Appendix 1: Fact Sheets



Fact Sheet 1: Characteristics of waterways used by Black Bass

Sustainable Management of Sport Fisheries
for Communities in Papua New Guinea

Fact Sheet 1: Characteristics of Waterways used by Black Bass

The papuan Black Bass (*Lutjanus goldiei*) occur in low salinity coastal estuaries and river systems throughout Papua New Guinea. They occupy a variety of different types of river/estuarine systems:

Freshwater drainage system with limited floodplain reaches

- Steep stream gradient continues almost to the coast resulting in downstream slow-flowing freshwater and estuary reaches of limited extent

Freshwater drainage system with extensive floodplain reaches

- Steep steam gradient transitions to extensive slow-flowing lowland reaches and estuaries in downstream areas

Coastal mangrove swamp

- *Rhizophora/Bruguiera/Sonneratia* dominated
- *Nypa fruticans* dominated

Each of these types of systems contains particular combination of stream reaches.

Reach Type	Freshwater (limited floodplain)	Freshwater (extensive floodplain)	Coastal mangrove swamp
Backbeach channel (slow flowing estuarine)	Limited to coastal side branches	Can be extensive	Can be extensive
Estuary channel	Limited – often poorly differentiated from freshwater stream reaches	Usually a substantial component of the system	Usually the main component of the system
Freshwater reaches (fast flowing)	Major component	Confined to upstream	Limited extent
Freshwater reaches (slow flowing)	Limited	Usually a substantial component of the system	Limited extent
Mouth sandbanks	Often contain snag habitats formed by logs washed from upstream	Often contain snag habitats formed by logs washed from upstream	Fewer snags due to low river flow
Nypa fruticans lined channel (slow flowing)	Limited to coastal side branches	Common along estuary reaches	Common – may dominate the estuary
Rhizophora/Bruguiera/Sonneratia lined channel (slow flowing)	Limited to coastal side branches	Common along estuary reaches	Common – may dominate the estuary

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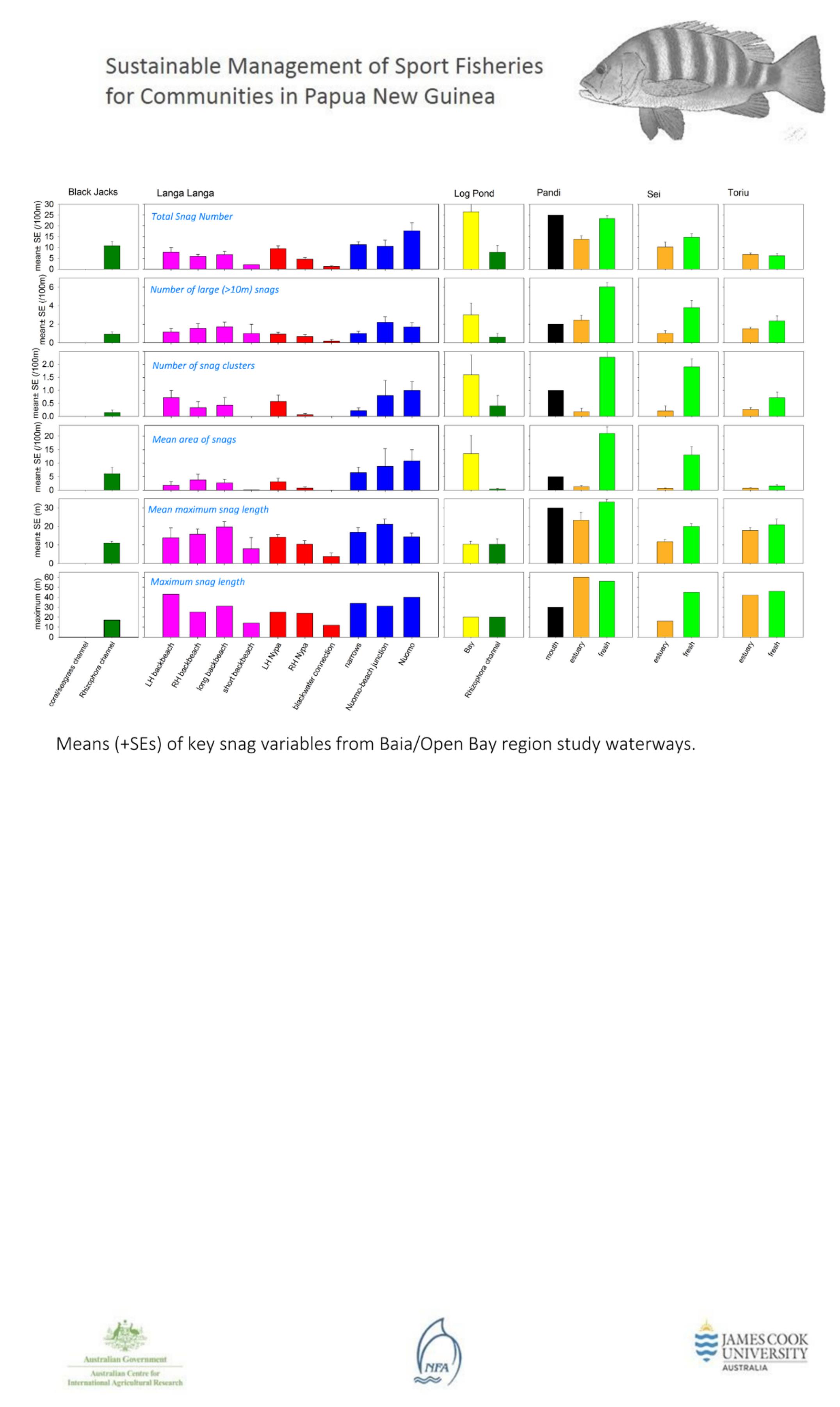
Sustainable Management of Sport Fisheries
for Communities in Papua New Guinea

Distribution of structurally complex habitat used by black bass waterways of the Baia/Open Bay region

LEGEND

- Blue: Very common/extensive
- Green: Common
- Yellow: Occurs
- White: Not common or absent
- # Sites where Black Bass have been recorded

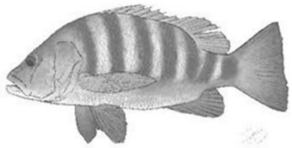
Waterway	Reach Type	Submerged timber (simple)	Submerged timber (complex)	Rock	In-water vegetation (grass/pitpit)	In-water vegetation (tree leaves/bamboo)	In-water vegetation (roots/pneumatophores)	In-water vegetation (Nypa fronds etc.)	Floating vegetation (kangkung etc.)	Newly fallen tree (with vines etc.)	Trapped rafts of floating vegetation
Black Jack Ck	Coral/seagrass channel										
	Rhizophora/Bruguiera swamp estuary #	Common	Common			Very common/extensive	Very common/extensive			Very common/extensive	
Toriu R	Mouth (sand channel with snags) #	Common	Very common/extensive								
	Estuary #	Common	Common	Very common/extensive	Occurs	Common	Occurs	Common	Common	Occurs	Common
	Freshwater (slow) #	Common	Common	Common	Common	Common				Occurs	Occurs
Log Pond	Bay	Very common/extensive	Very common/extensive								
	Rhizophora/Bruguiera swamp estuary #	Common	Common			Very common/extensive	Very common/extensive			Very common/extensive	
Sei R	Mouth (sand channel with snags) #	Common	Very common/extensive								
	Estuary #	Common	Very common/extensive		Common	Very common/extensive	Very common/extensive	Common		Very common/extensive	Very common/extensive
	Nypa channel #	Occurs	Occurs			Common	Common	Very common/extensive			
	Freshwater (fast) #	Common	Very common/extensive		Very common/extensive	Very common/extensive			Very common/extensive	Very common/extensive	Very common/extensive
Movolo R	Freshwater (fast) #	Common	Common		Very common/extensive	Very common/extensive				Very common/extensive	
Pale R	Freshwater (fast)	Common	Common		Very common/extensive	Very common/extensive				Very common/extensive	
Vatu coast	Mangrove/seagrass/reef complex #	Common	Very common/extensive			Very common/extensive	Very common/extensive			Common	
Tobeni Ck	Estuary	Common	Very common/extensive			Very common/extensive	Very common/extensive			Common	
Baia Ck	Estuary	Common	Very common/extensive			Very common/extensive	Very common/extensive			Common	
Langa Langa R	Backbeach main channel #	Common	Very common/extensive							Very common/extensive	
	Backbeach blind channel #	Common	Very common/extensive							Very common/extensive	
	Nypa channel #	Occurs		Occurs			Common	Very common/extensive			
	Nypa/bamboo channel #	Occurs				Very common/extensive	Common	Very common/extensive		Occurs	
	Nypa/forest channel #	Common	Very common/extensive			Common	Common	Common		Common	Occurs
Nuomo R	*Nypa*/forest complex freshwater #	Common	Very common/extensive			Very common/extensive	Very common/extensive	Very common/extensive	Common	Common	Very common/extensive
Pandi R	Mouth (sand channel with snags) #	Common	Very common/extensive								
	Estuary #	Very common/extensive	Very common/extensive		Common	Very common/extensive	Common	Occurs	Common	Very common/extensive	Very common/extensive
	Freshwater (fast) #	Very common/extensive	Very common/extensive		Very common/extensive	Very common/extensive				Very common/extensive	Very common/extensive



Means (+SEs) of key snag variables from Baia/Open Bay region study waterways.

Fact Sheet 2: Black Bass habitats

Sustainable Management of Sport Fisheries for Communities in Papua New Guinea

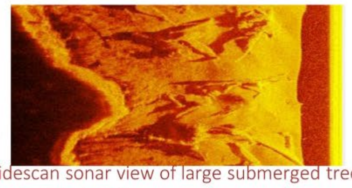


Fact Sheet 2: Black Bass Habitats[1]

Papuan Black Bass (*Lutjanus goldiei*) are found throughout PNG's freshwaters and low salinity estuary systems. These include both fast-flowing rivers and low salinity coastal swamps. Within these, systems black bass are closely associated with a range of structurally complex habitats.

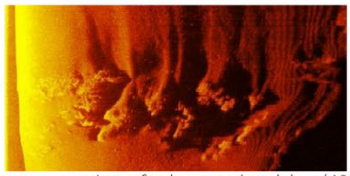
These complex habitats provide the necessary shelter, feeding and resting sites, and so their abundance and quality are the principal resources determining the sustainability of black bass populations. Some of the key habitats are:

- Submerged timber (snags) washed in from bankside forests
- Fallen trees resting in the water
- Submerged rock bars
- Flooded vegetation such as grass and leaves
- Mangrove forests
- Floating vegetation
- Rafts of floating debris accumulated on snags



Sidescan sonar view of large submerged trees (up to 20m long)

Fallen bankside tree covered with vines



Sidescan sonar view of submerged rock bar (40m long)

Flooded bankside pit-pit grass (*Miscanthus floridulus*)

A surface mat of Kangkong (*Ipomoea aquatica*) and floating timber

Mangrove and Nypa forest

[1]See Fact Sheet 12: Interpreting side scan sonar

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Fact Sheet 3: Critical Black Bass habitats

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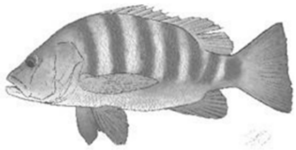

Fact Sheet 3: Critical Black Bass Habitats

Many snapper (*Lutjanus*) species have a life-cycle that includes one or more nursery habitats – places separate from the adult population where juveniles spend their vulnerable early stages. These habitats are critical to the development of the individual, providing a bridge from larval to adult ways of life. Sometimes the availability of nursery habitat can be a limiting factor in population size – a bottle neck that determines survival from larvae to adult. The loss of suitable nursery habitat from human impacts is one of the greatest risks to the sustainability of coastal and river fish species.

Black Bass

Black Bass (*Lutjanus goldiei*) have specialized nursery ground requirements. In the New Britain study area, young juveniles are found in slower flowing fresh water locations, such as the shallow edges and side arms of rivers. In these areas they are found exclusively in and around aquatic and partially submerged riparian vegetation. Key habitats include:

- Stretches of bank dominated by tall grasses with floating root mats, such as pitpit grass (*Saccharum edule* and *Miscanthus floridulus*);
- Areas dominated by floating mats of kangkong (*Ipomoea aquatic*);
- Banks with tree roots and over-hanging riparian vegetation;
- Areas with large beds or mats of submerged aquatic vegetation.

Flooded bankside pit-pit grass

In the study areas, young juveniles (0-1 yrs) inhabit shallow water areas containing these habitats exclusively and are not found in the same habitats used by adults. Older juveniles use a broad range of habitats including the same areas as used by young juveniles, as well as deeper bank habitats in rivers. They also move into estuaries, using a range of adult habitats there. Rivers have not been surveyed extensively further than 5km upstream of the mouth. It is likely juvenile Black Bass occur further upstream, and the exact nature of the habitats they use in these areas is currently undetermined.

juveniles	sub-adults	adults

Shallow areas (<0.5m) containing:	Deeper areas >0.5m containing:
• grass root mats • mats of floating water plants • tree roots • overhanging vegetation • submerged plants	• snags and snag complexes • rock bars • overhanging vegetation • mats of floating water plants • rafts of accumulated debris

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Fact Sheet 4: Spot-tail Bass habitat requirements

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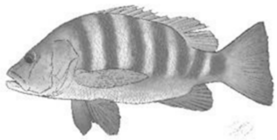

Fact Sheet 4: Spot-tail Bass Habitat Requirements

Like many snapper species, the Spot-tail Bass (*Lutjanus fuscescens*) makes use of various structures as living areas. Structures can provide a variety of advantages which help fish survive and grow, such as refuge from fast flowing water, refuge from predators, a location for feeding activities, and as an aggregation point. Spot-tail Bass are generally restricted to rivers, and prefer large, fast-flowing rivers. Therefore, the vast majority of structures available to them are formed by rainforest vegetation of some kind. In particular, large rainforest trees provide important habitat from the day they fall to the day they finally leave the system, in some form or another.

Types of Spot-tail Habitat

There are two distinct kind of structures used by Spot-tail Bass, and each can be formed by a variety of vegetation and woody debris. Overhanging structured habitat, which covers fish from above and shades the area underneath, is a type of structure particularly favoured by Bass. This can be formed by:

- Floating rafts of debris
- Fallen trees (live or dead) still attached to the bank
- Bamboo

Bamboo

Submerged structured habitat, which rests on the river bottom, is another type of structure particularly favoured by Bass. It can be present throughout the river channel, but tends to be concentrated at bends. This can be formed by:

- Entire trees with intact branches and root balls
- Logs without branches
- Collections of logs and sticks that form 'jams'

Intact tree

Nursery Requirements

Spot-tail bass do not appear to have specialized nursery requirements in the areas that have been surveyed by our team. As with adults, juveniles use complex woody debris habitat. While they can be found along-side adults, juveniles also use woody debris in shallower water, outside the depth range favoured by adults.

Spot-tail sub-adult using a log jam

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Fact Sheet 5: Threats to Black Bass habitats

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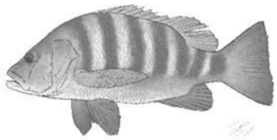

Fact Sheet 5: Threats to Black Bass Habitats

Papuan Black Bass (*Lutjanus goldiei*) are native fish that rely on the specific habitats provided by Papua New Guinea's pristine freshwater and estuarine systems. The continued health of Black Bass populations relies on maintaining the high quality of those habitats. As a result Black Bass are susceptible to many pressures resulting from human development and population growth that negatively impact the quality of the key habitats factors that they rely on.

Turbidity and Sedimentation

PNG's streams are naturally clear but many systems are now experiencing frequent high turbidity events. In addition excess sediments are increasingly blocking rivers. This turbidity and sedimentation results from a diversity of human activities such as:

- Poorly contained mining wastes;
- Poor management of logging and roads that fails to prevent erosion of soils;
- Poor management of extraction of gravel from stream beds;
- Construction of plantations and gardens on steep slopes;
- Lack of maintenance of ground cover on plantations and gardens.

Loss and damage of Riparian Vegetation

Riparian vegetation along stream banks is the principal source of the submerged trees (snags) that are critical black bass habitats. It also shades narrow streams, reducing water temperature, and provides food that supports Black Bass food webs. Sources of riparian loss include:

- Clearing for plantations and gardens;
- Logging close to streams.

Clearing along the banks of the Toriu River

Pollution

Pollution can lead to poor water quality and toxic effects. It comes from many sources:

- Fertilizer and pesticides from plantation agriculture;
- Poorly managed mine tailings and agricultural treatment wastes;
- Oil etc. from machinery associated with mining and road and plantation construction;
- Human waste and household activities (e.g. washing clothes in streams).

Destructive Fishing and Overfishing

Rapidly increasing populations mean that fishing practices used in the past may not be sustainable into the future. These include:

- Destructive practices such as poison fishing, explosive fishing and extensive spear-fishing;
- Lack of regard for the impact of large catches of fish when many people are fishing the same fisheries resource.

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Fact Sheet 6: Life-cycle movements of Bass

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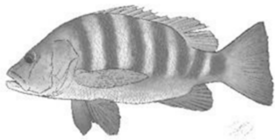


Fact Sheet 6: Life-cycle movements of Bass

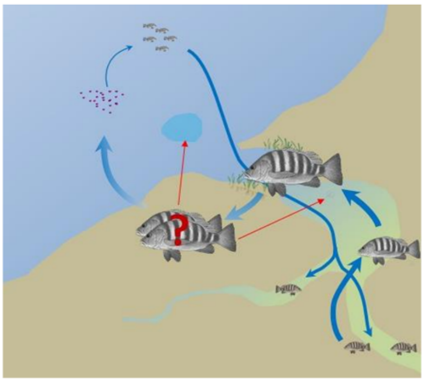
Very few fish use a single habitat all the time but usually use many different habitats at different times of their lives and for different functions (e.g. feeding, refuge). This group of habitats are part of a mosaic of connected habitats used by fish at various times during their lives. Ensuring healthy fish stocks requires the protection of all habitats and resources used throughout the fish's life. Using a technique called otolith microchemistry, we can determine where fish have lived throughout their lives, and their movements through the coastal seascape.

How otolith microchemistry works

Fish's otoliths (or ear bones) grow continuously throughout the fish's life. The material laid down to form the bone includes naturally occurring chemicals from the water the fish is living in. Different waters, e.g. fresh Vs salt, turbid inshore Vs clear offshore, have different chemical compositions. We cut a thin slice through the otolith, and use a laser to vaporise a line across it from the core, laid down when the fish was first born, to the edge, laid down just before the fish was caught, and measure the chemical composition of the vapour. From this we can determine where the fish lived at each stage during its life.

Life-cycle Movements of Black and Spot-tail bass

Both black and spot-tail bass have marine larval phases, indicating that from wherever they are spawned, they are quickly washed into ocean waters. When their larval phase ends, they migrate into coastal rivers. Spot-tail bass typically move directly into freshwaters and stay there until around the age that they mature. At this time, many move downstream to the upper limits of salt in the top of the estuary. This movement is probably related to moving closer to their spawning areas. Black bass tend to range more widely through the coastal seascape. Some spend most of their lives in the brackish parts of estuaries, while other spend several years in freshwater. As with spot-tail bass, at around the age of maturity, black bass tend to migrate downstream and live in the brackish or salty parts of coastal rivers.



Life-cycle movements of Black Bass, including offshore larval phase, recruitment of juveniles to freshwaters, and staged migration downstream to estuarine areas where many adults live. Red '?' and arrows indicate that the exact spawning location remains uncertain.

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Fact Sheet 7: Small Bass can be quite old

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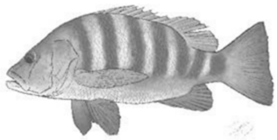
for Communities in Papua New Guinea



Fact Sheet 7: Small Black Bass can be quite old

Papuan Black Bass (*Lutjanus goldiei*) and Spot-Tail Bass (*Lutjanus fuscescens)* are native fish that vary widely in size and age. We found black bass around 46cm in length to range in age from 3 to 12 years. These are amongst the smallest bass captured in the sport fishery, meaning that a small fish is not necessarily a young fish, and that the presence of small fish might not indicate successful recruitment of young fish to the population. Because small fish can be quite old, recruitment failure could go unnoticed for a decade before the lack of small fish became apparent.

Black Bass measuring 46 cm and aged 12 years old

Possible Reasons for Future Recruitment Failure

- Fishing the breeding stock
- Impacts to critical juvenile habitats
- Declines in water quality due to logging

This highlights how critical it is to monitor the age structure of bass populations to ensure that new recruits are arriving to sustain the population. It is not simply enough to note that small fish are present among the catches.

Non-Lethal Ageing Methods[2]

Black bass can be aged from sections of the dorsal spines, which can be clipped from live fish before release. This means anglers and operators could provide management scientists with samples of spines from a number of smaller fish from each river each year, allowing checks to ensure that some young fish successfully arriving to sustain the population.

[2] Fact sheet 13: Non-lethal aging

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Fact Sheet 8: When do Bass breed?

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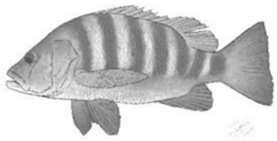


Fact Sheet 8: When do Bass breed?

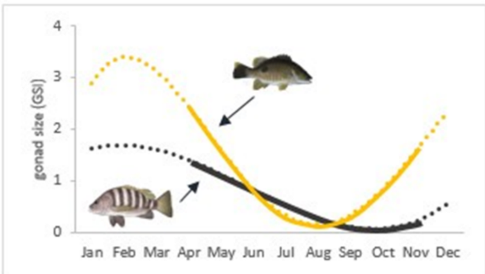
Knowing at what size and age, and what time of year fish breed, is important for management. Fast-growing species that breed young can sustain more pressure than slower-growing, late-breeding species. Although the details of black and spot-tail bass breeding are yet to be confirmed, other tropical snappers aggregate to spawn, and fishing these aggregations, even catch-and-release fishing, could disrupt spawning activities.

Size and Age at Maturity

Some black bass are mature by a little over 40 cm in length, with most fish we have examined being mature by 45 cm. These fish are typically around 7 to 10 years old. Spot-tail bass mature at smaller sizes, with most fish mature by around 35 cm, and some as small as 29 cm. Spot-tails also seem to mature at a younger age, between 4 and 7 years old.

Spawning Season

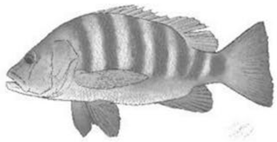
We have found black bass in spawning condition from April to June, and their gonads are starting to enlarge again by November. This suggests the peak spawning season is through the wet season leading up to April. Spot-tail bass start spawning earlier in spring, with fish in spawning condition from October through to April. During this period we have observed large aggregations of spot-tail bass on snags in the mixing zone of salt and freshwaters, and this may be their spawning location. The location of black bass spawning remains uncertain, but acoustically tagged fish have been recorded moving to similar areas of the estuary on the new moon, again, possibly for spawning.



Spawning seasons for Black and Spot-tail Bass inferred from gonad size (GSI = gonad mass as % of body mass). Solid lines represent measured GSI, dotted lines are inferred breeding condition during wet season when study sites are inaccessible.

Fact Sheet 9: Bass diets

Sustainable Management of Sport Fisheries
for Communities in Papua New Guinea



Fact Sheet 9: Bass diets

The sustainable management of black and Spot-tail Bass populations includes understanding and managing the food types they rely on most heavily. Examining the gut contents of these fish tells us what prey types are important to them.

Stomach Content Analysis

A large proportion of black and spot-tail bass examined for gut contents had empty guts. This suggests that individual fish do not feed continuously, but have periods of high and low feeding activity. Both species consume a variety of fish and crustacean prey, but spot-tail bass also feed on terrestrial invertebrates and plants. For black bass, smaller fish (35-45 cm TL) feed mostly on crabs and shrimp/prawns, while for larger individuals fish become increasingly important and the importance of crabs decreases. For spot-tail bass, smaller individuals (<25 cm TL) feed mostly on crustaceans such as freshwater shrimp and crabs, and larger individuals (>25 cm TL) also feed on fish, terrestrial insects and plant material.

Both black and spot-tail bass eat a variety of fish and crustacean prey, demonstrated by the variety of animals found in their stomachs.

Whitebait runs: a brief feast

Although black and spot-tail bass eat a variety of fish and crustacean prey from various habitats within the coastal rivers, they enjoy occasional feasts during a feeding frenzy when the whitebait runs arrive. On some new moons during the year, tiny whitebait flood into the rivers in huge numbers from coastal waters. These fish, around 2-3 cm long, are post-larval gobies that have spent several months growing in the ocean before attempting to migrate upstream to freshwaters where the adults live. When they arrive in large numbers, they are easy and nutritious pickings for hungry fish, including bass. Although it is challenging to measure directly, it appears these whitebait may be very important parts of the food webs supporting bass.

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Fact Sheet 10: Stable isotope analysis

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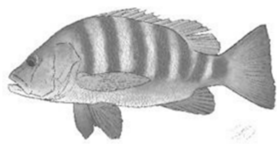
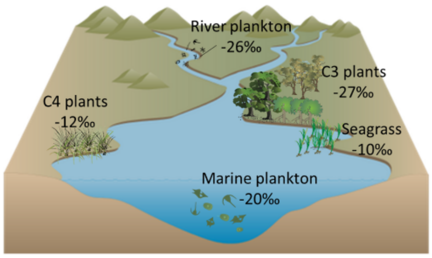


Fact Sheet 10: Stable Isotope Analysis

Stable isotope (SI) analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) can be used to study fish diets and habitats used. This is because different primary producers can have different SI composition (particularly $\delta^{13}C$), and because the SI composition of a food source changes in a predictable manner as it is passed on to a consumer. $\delta^{13}C$ typically changes by +1‰ per trophic link, while $\delta^{13}C$ changes about +3‰. This means that the SI composition of a consumer is a reflection of its food sources.

SI analysis was particularly useful for our project because our study areas encompass environments characterized by well separated $\delta^{13}C$ values. For example, $\delta^{13}C$ of forest trees and freshwater producers are typically lower than $\delta^{13}C$ of marine and estuarine producers. So, SI analysis can be used not only to study diets and identify the ultimate sources of nutrition, but also to study habitat use and movement between habitats. Since an animal's stable isotope composition reflects its average diet, it can also be used to study the variability in diet within a species and to quantify the dietary overlap between species.



Typical $\delta^{13}C$ values of the different primary producers that can support black bass populations around Baia, from freshwater to estuarine and marine environments.

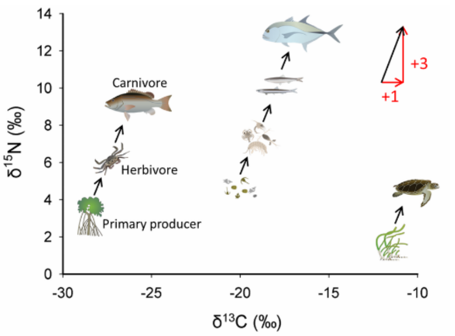


Diagram showing a representation of three hypothetical food chains in the $\delta^{13}C$ vs. $\delta^{15}N$ space, demonstrating the change of +1 ‰ for $\delta^{13}C$ and +3‰ for $\delta^{15}N$, that can be used to study diets and trace the ultimate sources of nutrition.

Sample collection

Sampling for SI analysis is an easy process. Muscle samples can be quickly obtained using a biopsy punch, blood can be obtained with a needle and syringe, and fish can be returned into the water quickly after capture. It is also important to sample primary producers and potential prey, so that their SI composition can be compared with that of bass. SI samples are processed in the laboratory and the stable isotope composition is analysed in an isotope ration mass spectrometer (IRMS).

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Fact Sheet 11: Interpreting sidescan sonar from shallow coastal waterways

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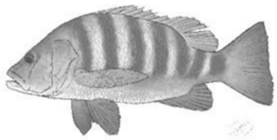


Fact Sheet 11: Interpreting sidescan sonar from shallow coastal waterways

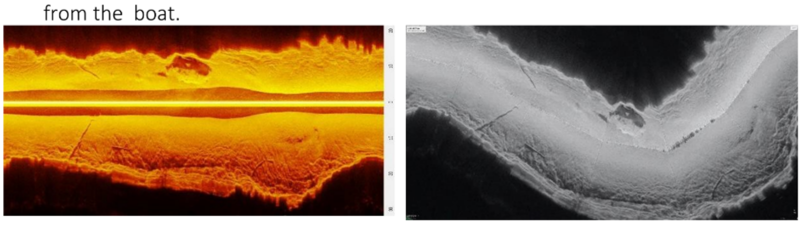
Side scan sonar is a key tool for surveying and mapping subtidal habitats. It is generally used from large boats and in relatively deep water (deeper than about 4m). When deployed from small boats side scan can be used in the much shallower water found in estuaries and rivers. This means that habitats can be surveyed safely where it is dangerous to enter the water, for instance because of the presence of crocodiles.

How side scan sonar works

Side scan sonar projects a sonar pulse to each side of the boat many times per second. The sonar signal is reflected off underwater objects and the time the reflected signal takes to return to the sonar receiver is used to measure how far away and object is. The side scan unit converts the information returned by successive echoes to produce a 2-dimentional 'map' of the underwater seascape and any structures that are on the seabed.

Interpreting side scan imagery from shallow estuaries and rivers is difficult because the shallow water can cause confused signals, because large numbers of submerged trees can block the signals from other objects, and because the side scan boat must follow the river channel causing distortion of the recorded signal. This means that a high level of experience and skill is needed to interpret side scan images from shallow water. Some of the key factors include:

- Use of appropriate software to process images to produce accurate images adjusted for the changing coverage seabed caused by the curved course that the boat often needs to follow;
- Specific training from experts experienced in the use of side scan in shallow water;
- Substantial time in the field examining side scan imagery as it is recorded so that interpretations can be ground truthed against actual structure visible from the boat.



Side scan images of a section of the Langa Langa River (New Britain). The left hand image is the original recorded by a Humminbird side scan sonar the right is an image corrected for the curved course of the side scan vessel. The straight light area in the original image is the boat track and the dark areas either side show the depth of the water (numbers on the right show distance from the centre track. The right hand image has been corrected to adjust for the slight distortion to the position of objects on the seabed in the left hand image caused by including the centre depth depiction. The side scan gives a 'bird's eye' view. The light areas are the river channel and the dark areas at the side are the land. Structures in the image are large submerged trees and a section of collapsed river bank (upper centre of the images).

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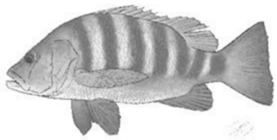
Fact Sheet 12: Non-lethal aging of Bass

Sustainable Management of Sport Fisheries
for Communities in Papua New Guinea



Fact Sheet 12: Non-lethal aging

Black and spot-tail bass size-at-age is very variable, meaning some fish grow slowly and small fish can be quite old. Because of the variation in growth rate, the presence of small fish does not necessarily indicate that there are young fish entering the population to sustain it. Therefore managers need to monitor the age-structure of the population to ensure that young fish are successfully recruiting to replenish populations.

Normal practice - lethal aging

The age of fish is usually estimated by cutting a thin section through the fish's otolith or ear bone and counting the number of growth rings. However, removal of the otoliths requires killing the fish, and so this is not ideal for the sustainable management of sportfish like the Niugini Black Bass.

Non-lethal ageing methods

Dorsal spines provide similar age estimates to otoliths for a number of species of tropical snapper, including black bass. Although the estimates are not quite as accurate as from otoliths, they are certainly close enough to distinguish a young fish (e.g. 5 year old) from an old fish (e.g. 12 year old) of similar size, and to meet the management objective of monitoring to ensure recruitment of young fish to the population is continuing.

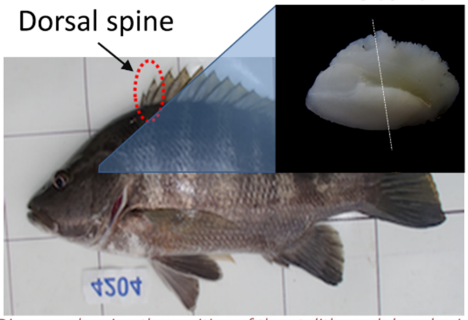
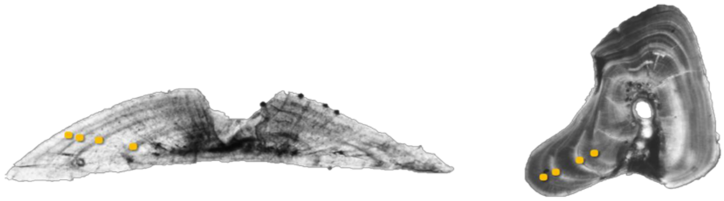


Diagram showing the position of the otoliths and dorsal spine in a black bass



The sectioned otolith and dorsal spine from a four year old mangrove jack, a close relative of black and spot-tail bass

Because a dorsal spine can be easily clipped from live fish before release, anglers and tour operators can provide NFA with samples from a number of fish from each river fished each year so that managers can monitor the populations.

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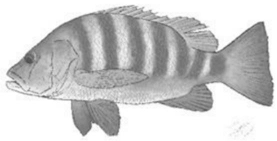
Fact Sheet 13: Acoustic telemetry: How it works

Sustainable Management of Sport Fisheries
for Communities in Papua New Guinea



Fact Sheet 13: Acoustic Telemetry: How it Works

Acoustic tracking provides long-term information on animal movements and habitat use. It can also be used to investigate activity patterns, energy expenditure and survival of fish after catch and release.

How acoustic telemetry works

Acoustic transmitters send a unique identification number (coded) to acoustic receivers deployed in the aquatic environment. These transmitters are either surgically implanted into an animal or attached to the surface of the animal. The acoustic receivers can detect transmitters up to 600 m away, but the actual range depends on the noise and depth of the habitats where they are deployed.

Acoustic tracking entails field intensive work to deploy receivers and implant transmitters into animals, but after this initial work data can be collected with minimal effort for years. The transmitters attached to animals can just send an identification code for each animal, or may include a range of sensors, e.g. depth (pressure), temperature or activity. The battery life depends on the size of transmitter tag (the largest transmitters have a 10 year battery life) and the sensors included. For the black bass project we are using standard coded transmitters with 3 year battery life to study long-term movements, habitat use and residency patterns. We also use activity transmitters with 6 month battery life to study activity patterns, fine-scale habitat use and the behaviour of fish after catch and release.

An acoustic receiver and two transmitters of different sizes. The smaller transmitter is the type used in the Black Bass Project.

A limitation is that tagged animals can only be detected in the areas where receivers have been deployed, meaning an effective design of the acoustic array is critical. For tracking black bass in New Britain, we deployed receivers in three rivers and the coastal areas just outside the rivers (see example below). Receiver locations were mostly dictated by depth of the river, i.e. many places were too shallow.

Acoustic array design for the Pandi (P receivers) and Langa Langa (LL receivers) Rivers. Circles represent acoustic receivers. Creek is the receiver in the creek connecting the two rivers.

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Fact Sheet 14: Acoustic telemetry: Success of tagging

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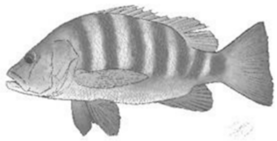
for Communities in Papua New Guinea



Fact Sheet 14: Acoustic telemetry[1]: Success of tagging

The attachment of an acoustic transmitter to a fish is either done externally or internally. Surgically implanting the transmitter is advantageous as it avoids fouling on the transmitter (which can occur for external attachments) and data are collected for the lifetime of its battery (externally attached transmitters often fall off before the battery runs out). In acoustic tracking studies where transmitters are surgically implanted (i.e. placed internally), survival of the fish after the surgery is important.

In West New Britain, we surgically implanted acoustic transmitters into 73 fish (50 black bass and 23 bpot-tail bass) in the Pandi, Langa Langa and Toriu Rivers. All fish tagged were adults or sub-adults. All but one fish were regularly detected in the acoustic array after tagging, indicating they survive the catch and tagging event. Two tagged black bass in the Toriu were captured by fisherman (one by a tourist and one by a local). The acoustic telemetry component of the study has been very successful, with millions of data points collected.

Surgically implanting an acoustic transmitter into the body cavity of a black bass.

A spot-tail bass recovering in a cage beside the boat after surgery. The fish are put to sleep for the surgery, so we wait till they have recovered before releasing back into the river.

[1] Fact sheet 13: Acoustic Telemetry: How it Works

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Fact Sheet 15: Acoustic telemetry: Movement and connectivity

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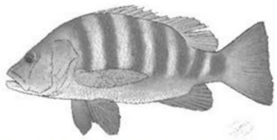

Fact Sheet 15: Acoustic telemetry[1]: Movement and connectivity

Both black and spot-tail bass move throughout the entire area monitored by the acoustic array (from the mouth to ~9 km upriver).

Black bass spend most of the time in estuarine waters, and but regularly move into the most upstream freshwater sites surveyed.

Receiver locations in the Toriu River, highlighting the rock bar receiver (T6). Both black bass and spot-tail bass moved between T1 and T8.

Spot-tail Bass spend most of their time in freshwater, but move into estuarine waters at times. In the Toriu River Spot-tails spent most of time at the upriver receiver (~9 km upriver). The rockbar receiver (~4.5 km upriver) at the interface between fresh and saltwater under normal river flow, was the downriver limit for many of the spot-tails detected. In contrast, Spot-tails in the Pandi River spent a greater proportion of the time in the downstream section of the river. This coincides with the fresh/saltwater interface being much closer to the mouth at the Pandi River.

Many black bass moved between the Pandi and Langa Langa, mainly via a small connecting creek. This demonstrates that apparent different systems can function as one unit even when only minor connections exist, indicating that care is needed to ensure that whole systems used by bass are managed as one unit.

Example of a black bass moving from its tagging location in the furthest arm of the Langa Langa River to the mouth of the Pandi River. Nineteen of the 27 Black Bass tagged in the Pandi/Langa Langa Rivers moved between rivers.

[1] Fact sheet 13: Acoustic Telemetry: How it Works

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Fact Sheet 16: Villagers' perspectives on livelihoods and sportfishing

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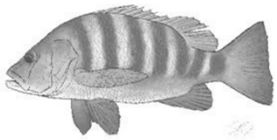

Fact Sheet 16: Villagers' perspectives on livelihoods and sportfishing

Household level survey interviews, conducted in three communities (Baia, Vesse, Somalani) in West New Britain, where sportfishing currently occurs, highlighted important differences in perceptions of Quality of Life (QOL) and the drivers of change.

Satisfaction with quality of life (QOL)

- Overall, people from Baia were very satisfied with their QOL, with the majority of people having seen big improvements over the last 10 years.
- In the villages of Vesse and Somalani the level of satisfaction with their QOL was lower with 40% of people feeling it could be improved.
- Villagers in Baia placed the highest importance on the food they were able to collect from the water and land, on their health and that of the environment. While Somalani and Vesse people felt that education and finding a paid job at the highest importance.

What can be done to improve QOL in the village

- All villages agree that QOL could be improved by cooperation, sharing and trust, more income opportunities, better education, infrastructure and health facilities.

Changes in the last 10 years

- All villages said that most changes had been positive, this included better education, health, church, roads and transport, housing, water tanks, increased income
- Baia people believed that most positive changes came from sportfishing tourism, and the provincial government
- Somalani people believed that most improvements arose from hardworking individuals, education and paid work with logging companies
- Vesse people believed that that most improvements arose from sportfishing tourism, logging companies and oil palms companies.

Most important activities in the household

There are some differences in importance of different activities between the villages. However, growing crops and fishing were amongst the two most important activities in all villages.

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Fact Sheet 17: Sportfishing as an alternative livelihood in the Pacific

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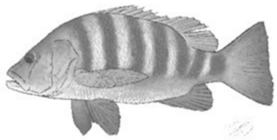
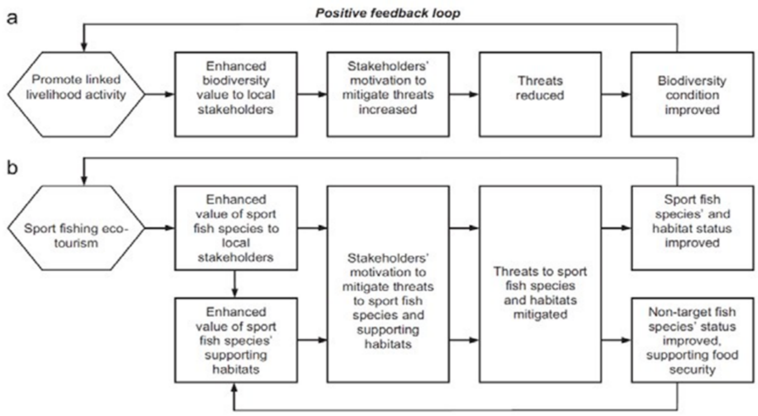


Fact Sheet 17: Sportfishing - An alternative livelihood strategy in the Pacific

Rural communities in the Pacific regions often rely on fishing as a source of protein and income. However high population growth rate and climate change are placing high stress on local fish stocks, therefore developing alternative livelihood strategies is becoming a necessity.

Sportfishing as alternative livelihood

Sportfishing is the recreational catch and release for particular species of predatory game fish, which has the potential to be a successful livelihood strategy. Differently from other industries, sportfishing can provide income for locals while protecting the ecosystem.



Conceptual representations of (a) the enterprise approach to integrated conservation and development, and (b) the double linkage between conservation of target sport fish and non-target species and their habitats, and livelihoods development created by a community-based sport fishing ecotourism (Source: Wood et al. 2013)

Principles for success

- Adequate local capacity and co-management
- Clearly delineated resource-ownership
- Governance arrangements which ensure even dispersal of benefits
- Social, biodiversity and ecosystem service co-benefits
- Monitoring and evaluation within an adaptive co-management framework

Reference

Wood AL, Butler JRA, Sheaves M, Wani J (2013) Sport fisheries: Opportunities and challenges for diversifying coastal livelihoods in the Pacific. Marine Policy 42: 305-314

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11.2 Appendix 2: Briefing Reports

Briefing Report 1: Profile of PNG's Black Bass sportfishery

1

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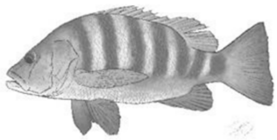

Briefing Report 1: Profile of PNG's Black Bass Sportfishery

Papua New Guinea's Black Bass Sportfishery is a high value, largely catch-and-release fishery that caters for high paying overseas guests. The fishery is based on the endemic Black Bass, *Lutjanus goldiei*, a large, hard fighting sportfish that has a distribution mainly confined to PNG. In some areas, like New Britain, a second species of large freshwater snapper the Spot-tail Bass, *Lutjanus fuscescens*, is also an important target. Both these sportfish grow to very large sizes (over 20kg) in rivers and estuaries providing unique fishing experiences for anglers.

Interviews and discussions with sportfishing operators, guides and customers yields extensive information about the Black Bass sportfishery.

A lure-caught black bass from the Pandi River, New Britain

Operation of the fishery

The fishery is conducted from small fibreglass or aluminium dinghies (4.5-6m long), with fish usually caught by lure casting, trolling or baitfishing, although some anglers employ fly fishing. A fishing party usually consists of 4 or more anglers, but usually no more than 2 fish in each boat. Each boat is operated by an expert guide, with the experience enhanced for the anglers if this guide is a local expert. Fish are generally released once they are caught, with the trained guide handling and releasing the catch.

Potential for expanded local involvement

At the moment most sportfishing ventures are operated by experienced national or international business men. However, the relatively small scale of operations and costs of equipment means there is potential for individual villages to develop their own operations. In some operations, local village people operate as highly skilled guides and direct the day-to-day operation of infrastructure such as guest lodges. Substantial training would be required to enable more extensive local involvement, including more detailed training in on-ground aspects such as guiding, cooking and hospitality, and in various aspects of business/tourism development, business management and logistics (Wood et al. 2013). Key equipment needed includes boats and fishing gear, appropriate transport to and from the site, and wilderness lodge-style accommodation.

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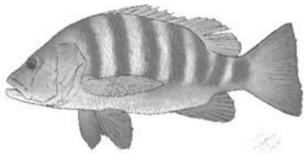

Advantages of the industry

There are many potential advantages to locally operated sportfishing ventures (Wood et al. 2013). The opportunity for extensive local involvement means sportfishing can provide a viable, cash producing livelihood for local people. Beyond this there are fisheries and environmental advantages. The current study has shown that released Black and Spot-tail Bass have very high survival rates so, if based catch-and-release principles, Black Bass sportfisheries should produce minimal mortality on target stocks. The presence of a sportfishery that relies on catch-and-release, and on fish stocks that require high quality habitats, provides substantial incentive to support ecosystem sustainability.

Risks and Management

Acoustic tagging Black Bass in the Pandi R., New Britain, from a sportfishing dinghy

Economic viability of Black Bass fisheries relies on a high quality fishing experience. This in turn depends on heathy fish stocks, which in turn depend on heathy ecosystems and access to appropriate spawning and nursery areas. Consequently, the sportfishery is vulnerable to overfishing and destructive fishing, declining water quality, loss of critical habitat, loss of connectivity between key habitat components (feeding, refuge, spawning and nursery areas), and degradation of food webs. The risks are high because little biological, ecological or fisheries data exists for either of the key species on which the industry relies (Sheaves et al. 2016).

Detailed science-based management is urgently needed to prevent damage to the resource and ensure its long-term sustainability. However, in addition to management of the fish and their environment, there is a need for appropriate management of the business and tourism operations, and for appropriate governance arrangements to ensure the equitable dispersal of benefits to all members of the local community (Wood et al. 2013).

One potential issue relates to the amount of fishing that can be imposed on a Black Bass fishing location while still retaining high catch rates. A number of current operators already limit the number of trips to each river in response to observations that catch rates decline as fishing intensity increases. This effect also means that their operations tend to migrate to new areas, increasing business costs and potentially reducing the long term viability of operations in any single location. The decline in catchability does not seem to stem from poor survivorship of captured fish; acoustic tagging studies show that post-release survival of carefully handled fish is close to 100%. Consequently, as long as

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fishing operations are well managed, and release rates are high, the fishery should have little impact on stocks. Although the reason for the observed decline in catchability is unknown it does indicate the need for diversification of operations to help maintain catch rates.

Options for diversification

There are a number of options for diversification of current Black Bass sportfishing operations that would provide resilience to the business and reduce the angling pressure on the resource. Some of these alternatives are already being employed to some extent but usually in a minor way incidental to the core business. For instance, various species of trevally (Canangidae) are regularly captured during Black Bass fishing operations, and oceanic pelagics are often targeted during travel to Black Bass rivers. These species are abundant across most of PNG's coastal waters so the potential exists to develop fisheries that explicitly have a broader focus. Key options for diversification largely stem from PNG's abundant fauna of unique species. Most of these are fish not found in the angling tourists home country, or not found in abundance or large size. Options such as providing trips that target a 'grand slam' of say 10 highly esteemed sportfish (with Black and Spot-tail Bass just two of the options) or providing trips where the anglers explicitly aim to catch as great a diversity of species as possible are options that are highlighted repeatedly during angler interviews, and appeal particularly to fly fishers and anglers who specialise in using light tackle.

A Giant Trevally, one of the high value sportfish that are bycatch in the Black Bass fishery.

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Wood A, Butler J, Sheaves M, Wani J (2013) Sport fisheries: opportunities and challenges for diversifying coastal livelihoods in the Pacific. Marine Policy 42:305-314

Briefing Report 2: Critical Black Bass habitat

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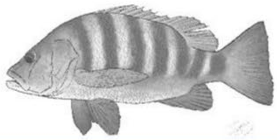


Briefing Report 2: Critical Black Bass Habitat

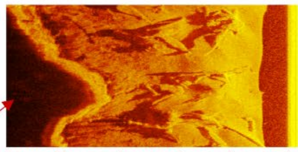
Papuan Black Bass (*Lutjanus goldiei*) are found throughout PNG's freshwaters and low salinity estuary systems, including both fast-flowing rivers and low salinity coastal swamps. A second species, the Spot-tail Bass (*Lutjanus fuscescens*), is absent from some mainland areas but common on islands like New Britain. These species form the core of a high value sportfishing industry.

Extensive underwater video surveys were conducted in the Baia/Open Bay area of New Britain to determine the habitats used by Black and Spot-tail bass, with all available habitats investigated.

Adult Black and Spot-tail Bass Habitats

As with other tropical snappers (Sheaves 1992) adults of both Black and Spot-tail Bass were closely associated with a range of structurally complex habitats that provided shelter, feeding and resting sites. Among the key habitats were:

- Submerged timber (snags) washed in from bankside forests
- Fallen trees resting in the water
- Submerged rock bars
- Flooded vegetation such as grass and leaves
- Mangrove forests
- Floating vegetation
- Rafts of floating debris accumulated on snags



Sidescan sonar view of large submerged trees (to 20m long)

Fallen bankside tree covered with vines

Sidescan sonar view of submerged rock bar (40m long)

Flooded bankside pit-pit grass (*Miscanthus floridulus*)

A surface mat of Kangkong (*Ipomoea aquatica*) and floating timber

Nypa fruticans mangrove palm forest

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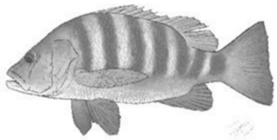


Juvenile Habitats

Most tropical snapper species have a life-cycle that includes one or more nursery habitats (Lindeman et al. 2000) – places separate from the adult population where juveniles spend their vulnerable early stages. These habitats are critical to the development of the individual, providing a bridge from larval to adult ways of life. The availability of nursery habitat is often a limiting factor in population size – a bottle neck that determines survival from larvae to adult.

Black Bass

Juvenile black bass (*Lutjanus goldiei*) have specialized nursery ground requirements. In the New Britain study area, young juveniles were found in slower flowing fresh water locations, such as the shallow edges and side arms of rivers. In these areas they are found exclusively in and around aquatic and partially submerged riparian vegetation. Key habitats include:

- Stretches of bank dominated by tall grasses with floating root mats, such as pitpit grass (*Saccharum edule* and *Miscanthus floridulus*);
- Areas dominated by floating mats of kangkong (*Ipomoea aquatica*);
- Banks with tree roots and over-hanging riparian vegetation;
- Areas with large beds or mats of submerged aquatic vegetation.

Flooded bankside pit-pit grass

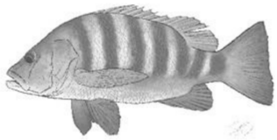
In the study areas, young juveniles (0-1 yrs) inhabit shallow water areas containing these habitats exclusively and are not found in the same habitats used by adults. Older juveniles use a broad range of habitats including the same areas as used by young juveniles, as well as deeper bank habitats in rivers. They also move into estuaries, using a range of adult habitats there.

Habitats used by black bass at different life-history stages

Juveniles	Late juveniles/ sub-adults	Adults

Shallow areas (<0.5 m) containing:
- grass root mats
- mats of floating water plants
- tree roots
- overhanging vegetation
- submerged plants

Deeper areas >0.5 m containing:
- snags and snag complexes
- rock bars
- overhanging vegetation
- mats of floating water plants
- rafts of accumulated debris



Rivers have not been surveyed extensively further than 5km upstream of the mouth. It is likely juvenile black bass occur further upstream, and the exact nature of the habitats they use in these areas is currently undetermined.

Spot-tail Bass

Juvenile Spot-tail bass (*Lutjanus fuscescens*) do not appear to have specialized nursery requirements in the areas that have been surveyed. As with adults, juveniles use complex woody debris habitat. While they can be found along-side adults, juveniles also use woody debris in shallower water, outside the depth range favoured by adults.

References

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Briefing Report 3: Black Bass size, age and reproduction

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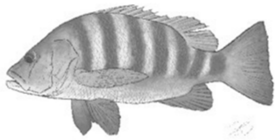


Briefing Report 3: Black Bass Size, Age and Reproduction

Size, Age, and Reproduction

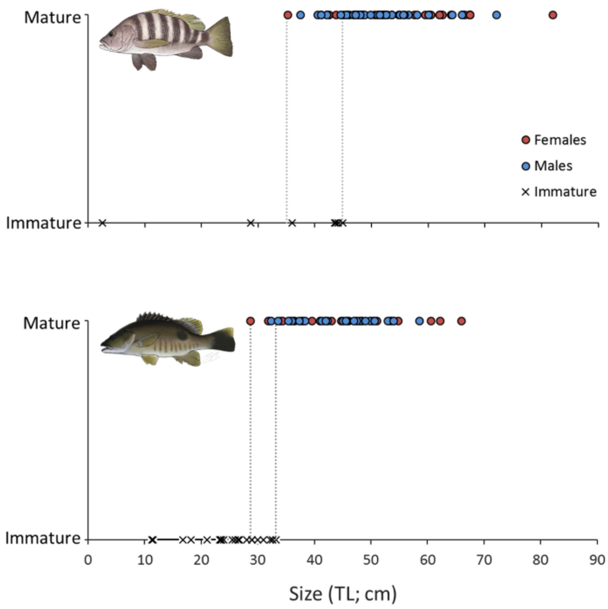
Growth rates and the age at which fish first breed are important parameters used by management to sustainability regulate fisheries. This is because fast-growing species that breed young can generally sustain heavier fishing pressure than slow-growing, late-breeding, species. By examining the size, age and reproductive condition of black and spot-tail bass collected at various times of year, we determined the size and age at which fish typically mature, and the time of year that they breed.

A ripe black bass captured in the Langa Langa River.

Age at maturity

Female black bass ranged from 35 to 82 cm, males from 37 to 72 cm, and immature individuals from 2.5 to 45 cm. Most mature individuals were larger than 40 cm in length, and data suggests that black bass start to mature at around 35 cm, and that most fish are mature by ~45 cm. Approximately 45 cm is also the minimum size typically caught in the fishery.

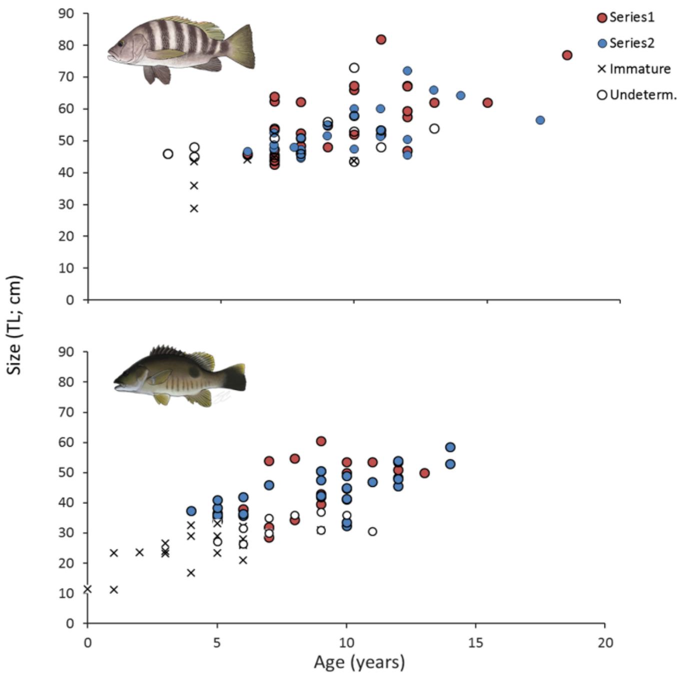
Spot-tail bass mature at smaller sizes than black bass, and all fish larger than 33 cm were mature.



Black bass size at maturity from rivers around Baia, West New Britain.

Size is a poor indication of age

Black and spot-tail bass vary widely in size at age. For example, we found black bass around 46 cm in length to range in age from 3 to 12 years. These are amongst the smallest bass captured in the sport fishery. This means a small fish is not necessarily a young fish, and that the presence of small fish might not indicate successful recruitment of young fish to the population. Because small fish can be quite old, recruitment failure could go unnoticed for a decade before the lack of small fish became apparent.



Size-at-age plots for black bass (top panel) and spot-tail bass (bottom panel) from the rivers around Baia, West New Britain. Fish ages are based on counts of yearly rings (annuli) in sectioned sagittal otoliths.

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The largest black bass examined was a 82 cm female, estimated to be 11 years old, while the oldest individual was a 77 cm fish estimated to be 18 years old. The second-oldest black bass sampled was 17 years and only 57 cm long. Only two black bass <40 cm were aged, a 29 cm and a 36 cm fish, and both were estimated to be 4 years old. Spot-tail bass also show a wide range of length at age. Fish around 30 cm long ranged from 5 to 11 years old. The oldest spot-tail bass sampled were two fish estimated at 14 years old, one 53 cm and the other 59 cm, while the largest fish was a 61 cm individual aged at only 9 years old.

Despite growing to large sizes (>20kg) black bass appear to have similar growth and maturity to similar species of tropical snappers such as mangrove jack (Russell & McDougall 2008), reaching maturity at 35-45 cm in length and 6-7 years old. Spot-tails seem to mature earlier, at around 4-7 years old and 30-35 cm in length.

However, both species also showed a wide range in maturity-at-age, e.g. the youngest mature black bass were 6 years old, while the oldest immature individual was 10 years old, and for spot-tail bass the youngest mature individual was only 4 year old, and the oldest immature fish was 9 years old. The smallest mature spot-tail was a 29 cm, 7 year old female, and the smallest mature male was a 32 cm, 10 year old fish.

This 46 cm black bass was 12 years old. Very few black bass smaller than this are captured in the fishery, meaning the smallest fish can be quite old. The capture of small fish does not mean that young fish are successfully renewing the population. It is essential to monitor the age structure of the populations to ensure a good supply of young fish are successfully arriving to sustain the population.

This new understanding of bass size at age highlights the importance of monitoring population age structure to ensure that successful recruitment of young fish is continuing. A lack of new recruits would indicate some impact on the population that may lead to collapse if left unchecked.

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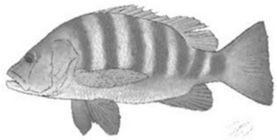
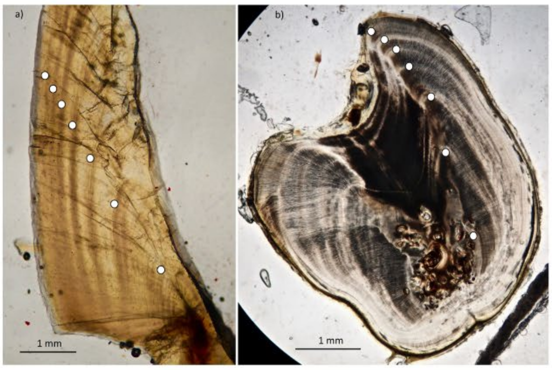
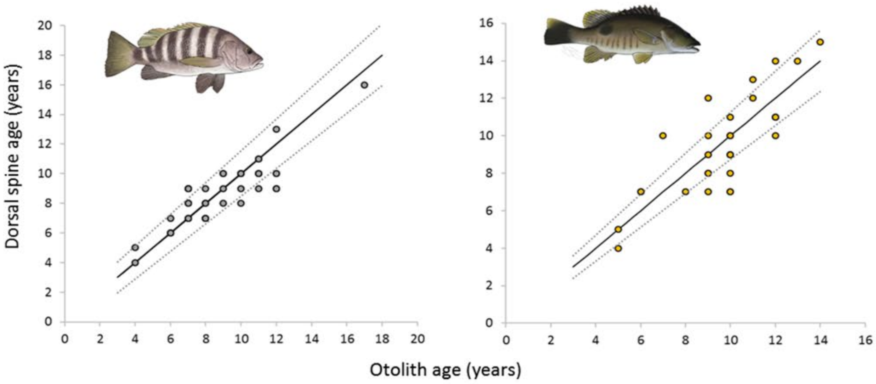


Non-lethal aging of bass

Black bass can be aged from sections of their dorsal spines (Freddi 2015). Although the age estimates are not as accurate as those obtained from otoliths, they provide age estimates accurate enough to distinguish young fish from old, and healthy populations from recruitment-limited ones. In addition, collecting dorsal spines is non-lethal as they can be clipped from fish to be released, while collecting otoliths requires the fish to be killed. As such, dorsal spines represent a relatively cheap and sustainable means of monitoring population age structure, and could rely on samples provided by anglers and tour operators. The image below is of the sectioned otolith and dorsal spine from a 4 year old mangrove jack (*Lutjanus argentimaculatus*), with the yellow dots indicating the visible increments in each structure.



Images of sections of a) otolith, and b) base of second dorsal spine of a 64 cm TL black bass, with seven annuli visible in each structure as indicated by white dots.



Comparison of otolith and dorsal spine base-section age estimates for black bass and spot-tail bass, showing the close correspondence between the two estimates.

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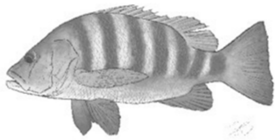
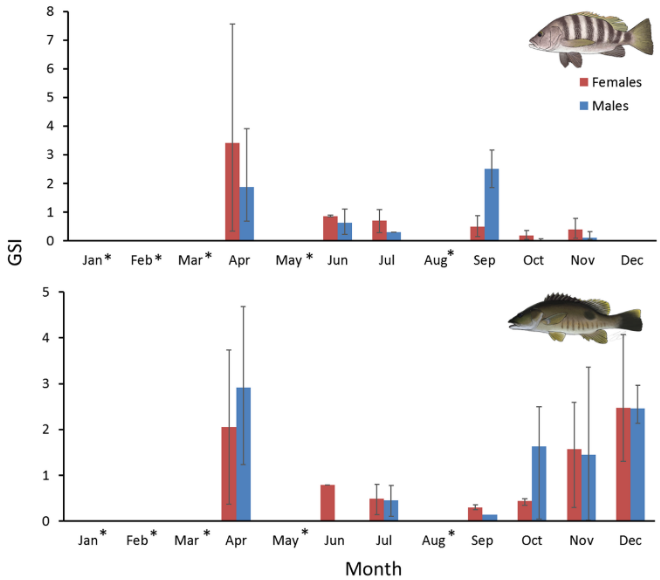


Spawning season

Due to the difficulty in site access during the wet season, few fish were collected between December and April. At least some individual black bass appeared to be close to spawning condition through most of the sampling months. There was clear trend in gonad size, as the gonadosomatic index was highest in fish collected in April, declining to a low towards the end of the year, at least until November. This suggests peak spawning period is some time during the wet season or at the end of the wet in April, perhaps extending into June. Spot-tail bass start spawning earlier in spring. Some fish were in spawning condition in October and many fish in spawning condition in November, December and April, and a minimum gonad size in July. This suggests that spot-tails also have a peak spawning season throughout the warmer summer months. Note however that these interpretations must be treated with caution as no fish were collected between January and March in any year, and no black bass were collected in December. However, given the consistent trends seen from year to year, with gonad size increasing into the summer, and declining from highs in April through to the winter/late dry season, this is consistent with peak spawning through the summer/late wet season for both species.



*Seasonal changes in black bass gonad size, measured as gonadosomatic index (GSI) which is gonad weight as percentage of body weight. Data are mean GSI by month and bars represent range in GSI. * - months for which no data was collected.*

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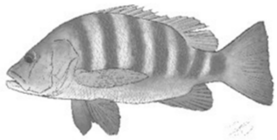

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Briefing Report 4: Black and Spot-tail Bass diets

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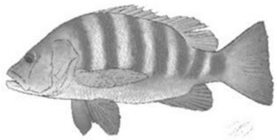
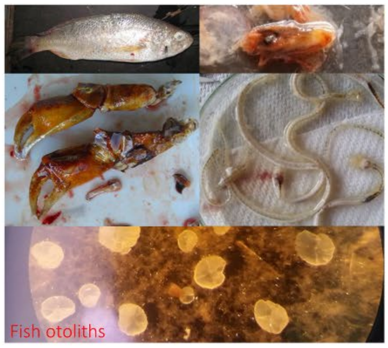


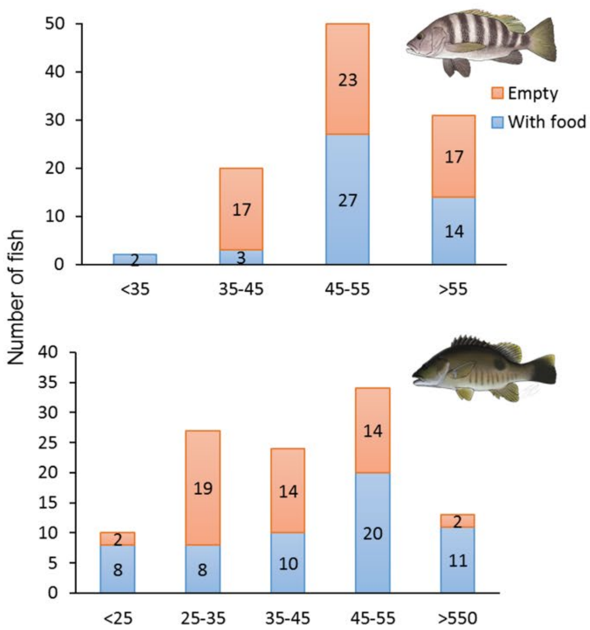
Briefing Report 4: Black Bass Diets

Stomach content analysis

The stomach contents of 106 black bass and 82 spot-tail bass were examined. A large proportion of the fish had empty stomachs, suggesting that individual fish do not feed continuously, but have periods of high and low feeding activity. As for other tropical snappers, the diets of black and spot-tail bass are dominated by crustaceans and fish (Sheaves et al. 2016), but the exact composition differs between the two species. Fish were more important for black bass diets, while freshwater shrimp were more important for spot-tail bass.



Some prey items found in black bass stomachs.



Size-structure of black bass (top) and spot-tail bass (bottom) examined for stomach contents, showing that a large proportion of fish had empty stomachs.

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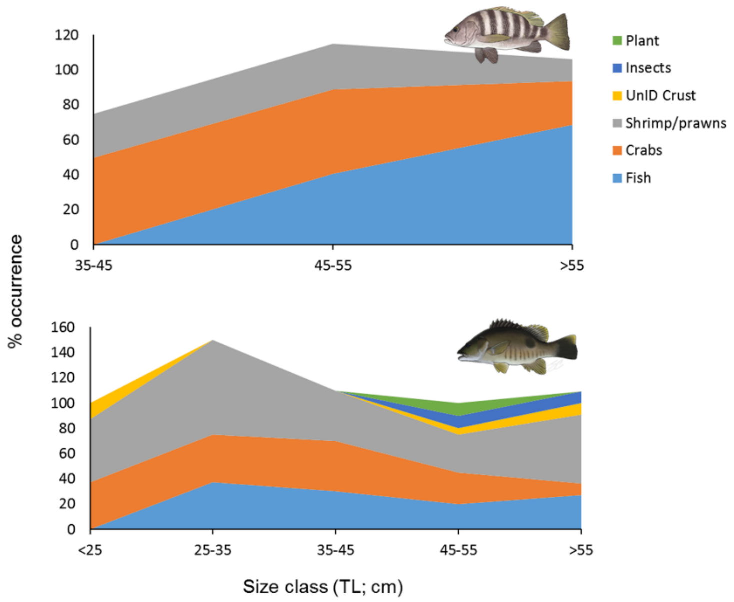
Smaller black bass (35-45 cm TL) feed mostly on crabs and shrimp/prawns, and as they grow fish becomes increasingly important in their diet, and the importance of crabs decreases. For spot-tail bass, smaller individuals (<25 cm TL) feed mostly on crustaceans such as palaemonid shrimp and crabs, and larger individuals (>25 cm TL) also feed on fish. Other foods such as terrestrial insects and plant material were also consumed only by larger individuals (>35 cm).



Black bass (top) and spot-tail (bottom) diet composition, per size class. Data are % occurrence, i.e. the proportion of stomachs containing each prey type, as a percentage of total stomachs containing at least some food.

Note however that our understanding of black bass diet is limited to medium-large fish, with only two individuals smaller than 35 cm were examined for stomach contents. Over half of the black bass examined had empty stomachs.

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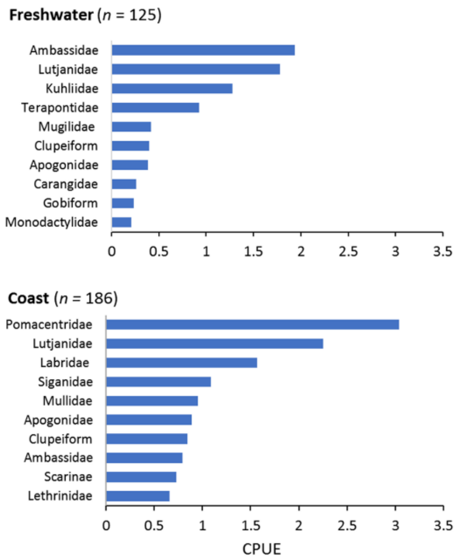
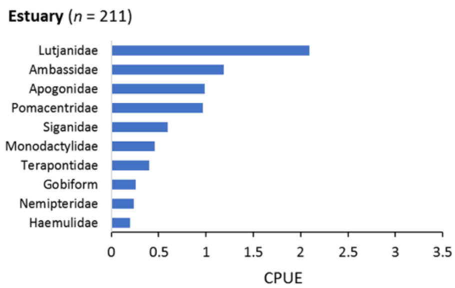
Prey availability

The relative availability of the different fish prey was estimated for each process zone (freshwater, estuary and coast) based on underwater video surveys. In freshwater, the most abundant fish prey were glassfish (Ambassidae), snappers (Lutjanidae) and flagtails (Kuhliidae) and freshwater grunters (Teraponidae); in estuaries, snappers were the most abundant, followed by glassfish, cardinalfish (Apogonidae) and damselfish (Pomacentridae). In coastal habitats, damselfish dominated the assemblage of potential prey, followed by snappers and wrasses (Siganidae).





Relative availability of the top 10 families of fish prey found at each process zone (coast, estuary and freshwater), based on underwater video survey data. Catch per unit of area (CPUE) was calculated for each family as the sum of the maximum number observed for each process zone divided by the number of samples per process zone.

Briefing Report 5: Sources of nutrition supporting Bass populations

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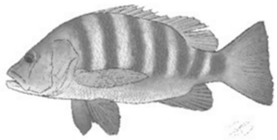


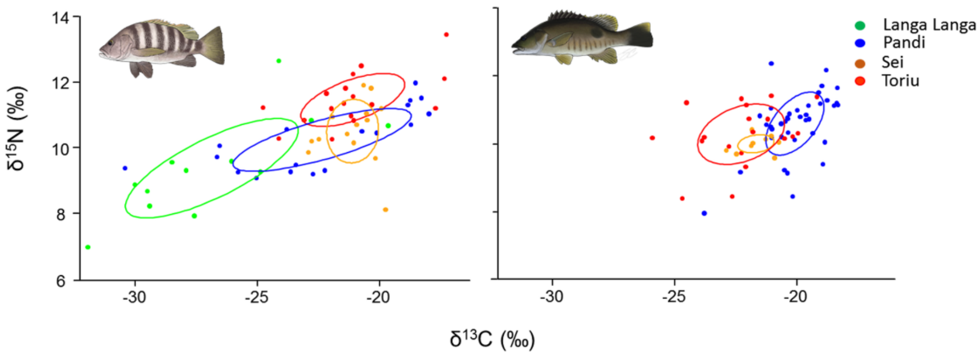
Briefing Report 5: Sources of nutrition supporting bass populations

Stable isotope analysis

Stable isotope analysis can be used to determine the main diets and main habitats used for foraging, when different diet/habitats have different stable isotope composition. Here, the stable isotope composition of 64 black and 66 spot-tail bass was measured, along with primary consumers and >400 fish and invertebrate prey to identify the main sources of nutrition.

In general, black bass had a wide variability in stable isotope composition. This suggests a wide variability in dietary sources and/or in different areas/habitats that provide nutrition, i.e. that different individuals rely on different prey and/or habitats.

Spot-tail bass had smaller isotopic niches, suggesting a less varied diet and/or a more specific range in habitats used.



Stable isotope composition (dots) and standard ellipses (SEAs) of black bass and spot-tail bass found at the four main study systems. Standard ellipse areas contain ~40% of the data and represent the isotopic niche widths, a proxy for dietary niche sizes, i.e. for dietary variability. So, larger SEAs indicate a more varied diet while smaller SEAs represent more specialised feeding. Since different habitats can be characterised by different stable isotope composition, isotopic niches are also indicative of the variability in habitats used by the different individuals within the population.

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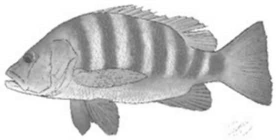
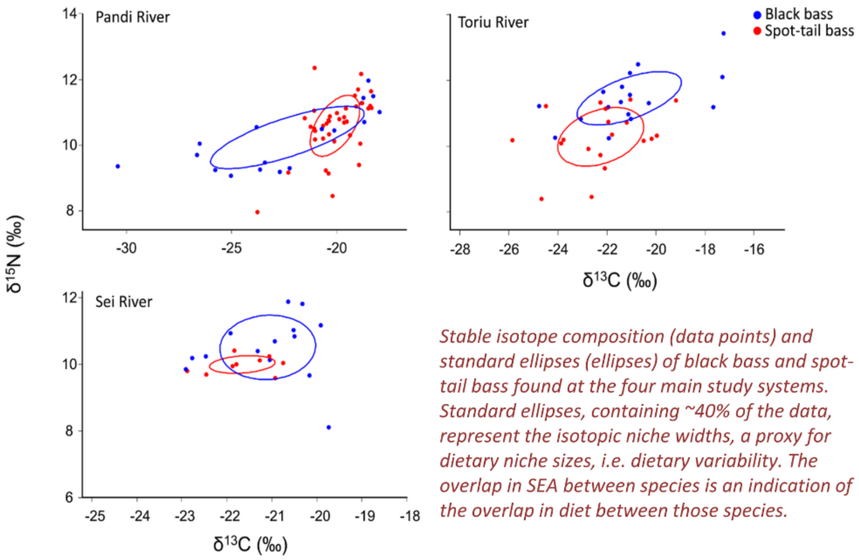


$\delta^{13}C/\delta^{15}N$ overlap between black bass and spot-tail bass

Stable isotope data also suggests a small overlap in diet/habitat between the black and spot-tail bass populations within the same river. At the Toriu and Sei Rivers, black bass tended to have higher $\delta^{15}N$ than spot-tail bass, suggesting a higher trophic level. This is in agreement with the stomach content study (see Briefing Report 4), which showed fish are more important to black bass than to spot-tail diets, and that invertebrates such as crustaceans are more important to spot-tails.



Stable isotope composition (data points) and standard ellipses (ellipses) of black bass and spot-tail bass found at the four main study systems. Standard ellipses, containing ~40% of the data, represent the isotopic niche widths, a proxy for dietary niche sizes, i.e. dietary variability. The overlap in SEA between species is an indication of the overlap in diet between those species.

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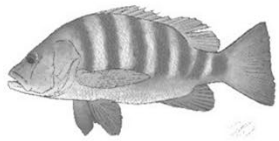
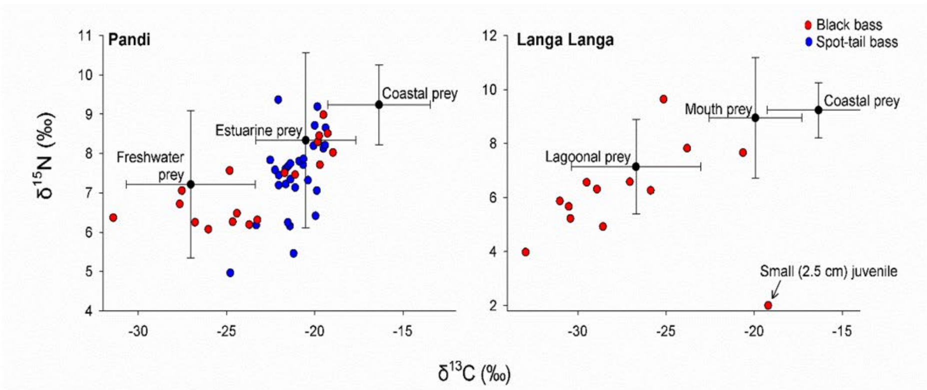


Sources of nutrition

The Pandi River provided the best conditions to allow the identification of habitats used by black bass for feeding, as it was the only system where there were strong enough differences in δ^{13}C between prey from the freshwater and estuarine/marine environments. In the Langa Langa, there were also sufficiently large differences in prey δ^{13}C between the mouth of the estuary and the interior of the lagoonal system, that would allow the identification of the main feeding environments. At both these sites, different black bass individuals had different δ^{13}C, from values that indicate feeding mostly in more upstream habitats to values that suggest feeding primarily in the estuary mouth, including values in-between, that suggest that fish feed on a mixture of prey from different habitats. This variability also suggests that different individuals specialise their feeding on particular habitats and/or prey. For the Pandi River, despite the short estuary and the extent of black bass movements throughout the landscape (Briefing Report 7), over half of the black bass analysed had δ^{13}C that suggest feeding almost exclusively on estuarine prey.



Stable isotope composition (δ^{13}C and; corrected for trophic fractionation) of black and spot-tail bass individuals captured at the Pandi and Langa Langa Rivers. δ13C values of potential prey groups found at each main habitat are also indicated (mean ± SD), calculated based on the average values of the different potential prey species. The similarity between δ^{13}C/ δ^{15}N of bass and of prey is an indicative of the importance of that prey group for bass diet. For example, no fish had stable isotope composition close to coastal prey, suggesting that coastal resources are not important for bass diet. On the other hand, for the Langa Langa black bass some results suggest that some individuals rely mostly on freshwater prey, while other rely mostly on estuarine prey.

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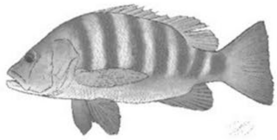


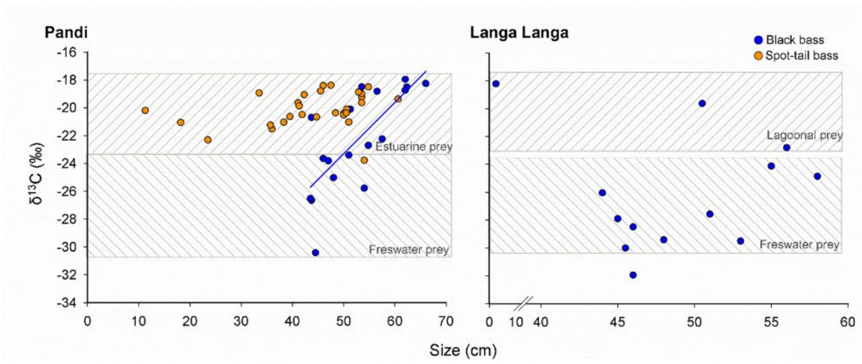
Changes in δ13C/ δ15N with size

δ13C

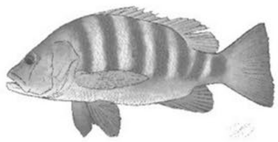
For black bass from the Pandi, smaller fish tended to have lower $\delta^{13}C$ than larger individuals, with values that suggest that, as they grow larger, black bass tend to become more associated to estuarine habitats. Note however that a limited range in black bass sizes was analysed at that site (43-66 cm) and that no smaller fish were analysed.

For spot-tail bass, there was no relationship between fish size and $\delta^{13}C$, despite that a wider range in sizes was analysed. This suggests a more limited range of prey/habitats used throughout the life-cycle.

Although in the Pandi River spot-tail bass $\delta^{13}C$ overlapped mostly with estuarine prey, it is possible that those values resulted from feeding on a combination of the sampled freshwater prey and of prey that feed on pit-pit grass (which had $\delta^{13}C$ of -13‰), although those prey were not sampled.

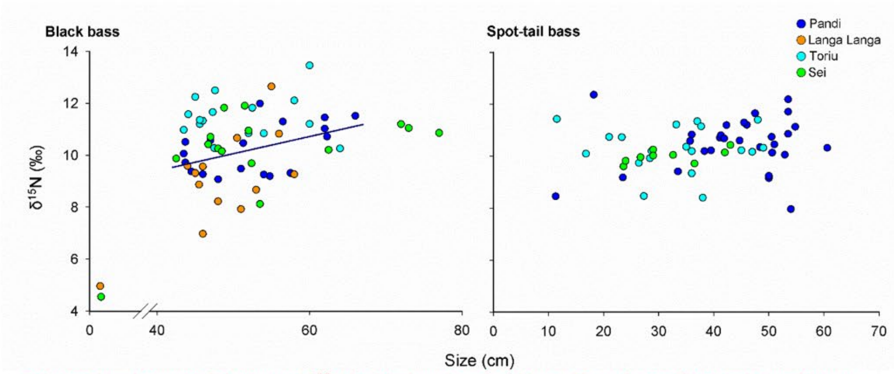


Relationships between fish size and $\delta^{13}C$ for black and spot-tail bass found at the Pandi and Langa Langa Rivers. $\delta^{13}C$ values of potential prey groups found at each main habitat are also indicated by grey dashed boxes (representing ±1 SD around the mean). Solid blue line represents a significant relationship ($p < 0.05$).

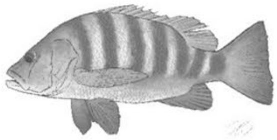


δ15N

Regarding $\delta^{15}N$, for most sites, there was no relationship between bass $\delta^{15}N$ and size. This indicates that, for the size ranges considered (~40-80 cm for black bass; ~10-65 cm for spot-tail bass), there is no increase in trophic level with size. Only for black bass from the Pandi there was a significant relationship. However, this relationship likely resulted from a shift from predominantly freshwater to predominantly estuarine prey as fish grow, as suggested by $\delta^{13}C$ (see figures above), and not due to an increase in trophic level.



Relationships between fish size and $\delta^{15}N$ for black and spot-tail bass. The only significant relationship was for black bass from the Pandi ($p < 0.05$). Note that the two smallest black bass individuals were not included in regression calculations.

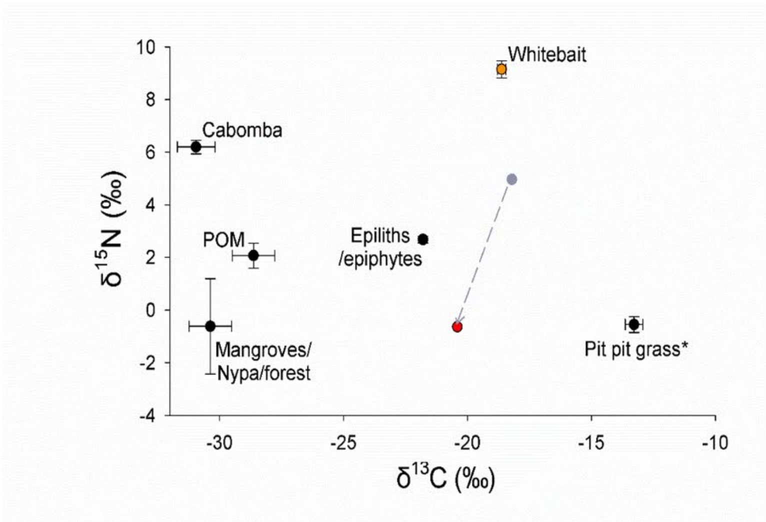


Small juveniles

Only two small (2.5 and 2.7 cm) black bass juveniles were captured throughout the study, one from the Langa Langa and one from the Sei River mouths, both captured in November 2016. Those fish had very similar stable isotope composition ($\delta^{13}C$: -18.2‰ and -18.3‰; $\delta^{15}N$: 5.0 and 4.5‰).

No other consumers had stable isotope composition close to these fish. Indeed whitebait had δ15N values much higher than those of the small black bass (9.1‰), suggesting that black bass that size are not do not share the same food sources with white bait, i.e. that they don't rely on marine/estuarine plankton.

Small (2.7 cm) juvenile black bass captured at the Sei River. Photo by R. Baker.



*Stable isotope composition of small (2.5 cm TL) black bass and potential sources of nutrition (black symbols) for the Langa Langa system. For black bass, both measured $\delta^{13}C/\delta^{15}N$ (grey symbol) and $\delta^{13}C/\delta^{15}N$ corrected for trophic fractionation (red symbol; while considering those fish to be of trophic level 3 and trophic discrimination factors of +1 for $\delta^{13}C$ and +2.8 for $\delta^{15}N$; McCutchan et al. (2003)) are shown. Whitebait is also presented for comparison (orange symbol). * - also includes samples collected at other sites.*

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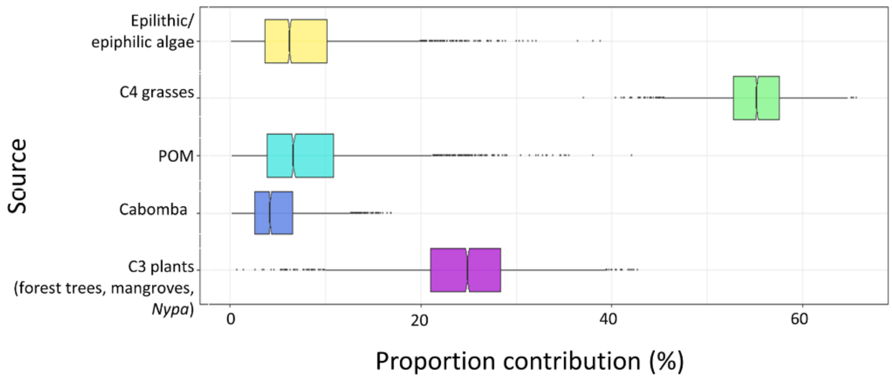
Bayesian mixing models suggest that C4 grasses such as pit-pit are the most important sources of nutrition for small juveniles, and that riparian vegetation such as forest trees, mangroves and *Nypa* also have some importance.

This stresses the importance of riparian vegetation for the resilience and conservation of black bass populations.



Mixing model results on the relative contribution of the primary producers to small black bass nutrition. Results show that C4 grasses such as pit-pit grass have the greatest importance, followed by riparian plants such as forest and mangrove trees.

References

McCutchan JH, Lewis Jr WM, Kendall C, McGrath CC (2003) Variation in trophic shift for stable isotope ratios of carbon, nitrogen and sulfur. Oikos 102:378-390

Briefing Report 6: Black Bass life-cycle movement patterns

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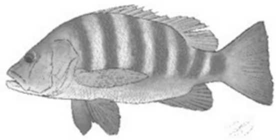

Briefing Report 6: Black Bass life-cycle movement patterns

Many members of the tropical snapper family Lutjanidae make strong ontogenetic habitat shifts through the coastal-inshore-offshore seascape during their lives (Nagelkerken et al 2000, Russell & McDougall 2005). Through these movements, individuals make use of a broad range of habitats, ecosystems, and resources to complete their lifecycle (Dorenbosch et al 2004, Nagelkerken et al 2015). The effective management of such species requires that all critical habitats used throughout the life-cycle need to be identified and protected (Sheaves et al 2015).

The Papuan black bass *Lutjanus goldiei* and spot-tail snapper *L. fuscescens* co-occur along the northern New Guinea coastline and the islands of New Britain and New Ireland in PNG (Allen 2004). Although almost nothing was known of their biology or ecology before the start of this project (Sheaves et al 2016), these two large tropical snappers appear to represent the extreme of freshwater occupation among the Lutjanidae. Sportfishers targeting these species regularly encounter individuals of >20 kg in freshwater rivers (Reimann pers comm). Until recently *L. goldiei* was considered to be almost exclusively a freshwater fish (Allen 2004), but the review by Sheaves et al (2016) confirmed individuals from small juveniles to large adults also occur in the brackish and saline parts of estuaries. There are also anecdotal reports of *L. goldiei* in coastal marine waters. Less is known about *L. fuscescens*; Fish Base calls it the Freshwater snapper (Froese & Pauly 2016), and guides and anglers report that it is the dominant species in the faster-flowing freshwater reaches of coastal streams and rivers, and is rarely captured in brackish or saline waters.

The approach

The extent of movement of individuals among components of the coastal seascape during their lives, the location of juvenile nursery habitats, adult spawning sites, and critical connectivities remain unknown (Sheaves et al 2016). Knowing what parts of the coastal seascape bass use throughout their lives allows us to understand what parts of the environment we need to manage and protect in order to ensure healthy populations of these fish to attract anglers (Barnett et al 2016). Using a technique called otolith microchemical analysis we measure the chemical composition of the ear bones or otoliths of the fish, giving us a record of movements between waters of different chemistry throughout the fish's life, such as between fresh and salty waters, or from coastal to offshore (Elsdon & Gillanders 2003).

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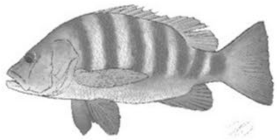
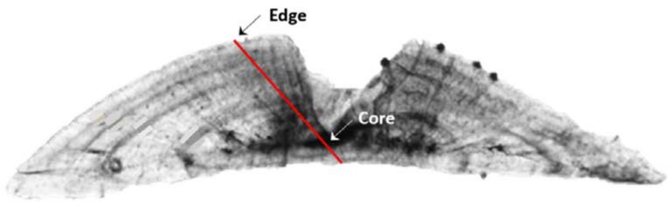
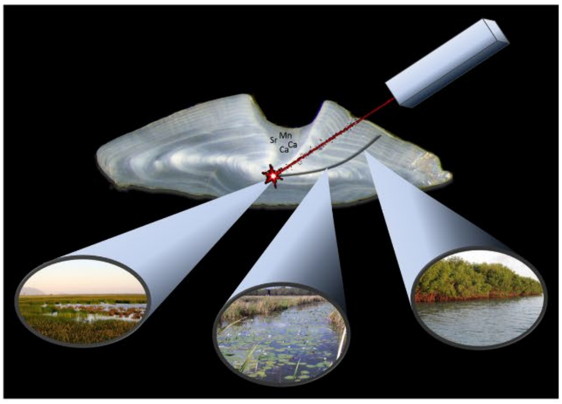


How otolith microchemistry works

Fish's ear bones or otoliths grow continuously throughout the fish's life. The material laid down to form the bone includes naturally occurring chemicals from the water the fish is living in. Different waters, e.g. fresh vs salt, turbid inshore vs. clear offshore, have different chemical compositions. We cut a thin slice through the otolith (image below), and use a laser to vaporise a line across it (indicated in red) from the core, laid down when the fish was first born, to the edge, laid down just before the fish was caught, and measure the chemical composition of the vapour. Certain elements are particularly useful for determining bass movement patterns in the coastal seascape. Strontium (Sr) is found in high concentrations in salty marine waters, and low concentration in freshwaters. Similarly, barium (Ba) is found associated with sediments washed in from the catchment, and provides a good indicator of occupation of turbid inshore waters from clear offshore waters. Together, Sr and Ba levels in the otolith allow us to determine where the fish lived at each stage during its life.





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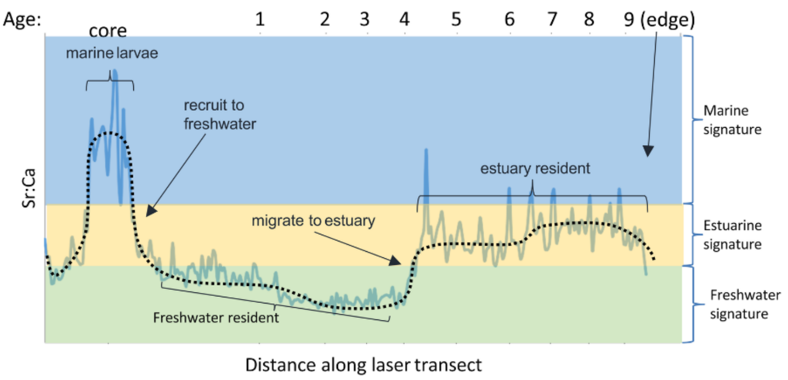
We collected otoliths from nine species of marine-resident snappers from the inshore reefs around Baia to define otolith chemistry profiles representing the continuous occupation of marine waters (represented by the blue region of the example plot below, defined by high Sr values). Likewise, we used samples from freshwater resident jungle perch and grunter to represent otolith chemical profiles for freshwater residents (the green area in the plot below, reflecting low values of Sr). The Sr values for the two reference groups of fish (marine and freshwater) were well separated, and values intermediate between them were considered to reflect occupation of brackish waters of intermediate salinity (brown area in plot below). By comparing otolith chemical profiles of each individual black and spot-tail bass to these reference values, we can determine patterns of movement through the coastal seascape during their lives.

What we learned

From the Niugini Black Bass Project we learned that black and spot-tail bass spend their larval phase in marine waters before recruiting to rivers as young juveniles. All otolith sections where we successfully hit the exposed core with the laser showed high Sr and very low Ba in the core. This corresponds to occupation of clear marine waters during the larval phase.



Otolith microchemistry profile showing life-cycle movements of a 61 cm spot-tail bass from the Pandi River. This fish was classified as a seascape migrant. It had a marine larval phase indicated by elevated strontium in the core of the otolith. It recruited to the river, moving rapidly into freshwater (low levels of Sr in freshwater) where it remained resident until 4 years of age. It then migrated into the brackish part of the river, and resided there until its capture.

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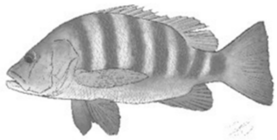

Spot-tail bass typically move straight into freshwaters and remain resident there for several years, indicated by a rapid transition from elevated Sr in the core, to low Sr immediately adjacent to it. At around the time of sexual maturity, many individuals make a distinct movement downstream to the brackish part of the rivers, indicated in the plot below as the stepped increase from low freshwater Sr values to intermediate brackish values at age 4. Although we have not yet confirmed where the spawning grounds are, observations of aggregations of these fish on the salt wedge in the estuary may be spawning aggregations, and these chemical profiles are consistent with this movement bringing spot-tail bass closer to the spawning grounds.

Black bass are more wide-ranging in their movements through the seascape. Some individuals remain in brackish waters for much of their lives, but most make staged movements between fresh, brackish and marine waters. As for spot-tail bass, black bass tend to move downstream to brackish or salty waters as they grow older, again this is probably related to accessing spawning grounds in the tidal parts of the estuary or coastal waters.

Each individual black and spot-tail bass and mangrove jack analysed with otolith microchemistry was classified into one of five life-history movement categories, based on their microchemical profiles (excluding the core, for which all fish reflected offshore larval phase). *Freshwater resident* fish were those whose entire profile (outside the core) matched with those of the freshwater resident reference fish. *Freshwater-brackish transient* fish were those with evidence of transition between FW and brackish waters, or occupation of intermediate waters which could indicate residence in areas with fluctuating but low salinity. *Seascape migrants* were those profiles showing transition between and occupation of different seascape components indicated by stepped profiles (e.g. figure above), or profiles ranging from FW to saline even if not in stepped manner. Fish with profiles showing transitions between brackish and saline waters, or occupation of intermediate waters that could reflect occupation of single area with fluctuating but high salinity, were classified as *saline-brackish transients*, while those with profiles indicating continuous occupation of high salinity waters were *saline residents*.

With marine larval phases and life-cycle distribution patterns shown in the next table, it is clear that both black and spot-tail bass range widely across the coastal seascape during their lives, from open marine water to up-river freshwater habitats. After settlement, spot-tail bass are predominantly freshwater fish, although more than one quarter of individuals showed movements into brackish/saline waters during their lives. These tended to be the larger individuals, and probably relates to moving downstream to spawning areas. Many of the smaller individuals analysed were close to the size at maturity and may not yet have spawned. Most of these fish showed profiles consistent with residency in freshwater since recruitment.

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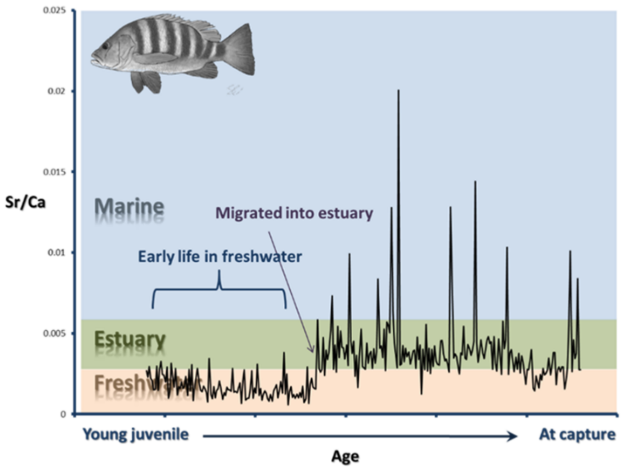
Life-history movement classifications of riverine and coastal fishes from the Pandi-Open Bay region, based on otolith microchemical profiles. Classifications excluded the core-portion of transects that reflect larval stage. Values represent the % of individuals in each category. Boxes indicate Seascape Migrants, and the thickness of the horizontal lines beneath data values indicates the general distribution of these fish during their lives.

Common name	Species	Freshwater resident	Fresh/ brackish transient	Seascape migrant	Saline-brackish transient	Saline resident	Total
Tapiroid grunter	*Mesopristes cancellatus*	100	0	0	0	0	**2**
Jungle perch	*Kuhlia marginata*	80	0	0	0	10	**5**
Spot-tail bass	*Lutjanus fuscescens*	46	24	26	4	0	**54**
Papuan black bass	*L. goldiei*	0	7	63	30	0	**57**
Mangrove jack	*L. argentimaculatus*	0	5	32	43	20	**44**
Indonesian snapper	*L. bitaeniatus*	0	0	0	0	100	**1**
Red bass	*L. bohar*	0	0	0	0	100	**1**
Blacktail snapper	*L. fulvus*	0	0	0	0	100	**1**
Paddletail	*L. gibbus*	0	0	0	0	100	**2**
Saddle-tail snapper	*L. malabaricus*	0	0	0	0	100	**2**
Samoan snapper	*L. mizenkoi*	0	0	0	0	100	**1**
One-spot snapper	*L. monostigma*	0	0	0	0	100	**1**
Tiger snapper	*L. semiscinctus*	0	0	0	0	100	**3**

Black bass range more widely than spot-tails, and tend to occupy the more brackish and saline downstream parts of the rivers. Although none had remained resident in freshwaters for their whole lives, many had spent periods resident in freshwaters before migrating downstream. For comparison, mangrove jack tended to live in the more downstream parts of the estuaries, although some individual spent parts of their lives resident in freshwaters.



Example of an OMA profile showing the life-cycle movements of a 77 cm black bass from the Sei River. This fish had a marine larval phase, indicated by high Sr:Ca ratio in the otolith core. It recruited into the river, moving rapidly into freshwater where it remained resident until ~3 years of age. It then migrated into the brackish part of the river, making occasional movements in to coastal marine waters and freshwater until its capture.

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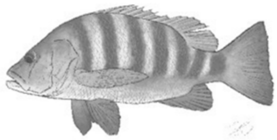

Implications

Black and spot-tail bass range widely across the coastal seascape during their lives. They use habitats from open coastal waters all the way up to freshwater parts of coastal rivers. This highlights the importance of maintaining good connectivity from the ocean through to freshwaters, of ensuring good water quality throughout the river systems, and protecting rivers and catchments throughout the coastal plains from impacts that will degrade bass habitats.

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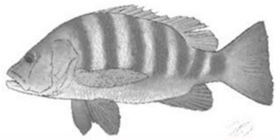
Briefing Report 7: Villagers' perspectives on livelihoods and sportfishing

Sustainable Management of Sport Fisheries
for Communities in Papua New Guinea



Briefing Report 7: Villagers' perspectives on livelihoods and sportfishing

For sportfishing to have tangible, sustainable livelihood outcomes it must provide benefits that are recognised by local people. Existing livelihoods, experiences of change, social capital, perceptions of tourism and other local characteristics will all influence people's reactions and adaptation to tourism. Household level survey interviews were carried out in three communities in the Province of Western New Britain to evaluate these qualities; at Baia, Vesse, and Somalani, villages located in the vicinity of two sportfishing lodges. The subsections below highlight some of the similarities and differences in the responses of the three villages (for full report see Diedrich et al. 2016).

Quality of life (QOL)

Background: If people are generally satisfied with their QOL then this indicates that their basic needs are being met. These conditions will favour them becoming involved in new development opportunities. However, if there are groups of people who are satisfied and others who are unsatisfied the potential exists that the benefits of sportfishing tourism may be unequally distributed (or perceived to be), which can lead to conflict within the community.

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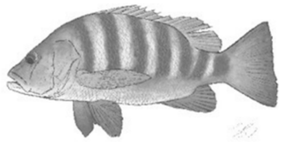

Demographic characteristics of respondents in 3 villages surveyed (Source: Diedrich et al. 2016)

Characteristic	Baia	Somalani	Vesse
Number of HH interviewed	34	68	55
% of HH interviewed	97%	100%	100%
% male respondents	65%	75%	76%
Age of respondents			
Under 21 years old	12.1%	4.4%	1.9%
21-30 years old	30.3%	20.6%	22%
31-40 years old	30.3%	25%	29.7%
41-50 years old	9.1%	19.1%	22.2%
Over 50 years old	18.2%	30.9%	24.2%
Formal education			
> 10 years	25%	40%	25%
none	9%	5%	5%

HH=household

Results:

- Overall, people from Baia people were very satisfied with their QOL, with the majority of people having seen big improvements over the last 10 years.
- In the villages of Vesse and Somalani the level of satisfaction with their QOL was lower with 40% of people feeling it could be improved.
- Villagers in Baia placed the highest importance on the food they were able to collect from the water and land, on their health and that of the environment. While Somalani and Vesse people felt that education and finding a paid job at the highest importance.

Conclusions: In Baia, social capital (e.g. trust, reciprocity and networks) was seen by most people as the most important factor for improving QOL, this indicates that conditions are favourable for equitable distribution of benefits. However, the fact that the people are focusing on this dimension could be an indicator that they feel it is in danger of breaking down; an aspect that should be kept in mind.

The value placed on income for improving QOL in Vesse and Somalani means they are likely to be predisposed to diversifying their activities into tourism development (this is also reflected elsewhere in the results). However, a focus on income over other aspects of QOL such as health, education and social capital, has the potential to promote development that does not benefit the whole community.

How people perceive change and what their expectations are for the future is a good indicator of (a) how they might respond to different types of changes in the community, and (b) the factors that are impacting on the community.

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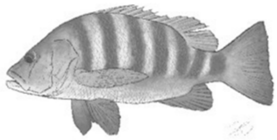


Perception of change in the last 10 years

- All villages said that most changes had been positive, this included better education, health, church, roads and transports, housing, water tanks, increased income
- Baia people believed that most positive changes came from sportfishing tourism, and the provincial government
- Somalani people believed that most improvements arose from hardworking individuals, education and paid work with logging companies
- Vesse people believed that that most improvements arose from sportfishing tourism, logging companies and oil palms companies.

Conclusions: In Baia, people had very positive perceptions of change, citing development of benefits to the entire community (e.g. health, education). They also attributed a large proportion of these changes to sportfishing, which is a clear indicator of potential benefit. The other communities also reported positive change, but these were associated with activities that could be unfavourable to sportfishing tourism, as this requires a healthy natural environment. Particularly, the division in perceptions of oil palm and logging in Vesse could create conflict around engaging in more environmentally sustainable activities in the village.

Main livelihoods

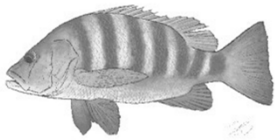
Background: In communities that depend largely on extractive use of natural resources for subsistence and income, their relative dependence on these resources is an important consideration for nature-based tourism, such as Sportfishing tourism. Highly subsistance lifestyles or complete dependence on the same resources (i.e. aquatic resources) could create potential for conflict.

Conclusions: All of the communiteis are highly dependent on aquatic resources for subsistence and income. Although they do not target Black Bass specifically as food, there is potental for overlap of fishing grounds. Further, Red Emperor, an important food species, is a common ancillary sportfish target species, so the potential for conflicing use of this resource needs to be considered.

Occupational Multiplicity

Background: If housholds diversify their activiites, they are less vulnerable to sudden changes in natural resource or market conditions as they have other activities to fall back on. Also, diversified households are better suited to capitalise on multiple opportunities associated with tourism devleopment.

Conclusions: All of the villages showed relatively high levels of occupational multiplicity. Some Somalani households showed notably high diversity of activities. Activities such as mat-making and



shell necklace construction (products that could potentially be sold to tourists) could be targeted by small businsess development and capacity building activities.

Material style of life

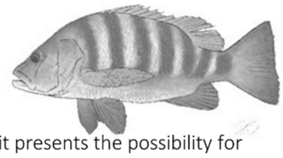
Background: Lack of basic amenities and infrastructure (e.g. boats, fishing equipment, accommodation and toilet facilities) present barriers to people becoming involved in tourism development; largely because such elements are required to accommodate customers. The distribution of wealth is also important as inequality can create conflict if people percieve there are 'winners' and 'losers' in the community.

Conclusions: Although Vesse and Somalani scored slightly higher with respect to 'wealth' in the community, all communities lacked very basic infrastrucutre that would be needed to accommodate tourists. This is less critical in Baia, as the existing Lodge is very close to the village and provides all the amenities needed by tourists, although they would need access to basic equipment and up-skilling to become more involved in tour guiding or in having tourists visit the village. Baia residents also expressed less interest in building accommodation than the other villages. A more even distribution of wealth in Baia is also more favourable to an equitable distribution of potentail toursim benefits. Somalani residents in particular showed an interest in accommodating tourists in the village (the relative distance from the lodge is a possible factor in this) and would need signigicant support in building the amenities necessary to achieve this.

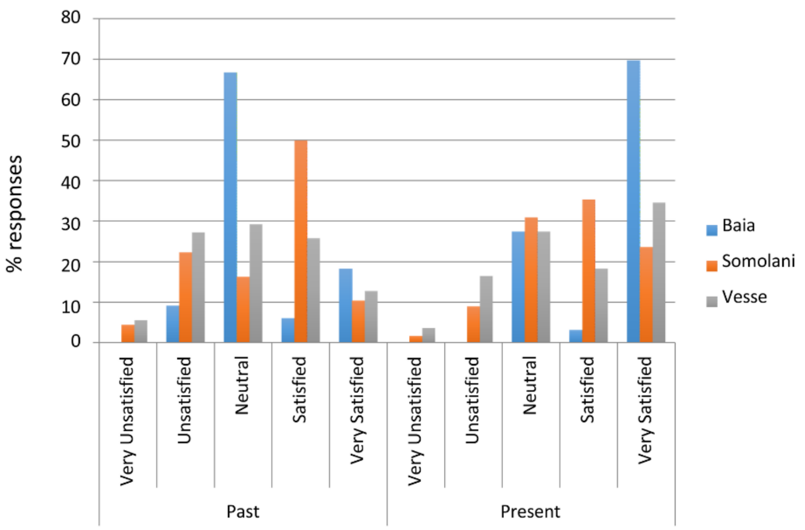
Social Capital

Background: Social capital, which includes trust, reciprocity and networks, is a key factor in ensuring positive outcomes for development, effective management of natural resources, and benefits of development in communities (e.g. from sportfishing tourism). This is because it increases the potential for cooperation and equitable distribution of benefits, thus reducing potential for conflict and raising people's capacity to diversify and work collectively to obtain benefits from new livelihoods.

Conclusions: Perceptions of social capital were high in all of the communities. However, the presence of a significant proportion of respondents who perceived less trust and reciprocity in the



community is an aspect that needs to be explored in more detail as it presents the possibility for conflict or inequitable distribution of benefits.



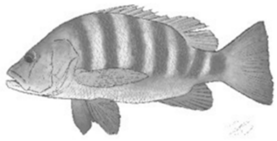
Overall satisfaction with quality of life now (present) compared to 10 years ago (past) (Source: Diedrich et al. 2016)

Perception of tourism

All communities expressed a strong interest in becoming involved in tourism, many of them citing activities spefiic to sportfishing tourism. Although most percieved it would be relatively easy to become more involved in tourism, it is important to consider their recognition of the need for education and capacity building in order to support this.

Perceptions of fish abundance and impacts

Background: Fish are the most important resource for both livelihoods and sportfishing tourism; thus, it is important to understand people's percpetions of how fish resources have changed over the years, and what is impacting upon them. In the absence of ecological monitoring of fish abundance (common in remote areas), people's perceptions can be good indicators of the nature and severity of impacts. Furthermore, insight into what locals believe to be impacting on resources can help focus conservation actions, which are necessary for creating a sustainable sportfishing tourism environment.



Conclusions

Although other communities reported improvements or no change in fisheries resources, Baia residents reported an overall decline in fisheries resources. Negative impacts were attributed to increased environmental damage from logging and oil palm.This suggests a need to address effective management of these activities in order to reverse these declines and ensure healthy enviroments and healthy fish stocks to support both livelihoods and sportfishing tourism. The fact that most villagers recognise the role of human agency in affecting the state of natural resources is favourable for supporting local conservation efforts.

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Briefing Report 8: Economic aspects

Sustainable Management of Sport Fisheries
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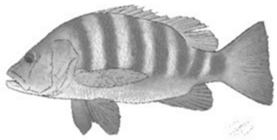


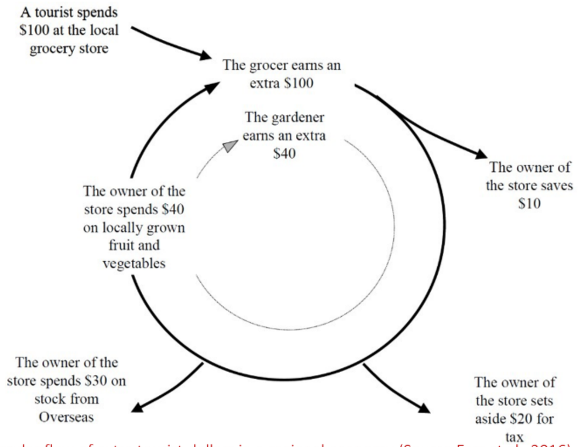
Briefing Report 8: Economic Aspects*

Background

This assessment was undertaken using data from three sources (a) the international literature; (b) data collected in a survey of households in three case-study sites (using a questionnaire which was jointly developed and administered[1] with other members of the social science team from the ACIAR project); and (c) data collected from sportfishers. Information from the literature and surveys has been combined, providing insights into the way in which sportfishing generates economic benefits for those in local villages, regional centres and PNG more broadly.

The potential long term financial viability of sportfishing ventures

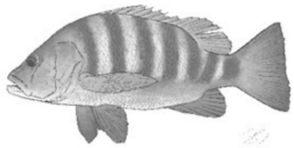
The majority of the sportfishing visitors surveyed reported fishing as the only reason to come to PNG and not one of the participants spent any extra time doing other things in PNG before or after the fishing trip. This means that sportfishing tourists are an additional segment of tourist market; the industry does not compete with the tourism ventures providing other types of tourism products in the country; but rather brings to PNG tourists over and above those who would come otherwise. Fishers reported high satisfaction rates with both the fishing trip overall and the fishing



The circular flow of extra tourist dollars in a regional economy (Source Farr et al. 2016)

experiences, indicating that the quality of the 'product' (sportfishing experience) is high and thus likely to compete well with other similar 'products' in the Pacific. It can be concluded that sportfishing ventures in PNG have a good potential for long term financial viability. However, the number of tourists in PNG is limited, and numbers of those interested in sportfishing is very small. Given such a small size of the market, and limited likelihood of rapid increase in the future, it can be concluded that although existing sportfishing ventures in PNG have a good potential for long term financial viability,

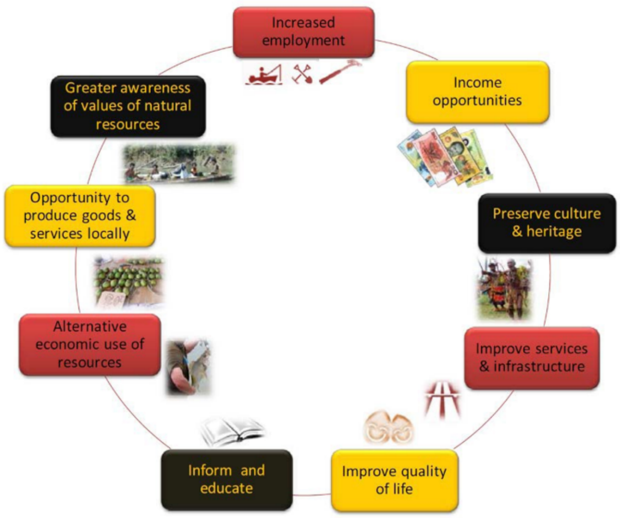
[1] This Brief is a reproduction of the report FIS/2013/015, authored by Farr et al. 2016



the numbers of such ventures that could function viably are limited. Sportfishing as an industry has a potential to continue successfully, and grow to some extent, but is unlikely that sportfishing will provide a 'magic bullet' that will significantly increase numbers of visitors to PNG.

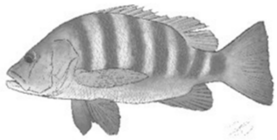
The potential benefits of these ventures for local communities

The literature review revealed that the financial benefits of sportfishing to entire nations is very small, relative to GDP, in most countries. Not only is the direct financial benefit low, mainly due to sportfishing tourists representing a very small proportion of tourism market, but indirect and induced financial benefits are also low, resulting in very small multipliers and hence low total economic benefit (Criddle et al. 2003). We found a similar situation in PNG. However, although the national and regional financial benefits of sportfishing might be minimal, the industry can create a significant change and financial benefit at the local level in the communities where the sportfishing venture operates. Future research and planning efforts should thus concentrate on, on the one hand, capacitating and enabling villagers to provide goods and services to the sportfishing ventures; and on the other hand, stimulating or requiring sportfishing ventures to obtain as many goods and services as possible from the neighbouring villages.



Benefits of sustainable sport-fishing tourism development: Source PNGTPA. 2006)

Given the small visitor numbers, it is economies of scope (that is, one or few people providing a wide range of different products, i.e. fish, seafood, garden products, fruit, wood carvings, bait, etc.) rather than economies of scale (that is, the whole village growing vegetables for sale to the lodge), that should be promoted at the local level. Even so, sportfishing ventures, as most other ecotourism ventures, will likely only provide an additional livelihood diversification activity and/or an additional income stream to some households; simply put, there are too few sports fishers to generate incomes that are sufficient to entirely shift more than a few people from an agricultural/fishing livelihood base



to services, and thus are unlikely to significantly change livelihood systems of entire communities. That said, sportfishing also generates numerous non-financial impacts, mainly at the local level, and hence provides opportunity for economic betterment of the communities in which sportfishing operates. Our research demonstrates a significant improvement in people's (subjective assessments) of their quality-of-life (QOL) over the last 10 years was reported in all villages surveyed and the majority of the changes in the last 10 years were seen as positive. Importantly, several positive changes (better houses, better health facilities, better educational facilities) and no negative changes were perceived as being linked to the sportfishing tourism developments (Diedrich et al. 2016).

There are a few aspects of life that, if improved, could generate significant improvements in welfare. These are aspects that respondents find very important to their QOL, but which they are currently not particularly satisfied with, namely: environmental condition (the health of environment), leadership, opportunities to find paid jobs and health services. As the current satisfaction with these life domains is relatively low, and the importance to the villagers is high, these are the aspects that have highest potential to improve the quality of life (individual welfare) of villagers, if improved. Several of those aspects play out at scales and societal levels that are beyond the village influence. From the environmental problems to health services provision and job availability, many are regional and national issues. The sportfishing industry might be able to provide some improvements to these aspects at the village scale, however, most 'solutions' remain outside of the control of villages and the sportfishing industry.

As an example, satisfaction with the current environmental conditions, in particular in Baia and Vesse villages, is rather low, and villagers expect the condition to deteriorate in the future. Environmental protection activities, in form of awareness campaigns and local sediment prevention activities, for example, could be supported by the sportfishing industry – but there is a limit to how much the industry can, or should, do. Some other activities, such as the introduction of protected areas, would require wider collaboration between villagers, the fishing tourism industry, and national or international NGOs and donor programs underway or planned for the region. Collaboration between villagers (providing agreement and labour) and sportfishing industry (providing networking, bridging social capital and language skills and acting as a 'champion') would potentially generate future benefits for both villagers and the sportfishing industry.

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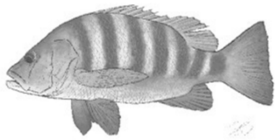
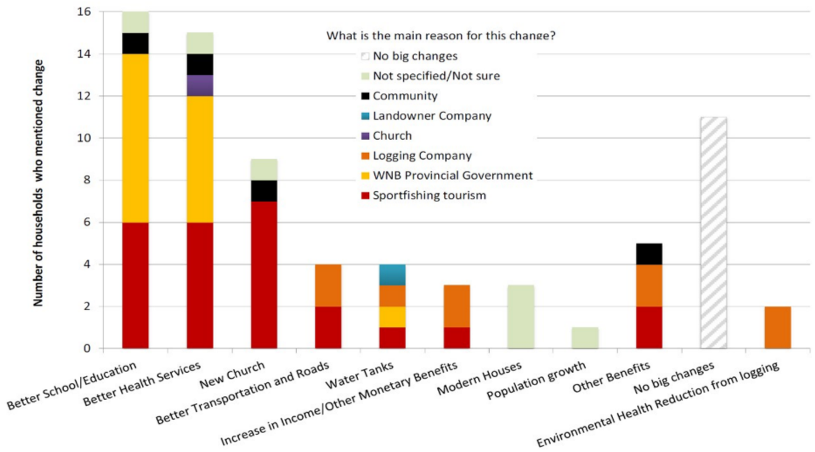


Local perceptions of environmental change and (local perceptions) of the environmental impact of those ventures

Perceptions held by the local communities of the ecological impacts of sportfishing ventures are important for the long-term viability of these ventures, in particular in cases where sportfishing and subsistence fishing compete for the same fish species (which could generate disquiet amongst locals). In our case study villages, the species targeted by villagers and tourists were different, hence no direct competition is expected. Perceptions about fish abundance now and five years ago vary between villages: Baia villagers reported less fish; Vesse about the same; and Somalani perceived increase in numbers of fish. Importantly, there was no perceived links between decreases in fish abundance and the sportfishing industry. The information provided in this report, when used in conjunction with other information collected from the biophysical and (other) social scientists associated with the large project, allows one to asses the potential of sportfishing to promote sustainable development in PNG, and make inferences to other developing countries. Our findings will also help the PNG government and policy makers understand what can be done to help promote the short and long term viability of sportfishing businesses, providing insights into ways of supporting sustainable development in remote areas of the country.



The biggest changes that have occurred in the village in the last 10 years and reason for that change, Baia Village (Source Farr et al. 2016)

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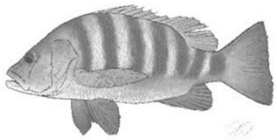
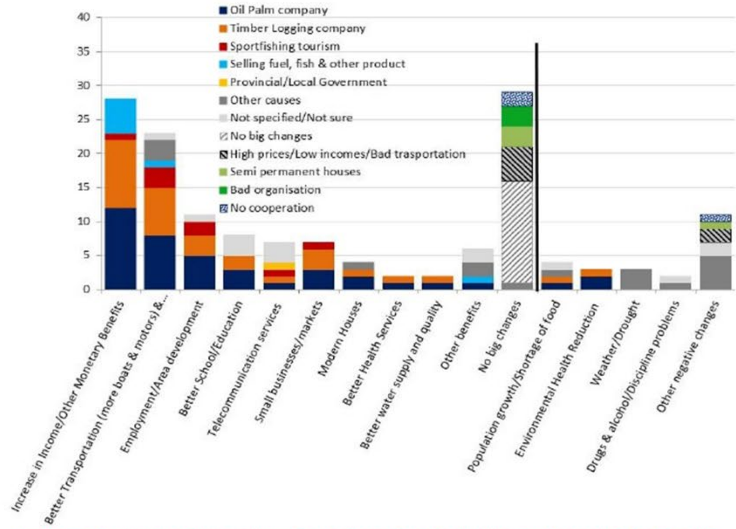
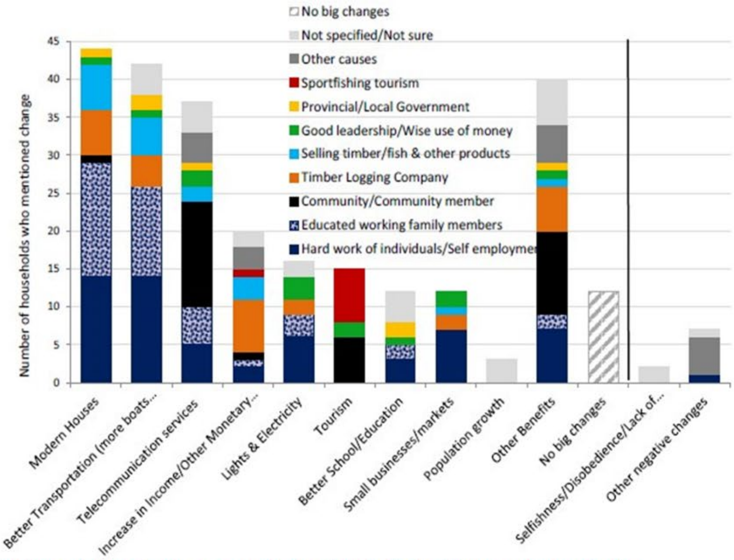
Sustainable Management of Sport Fisheries for Communities in Papua New Guinea





The biggest changes that have occurred in the village in the last 10 years and reason for that change, Vesse Village (Source Farr et al. 2016)



The biggest changes that have occurred in the village in the last 10 years and reason for that change, Somalani Village (Source Farr et al. 2016)

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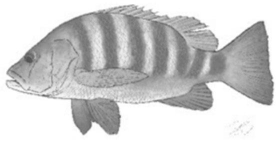

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11.3 Appendix 3: Fish-habitat matrices

Fish-habitat matrices that show life-history habitat and migration requirements of the Niugini Black and Spot-tail Bass were constructed based on literature review of Sheaves at al. (2016) and data collected between 2014 and 2018 at the different rivers around Baia.

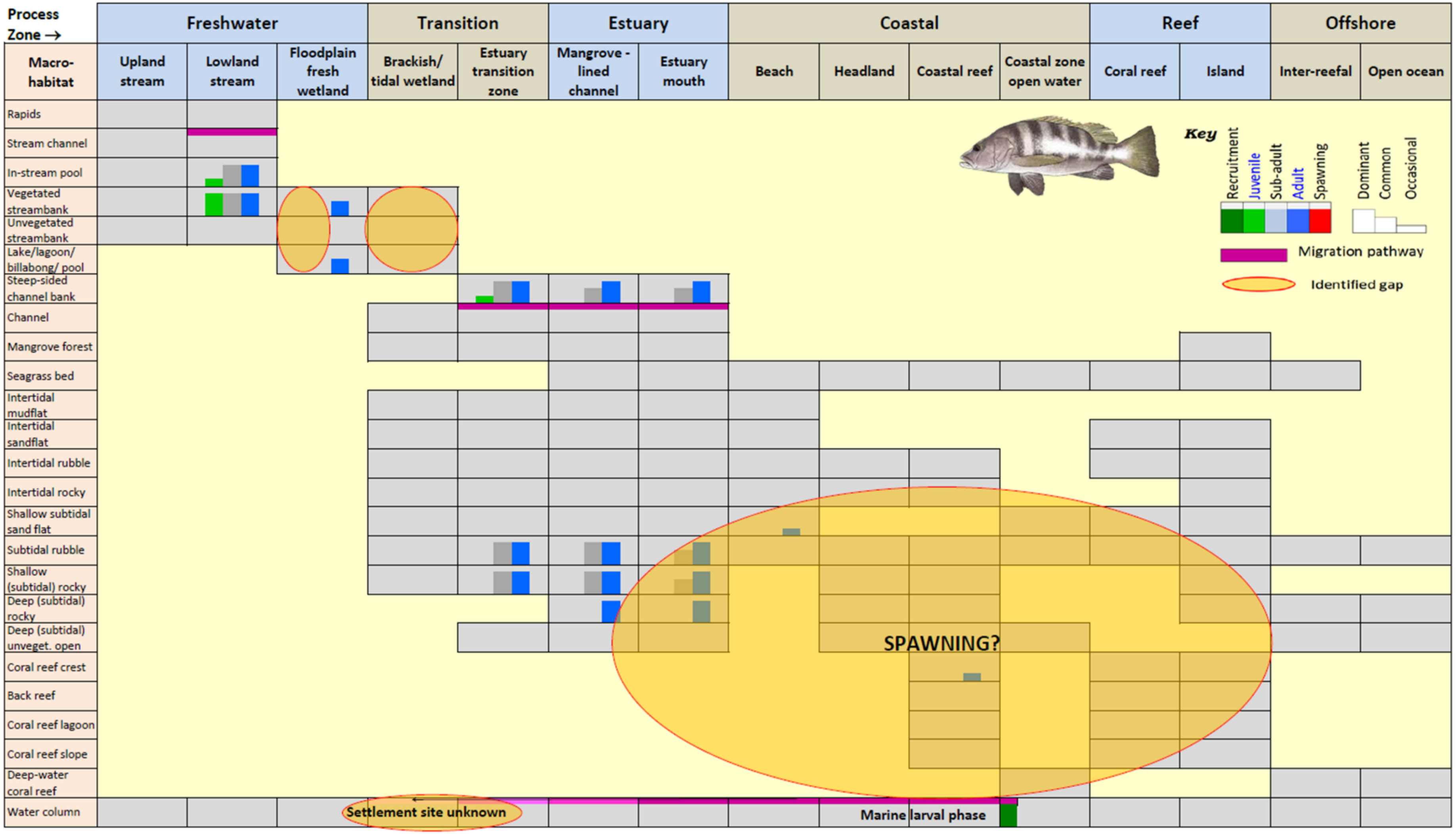
Black Bass

The distribution of sub-adult and adult Black Bass across freshwater to estuarine process zones, and the occupation of some macro-habitats, is based on underwater video surveys, otolith chemistry, field sampling, captures by the sportfishery and published fish surveys from around PNG. Underwater video, field sampling, and reports from anglers indicates woody debris as the dominant meso-habitat utilised by Black Bass. Juvenile distribution is based on underwater video survey. Otolith microchemistry analysis indicates a marine larval phase, with juveniles recruiting into saline estuaries and many moving on into freshwaters for the early part of their lives. However the site of larval settlement remains unknown. Otolith chemistry and acoustic tracking data indicates considerable movements along rivers, implying potential use of a range of non-structured habitats. Acoustic tracking and reports from locals indicate the movement of some individuals out of river mouths into coastal waters. Additionally, reproductively mature Black Bass individuals in close to spawning condition were captured in the lower reaches of Rivers, but the exact spawning sites remain unknown. Acoustically tagged fish in the Toriu River make regular migrations on the new moon, from the lower estuary to the rockbar at the transition zone during the dry season, and out of the estuary mouth to the nearest coastal reefs during the wet season. Two of the possible explanations for this are: movement to structured habitats at the saline-freshwater mixing zone for spawning; or movements associated with feeding on on whitebait runs during the new moon.

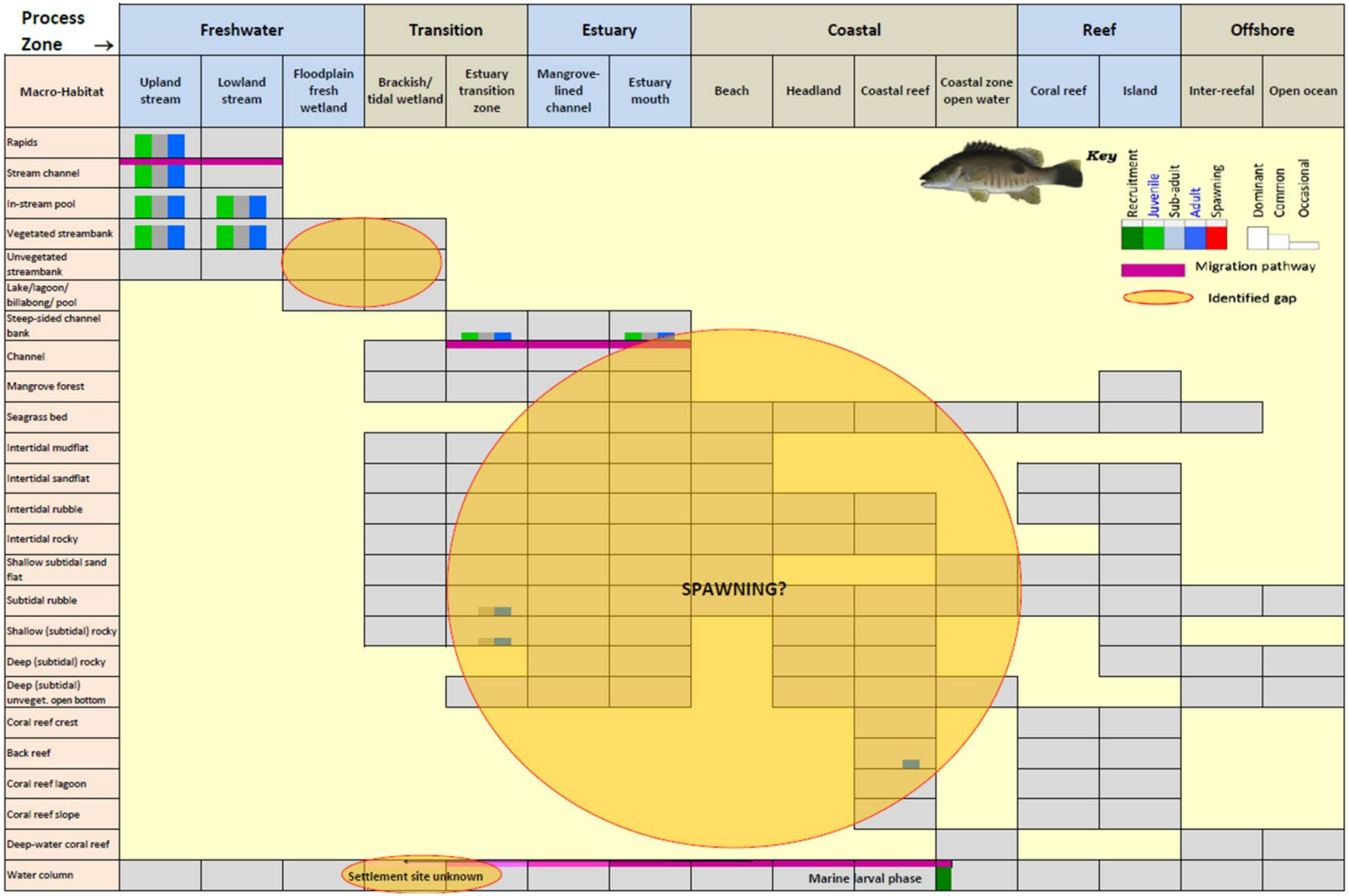
Spot-tail Bass

Sub-adult and adult Spot-tail Bass can be primarily found in the freshwater and low salinity reaches of rivers. In river mouths, they were collected only in areas of high freshwater flow. Although they overlap with Black Bass, Spot-tails dominate the faster-flowing sections of freshwaters, while Black Bass are more common in slower waters. Reports from fishing guides indicate Spot-tails penetrate through rapids well up into flowing streams. As for Black Bass, otolith microchemistry indicates a marine larval phase followed by recruitment through estuaries into freshwaters. It also indicates adults move into saline waters at times, and Baia villagers reported spearing Spot-tail Bass from the back reef in front of Baia Village, several km from the nearest known rivers holding these fish. Juveniles are widely distributed and common on any structured habitat in the freshwater reaches of Baia rivers. We captured ripe males and heavily-rowed females from the mouth of the Pandi River (flowing freshwater) but their exact spawning locations remains unknown.

Fish-Habitat Matrix for Black Bass



Fish-Habitat Matrix for Spot-Tail Bass



11.4 Appendix 4: Evaluating current sportfishing operations within PNG

This briefing report covers fish handling practices and the gears used in the Black Bass sportfishery in PNG, based on data collected from online images posted by PNG sportfishing operators and our direct observations of fish handling practices.

There is extensive literature on catch-and-release (C&R) angling practices that provides insights into the consequences of fish handling practices on fish recovery and survival from capture and release (summarised in Barnett et al. 2016). Although only a limited range of species have been examined in detail, there are some practices and factors known to impact on fish recovery and survival from C&R fishing that are either consistent among all species examined thus far, or simply based on general fish physiology. Fight time, air exposure, physical injury from hooks, landing nets, handling methods, and fish orientation when held out of water (i.e. vertically or horizontally) can all impact on fish recovery and survival (Cooke & Suski 2005; Pelletier et al 2007). Of these factors, we were able to assess handling methods, fish orientation and position, and visible injuries from hooks, landing gears and handling practices from online images posted by sportfishing operators and our direct observations during field trips.

Images of 391 fish were assessed for handling practices (Table 1). It is clear that the majority of anglers try to implement good handling practices; 96% of fish were held horizontally with some form of support under the body. However, less than 30% of all fish and 21% of Black Bass were held in a way that could be considered best-practice. Best-practice was defined as fish held horizontally, supported ventrally beneath the body and not otherwise in contact with the anglers clothing or body, with the head, gill and throat structures aligned normally and not distorted by handling, and with no visible signs of injury (Fig. 1). Over half of the 250 Black Bass pictured were held by jaw grips in a way that bent the head upwards, flared the gills and caused the gill juncture to protrude (Fig. 2). Such handling places strain on the skull, spine, jaw, and gills, and has potential to cause serious injury, especially if the fish struggles when held this way. In addition, there is a trend among some anglers to twist the jaw grip behind the body of the fish, distorting the jaw (Figs. 3, 4).

Twenty-seven percent of Black Bass, 9% of Spot-tail Bass and 32 % of barramundi were held in contact with the anglers clothing, either embraced against the torso, or held across the legs in a seated position (Table 1, Fig. 3), and this was most common with larger fish. Such handling can remove the protective slime coasting from the fish, making them vulnerable to disease (Pelletier et al 2007). Larger fish were generally handled more poorly than small fish, and the largest of all were pictured hanging vertically by jaw grips (Fig. 5). The only pictures of fish being weighed were hanging vertically in this manner.

Images of 61 lures allowed assessment of the type of hooks used. Only 7 (12%) of the lures pictured used single hooks, with the rest having two (57%) or three (31%) treble hooks. Multi-hook lures fitted with treble hooks can inflict additional injuries around the mouth, eyes and gills of the fish during the fight, and 10% of all fish showed visible signs of such injuries (Table 1). There were 14 images of landing nets used to land the fish. Of these, 8 were coarse material mesh that can inflict damage to fins, scales and slime coatings, making the fish vulnerable to disease (Barthel et al 2003). The remaining 6 showed a soft-meshed rubber landing net that would minimise damage to fish during landing.

Table 1. Summary of fish handling practices derived from online images from tour operator websites and social media pages. Non bold values are proportions (%) of fish in each condition; N handling - number of images analysed; vertical/horizontal - the orientation of the fish; jaw grips – fish held by jaw using boga-grip or similar; hands support body – if the fish is being supported by hand under the body; hand gills – if the fish is held with hand/fingers inserted under the operculum; gills flared – if the operculum, branchiostegal rays and gill juncture are flared and protruding this indicates the head being tilted back in a way that may cause serious injuries to the jaw, skull and gills of the fish (see images below); N position – number of images analysed for position of fish; against body – slime and scales from fish can rub off on the clothing of the person holding them; air – a fish held so that the body is not in contact with clothing of the person holding it; other – includes fish pictured lying on the deck of the boat, on the ground, or in the water; N injuries – number of images that could be assessed for visible injuries on the fish; bleeding – visible blood; line/net scrapes – clear markings on the body of the fish caused by the fishing line during the fight, or the net upon landing; hook damage – visible damage around the head of the fish caused by hooks other than the primary hook holding the fish; scales dislodged – in addition to hook damage and net/line scrapes; jaw distorted – all fish suspended vertically by the jaw, and those held horizontally by hand or jaw grips used in a way that distorts the jaw out of shape, in particular there is a trend among some anglers to twist the jaw grip around behind the body of the fish, presumably so it is less visible in the picture, but this often twists the jaw in a way that potentially directly injures the fish, or makes them vulnerable to injury should they struggle during this pose (see images below); % best handling – fish held horizontally, supported under the body, held in water or in the air (i.e. not in contact with clothing, deck, or ground), with no flaring of the gills, and no visible signs of injury.

Species	**N handling**	vertical	horizontal	jaw grips	hand support body	hand gills	gills flared	**N position**	against body	air	other	**N injuries**	bleeding	line/net scrapes	hook damage	scales dislodged	jaw distorted	**% best handling**
Lutjanus goldiei	**250**	5.2	94.8	87.2	89.6	5.2	51.6	**249**	27.3	66.3	7.6	**240**	7.5	6.3	13.8	29.6	19.3	21.2
Lutjanus fuscescens	**92**	3.3	96.7	77.2	91.3	6.5	30.4	**92**	8.7	84.8	6.5	**88**	0	9.1	5.7	5.7	8.0	44.6
Lates calcarifer	**31**	0	100	71.0	93.5	3.2	38.7	**31**	32.3	61.3	6.5	**26**	7.7	11.5	3.8	26.9	6.5	32.3
other spp. (8 spp.)	**18**	0	100	77.8	94.4	0	11.1	**18**	0	94.4	5.6	**17**	5.6	0	0	0	5.6	64.7
Grand Total	**391**	4.1	95.9	83.1	90.5	5.1	43.7	**390**	22.1	71.5	6.4	**371**	5.7	7.0	10.5	22.4	15.0	**29**

Based on analysis of the images, and our observations in the field, it appears that most fish are landed by net, often rough-material nets that damage fins and dislodge slime and scales, de-hooked and lifted vertically by the lower jaw using jaw grips, weighed vertically, and then photographed held horizontally. The most important fish for the fishery, the large trophy sized individuals, are handled the worst and likely held out of the water the longest. It was also clear in the images that handling practice was angler-specific, i.e. some individual anglers showed good handling practices in all images, others consistently handled fish poorly. Angler experience will play a role in the manner in which they handle fish. Implementing good handling practices will be as much about empowering guides to confidently and authoritatively ensure good handling, as it will be about providing specific best-practice guidelines for guides and anglers. Although we lack species-specific data for Black or Spot-tail Bass at this stage, some general handling recommendations can be made based on published literature and observations during this study:

- Where possible, do not remove the fish from the water. Air-exposure time is often the greatest threat to fish recovery and survival.
- If the fish must be removed from the water, minimise air exposure time. Ensure dehooking equipment and cameras are ready before removing the fish from the water.
- Use soft-meshed landing nets, and ensure the deck of the boat is wet where the fish is to be placed in the net.
- Use barbless hooks for ease of removal, and remove hooks while the fish is horizontal (preferably in the water).
- Ensure only soft wet materials come into contact with the fish's body, do not rub fish against clothing, dry hands, or dry carpet.
- Weigh fish in the landing net or a sling, do not hang any fish vertically by the jaw. Their internal organs can be damaged by hanging vertically when out of the water.
- Always support the fish in a horizontal position while minimising contact with any dry or abrasive material that can rub off slime.

Figure 1. A small Black Bass classified as best handling in table 1; horizontal, supported under the body, jaw grips not bending the head back, flaring the gills, causing the gill juncture to protrude (see Fig. 2) or distorting the jaw, and with no visible signs of injury.

Figure 2. Although the body of this fish is being well supported by hand, this is a typical example of the jaw grips pulling the head upwards, putting strain on the skull (red arrow at top) and causing the gills to flare and the gill juncture to protrude (red arrow beneath head). This has the potential to cause serious injuries to the skull, spine, gills and jaw of the fish.

Figure 3. Many larger Bass are held with the body supported either across the knees of the angler (upper), or embraced in their arms (lower), and the side of the fish resting against the anglers' shirt. Either of these practices will rub the protective slime off the scales of the fish making them vulnerable to disease. The upper fish is also showing considerable signs of damage to the body, with scrape marks and dislodged scales. The lower fish has the jaw distorted by the jaw grip.

Figure 4. The jaw of this fish is being twisted out of shape by the jaw grip, and it is close to piercing the membrane. Several images show the jaw grip having punctured the membrane as e.g. a jaw gaff would do. There is also hook damage visible below the eye.

Figure 5. Large Black Bass being suspended vertically by the lower jaw. This places considerable strain on the jaw, gills, spine and skull, as well as potentially damaging internal organs not equipped to hang vertically out of water. Although few images are published showing fish hanging vertically, it appears this is how the majority of fish are weighed using built in scales on the jaw grips. There were no images of fish being weighed in a sling or landing net.

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11.5 Appendix 5: Black Bass best practices guidelines

Black Bass Best-Practice Catch-and-Release Guide

Catch, handling and releasing a fish in a way that minimises injury and improves its probability of surviving is an important factor in maintaining sustainable catch-and-release sportfisheries, and is an important components of sustainable management of sportfisheries and the ecosystems they depend on. Observing best-practices techniques, using the right gear and planning ahead for quick and efficient release, will ensure the optimal outcomes for released fish, and ensure that your fishing activities are as sustainable as possible.

10 Key Points

1. Plan your catch-and-release trip
2. Use approved hooks (preferably single, non-offset circle hooks)
3. Minimise the stress on fish while playing them
4. Once brought to the boat, whenever possible leave the fish in the water rather than boating it.
5. Only remove a hook if the hook is in the mouth and easily accessible, otherwise cut the line.
6. If the fish is brought on board the boat minimise the time out of water.
7. Handle the fish as little as possible and then only with wet hands or wet rubberised gloves.
8. Minimise the time the fish is out of the water and make sure the fish is kept wet, and not placed on a hot dry surface.
9. Spread your fishing effort around many sites.
10. Don't leave discarded fishing gear or rubbish behind.

Best-Practice Catch-and-Release in Detail

The Catch-and-Release Process

Rapid and careful catch-and-release that optimises survival should always be the aim of a catch-and-release sportfishery. To this end five overall rules should be observed:

1. Be prepared – ***plan*** how you will handle the fish and release it before you start fishing, and make sure all participants understand what will happen and what their role is.

2. Make sure all participants are ***trained*** in the objectives and techniques of effective catch-and-release.
3. Before you start fishing decide on the ***criteria*** for which fish are to be released and which, if any, are to be kept.
4. Make sure the ***correct equipment*** is on the boat and readily accessible when needed.
5. Keep ***records*** of the handling and release, noting any issues and the health of the fish. This information will help you assess how effective your procedures are, what additional training of staff is needed and what additional resources are required. It will also provide data to assist with the continued improvement of best-practice procedures (see Monitoring the Outcome of Sportfish Release below).

Hooks

- ***All hooks used should be barbless*** or have their barbs crushed. Such hooks are easier to remove, reducing damage at release, increasing survival and are easier for the fish to get rid of if they break the line or the hook is cut off.
- ***Single hooks*** should be used rather than treble or double hooks.
- ***Non-offset Circle Hooks*** tend to hook fish in the mouth more often, reducing gut and gill hooking, and making removal easier and increasing survival. These hooks are designed so that the point turns away from the shank, allowing the hook to slide back out of the fish's stomach if it swallowed, and to lodge in the corner of the mouth.
- ***Stainless steel hooks should never be used***. While an ordinary, steel hook left in a fish will corrode away, stainless steel hooks remain in the fish indefinitely with the possibility of long-term impacts on fish health. Lost stainless steel hooks also stay in the ecosystem for a long time with the potential of on-going damage to fish and other wildlife.

Playing the fish

- Where possible ***limit the time playing a fish*** and endeavour not to play the fish to exhaustion. Being hooked is a stressful event for a fish causing stress hormone levels to rise in the blood. High levels of stress hormones has been linked to mortality that can occur after an apparently successful release.
- Minimise the chance of a hooked fish ***making it back to cover*** where it may become tangled and trapped.
- Both these aims are helped by ***using tackle of sufficient strength*** for the size of the fish you are targeting. Black Bass are one of the world's toughest fighting fish so heavy tackle should be used whenever possible.

Landing the fish

- Whenever possible the ***fish should be left in the water and released from there***.

- If the fish must be landed/boated ***never lift it from the water using a jaw or lip gripping device***. Lifting a fish by its mouth places excessive strain on the jaw and causes the internal organs to sag downward increasing the risk of injury.
- ***Never gaff the fish*** in the body or the jaw.
- If landing/boating is necessary ***use a soft knotless mesh or rubber landing net***. These are less damaging to eyes, fins, scales and the fish's protective mucous layer than other nets.

De-hooking

- If possible ***leave the fish in the water to remove the hook***.
- Hooks should only be removed ***if they are visible in the mouth***.
- Be particularly aware of exactly where the hook is. In particular, if the hook is in the gills or protruding from the fish's stomach ***no attempt should be made to remove it***.
- ***Never pull on the line*** to drag the hook into sight.
- If a hook has been swallowed, or visible but protruding from the stomach, or it is hooked in or around the gills, or if it is in the mouth but can't be easily removed, ***cut the line as close to the hook as possible and leave the hook in the fish***. Never use the 'through the gills' hook removal approach – rather cut the line.
- There are various ***tools***, such as long-nosed pliers, hook disgorger and line-cutting scissors that can help with gentle, rapid and successful release. These tools should be kept readily available.

Time out of water

- Where possible ***leave the fish in the water*** and carry out release activities there.
- If you must remove the fish from the water ***keep air exposure to a minimum*** (less than 1 minute if possible).

Handling the fish

- ***Handle the fish as little as possible*** always using ***wet hands***. If you need gloves use wet rubberized but not cotton gloves.
- If you remove a fish from the water, do not lift it by its mouth but ***support its weight along the length of its body***.
- ***Don't squeeze the fish*** or handle it more than necessary. Don't touch the gills – they are especially sensitive organs.
- ***Keep the fish wet***. Remember, in the tropics exposed surfaces quickly become hot and likely to burn a fish's delicate skin. So if a fish is brought on board do not lie it on a hot, dry surface. Rather place it on a smooth, wet surface, preferably a vinyl covered foam mat. There are many catch and release measuring mats manufactured from UV stable material, designed

to help anglers accurately record their catch. These should be wet before laying a fish on them.

- It is often useful to keep a fish calm by covering its eyes with a wet cloth while de-hooking and measuring.

Photos

If you are going to take photos of your fish before release;

- Plan your photo beforehand.
- Support the fish properly.
- Take the photo quickly.

Release

- Release the fish carefully. If it has been removed from the water ***lower it back in gently***.
- Check the condition of the fish before releasing it. If the fish is sluggish when placed in the water, ***resuscitate the fish before releasing it*** by facing it into the current or moving it back and forth in a figure eight pattern until it regains strength and becomes active.
- Be alert for predators, such as crocodiles, that might take advantage of the fish's exhausted state. Conduct the release away from such animals if they are noted.

If you are going to tag

- Follow the best-practice handling procedures.
- Make sure all your equipment is ready before the fish is hooked.
- Make sure those conducting the tagging exercise are fully trained in proper tagging techniques.

Distribute your effort

The quality of a sportfishing trip relies on a plentiful supply of willing fish.

- Spread your effort over a number of sites to reduce pressure on any one location.

Leave no trace of your trip

Sportfishers have a responsibility for the cleanliness of the environment; trash in the ocean is a global issue.

- Leave no discarded gear – line, lures, sinkers etc. or rubbish, bottles, bags behind. Take it home and recycle it.

Monitoring the Outcome of Sportfish Release

A number of authors (***e.g. Davis, M. W. (2010). Fish stress and mortality can be predicted using reflex impairment. Fish. 11, 1–11; and Raby, G. D., Donaldson, M. R., Hinch, S. G., Patterson, D. A., Lotto, A. G., Robichaud, D., et al. (2012). Validation of reflex indicators for measuring vitality and predicting the delayed mortality of wild coho salmon bycatch released from fishing gears. J. App. Ecol. 49, 90–98***). Have developed approaches to assess the state of impairment of fish on release. These approaches were developed for using in an experimental situation but are modified below in a 'Multifactor Impairment Test' as a means of monitoring the success of Black Bass sportfishing release.

Multifactor Impairment Test

- Four factors are scored. Each is scored as 0 = unimpaired, 1 = impaired, in a conservative matter. That is, if the handler has doubt as to whether the reflex is present, it is recorded as being impaired.
- The entire reflex assessment should take ~20 seconds to complete and conducted immediately prior to release. If a fish is too vigorous to allow handling and assessment of reflexes, it is assigned an unimpaired status for all reflexes.

Test	Method	Score
Respiration (head complex)	Head complex is noted as unimpaired (= 0) if the fish exhibits a regular pattern of ventilation (for ~5 secs.) observable by watching the opening and closing of the lower jaw.	
Response (tail grab)	Presence of the tail grab response is assessed by the handler attempting to grab the tail of the fish with the fish submerged in water (in a fish bag or holding trough, or at the side of boat prior to release); a positive response is characterized by the fish attempting to burst-swim immediately upon contact.	
VOR	VOR is observed by turning the fish on its side (i.e. on a lengthwise axis). An unimpaired VOR is characterized by the fish's eye rolling to maintain level pitch, tracking the handler.	
Orientation	Upon release, the fish is placed upside-down just below the surface: a positive orientation reflex is recorded if the fish rights itself within 3 secs.	
	Total	

11.6 Appendix 6: Focus Group Report

Sustainable Management of Sportfishing Communities in PNG: Further insight into Fishing, Infrastructure, and 'Future Visions' of Communities in Western New Britain

Focus Group Report

ACIAR Project Number FIS/2013/015

June 2017

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Introduction

In August 2016, Lina Pandihau from the PNG National Fisheries Authority and Amy Diedrich from James Cook University returned to the three Western New Britain communities that participated in the socio-economic surveys (Baia, Somalani, Vesse; Fig. 1) to conduct a series of focus groups with the objectives to:

1. Gather spatially explicit information related to fishing and identify any potential overlaps with tourism activity.
2. Describe access to markets and infrastructure in the communities.
3. Capture the communities' desires, goals, and needs associated with Sportfishing Tourism (SFT) and other forms of development.

This report contains the procedure, results and preliminary conclusions of this activity. The following trip built on the theme of exploring sustainable livelihood pathways for the communities with a second focus group meeting on perceptions of impacts and trade-offs among available livelihood options in the communities (e.g. logging, oil palm, tourism, etc.).

Figure 1. Map of Study Site: Sportfishing Lodge at Baia is adjacent to Baia Village, the Lodge at Uluai is on an island adjacent to Vesse and Somalani Villages (Diedrich et al. 2016).

Focus Group Procedure

The town councillor of each village was asked to gather two groups of six individuals (one male and one female group) representative of different sectors (e.g. fishing, farming, tourism) and different age groups (e.g. elders, youths) to engage in a focus group interview and mapping exercise. The meetings were held in the village and took approximately an hour and a half to complete.

Two activities were carried out: one participatory mapping exercise (Fig. 2) and one 'Future Visions Workshop' (Fig. 3). The mapping exercise used laminated aerial views of the villages and the surrounding environment obtained from Apple Maps to stimulate discussion around various themes; men and women's fishing (including sportfishing), access to markets, and infrastructure.

Figure 2. P*articipatory Mapping Exercise*.

First, the group was asked to map the areas where they fished or gleaned for food. Information about species, seasons, and gear was also collected. Second, they were asked where they took the sport fishers to catch fish and whether there had been any conflict or overlap with respect to fishing locations. Next, they were asked to describe the procedure and associated costs for taking fish to market. Finally, questions were asked about village infrastructure (locations of schools, access to roads, medical facilities).

Once the mapping exercise was complete, men and women were separated and asked to discuss amongst themselves the five changes they would most like to see in their communities in the next 10 years. Once consensus was reached, they were asked to present the results back to the project team members.

The results of the meetings are reported in the following section. Note that the mapping exercise acted as a way of stimulating a general discussion around fishing, markets and infrastructure, and for identifying potential areas of spatial conflict associated with sportfishing. Thus, the level of accuracy and detail from a spatial perspective was not sufficient for justifying the creation of digital GIS layers. In most cases, spatial references are provided in the format of place name and descriptions of distances (e.g. 5 km radius around the island). It is also important to note that the results reported below represent the views and opinions of the focus group members only. Although the focus group method is an effective way of obtaining generalized information about the village, it is important to cross-reference it with information from the survey and observation to ensure further accuracy (see Diedrich et al. 2016; Farr et al. 2016).

The results are presented as notes from the focus group interviews with added pictures where relevant. The extensiveness of the notes represents the level of engagement with each of the groups.

Figure 3. Women *Future Vision Exercise.*

Baia Focus Group, *August 23 2016*

A. Participatory Mapping

Description of fishing

The fishing area for Baia villagers extends from Sai to Pandi. All the reefs, rivers and sea within the two rivers are their fishing ground. These include the rivers of Sai, Mavule, Pale, Langalanga, Matabulua, Palao, and Pandi. They do not travel far out into the sea to fish, the furthest they travel is up to 1 km from the shore. They do not follow any specific seasons for fishing; they fish all throughout the year, although they tend to intensify their fishing every new moon when the white bait comes in.

They mainly use spears and handlines to fish. The focus group reported that only one person in the village uses a gill net around the mouth of Pandi and Sai to catch species such as trevally and mullet. They do catch fish once in a while from the rivers, but not often as they prefer marine fish. At the river mouths, they normally catch trevally, Black Bass, and mangrove jack. The reef outside of Silaleve is where they mainly catch red emperor and tuna. Overall, the species of fish they mainly catch from the sea is tuna, red emperor, trevally, marlin, sailfish, ruby snapper, rainbow runner, and mackerel.

Though their fishing area stops at Sai, women tend to go as far as Toriu to collect kina shells. They collect shells from all the rivers listed previously. The black kina shells are collected in rivers while the white ones are collected in the mangrove areas near the village. They also collect clam shells from the reefs just outside of the main Baia village.

Women reported the following distances travelled upstream to collect shells: Toriu (2km), Sai (1 km), Mavulu (300 m), Pale (100 m), Palao, Pandi & Lanaglanga (100 m to 1 km).

Overlap with Tourism

The villagers take tourists to fish in the sea and all the rivers. They reported the following distances up-stream: Toriu (4 km), Sai (2 km), Mavulu (500 m), Pale (200 m), Langalanga (2 Km), Matabulua (1 km), Palao (1 km), Pandi (5 km) (Fig. 4).

In the rivers, the tourists mainly catch Black Bass, spot tail bass, mangrove jack and trevally (even though they said they are not targeted in the rivers). In the sea, they mainly catch tuna, mackerel, rainbow runner, sailfish, trevally, and ruby snapper.

Tourists and locals fish in the same rivers, except for Toriu, which is not their fishing ground (note that women reported going up stream for shells in this river). The group reported no conflicts with the tourists over fishing areas or species. They reported that there is a lack of agreement among communities around tenure and access to the rivers, but that there is agreement with the tour operator and the owners of the rivers; They are all paid an access levy every month by the operator to allow fishing. Participants commented that sometimes, if there is a delay in payment, the owners of the river can prevent the tourists from going fishing.

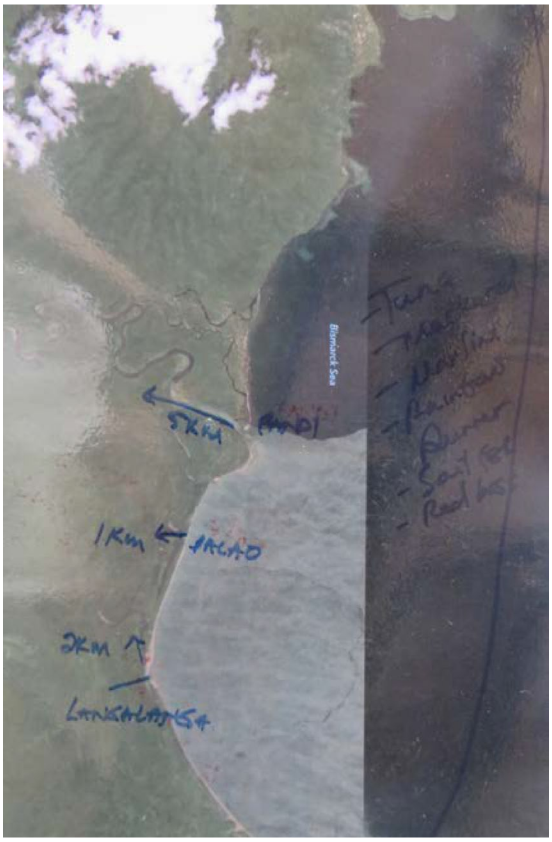


Figure 4. Tourist Fishing Areas, Baia

Access to market

There are several areas where villagers bring their catch and garden produce to sell (including fish, kina shells, betel nut, lime, mustard). All of these market areas are located at logging camps and oil palm plantations and include: Open Bay (logging), Point Mambu (logging), Vatu (logging), Toki (logging), Bakada (oil palm & logging), Ulamona (oil palm), and Sabalbala (oil palm). They go once a week on Saturdays. They do not travel to Kimbe or Bialla to sell their produce as it's far and too expensive.

The reported cost of a return trip to market is:

- Open Bay, K20 (they do not use ice).
- Point Mambu, K50
- Ulamona, K40-50
- Vatu, K5

They typically make K50-K150 from the sales.

Infrastructure

Health: There is a clinic in the village with one nurse. They are in the initial phase of construction of a rural health centre, funded by the WNB government and the Asian Development Bank (ADB). If there is an emergency, the nearest health centre is at Ulamona, but if they cannot get help they go further to Bialla and Kimbe.

Education: The village has an elementary and primary school. There are three teachers in the village who teach across the three schools. They could not estimate the number of students.

Transport: There is a logging road that is near the village but there is no PMV. They travel by boat to Ulamona or Bialla and then get on PMVs to get to Kimbe or elsewhere.

Other: There is no piped water, electricity or mobile coverage.

B. Future Vision

The five items listed by the men were (Fig. 5):

1. A fish market established in the village.
2. Better classrooms and more teachers.
3. Bigger health facility with more health workers to adequately meet their medical needs.
4. Clean drinking water supply. It is very difficult to obtain clean drinking water. They previously had a water supply system but the government failed to maintain it so it is no longer there.
5. A communication tower in or close to the village for ease of mobile phone communication.

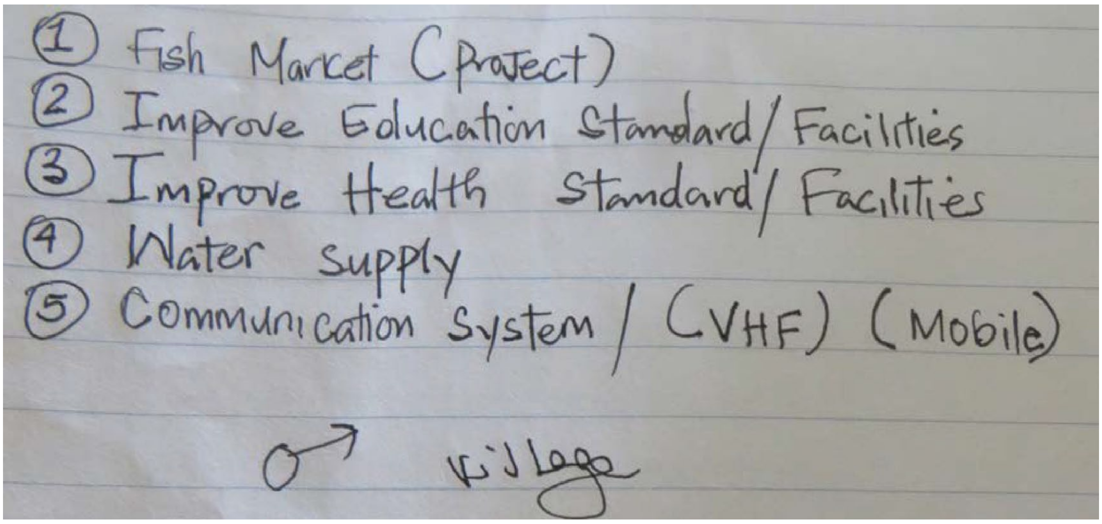


Figure 5. Men's Future Vision, Baia Village.

The five items listed by the women were:

1. Development in the village (they want to improve their overall standard of living).
2. Better services (e.g. transportation).
3. Better houses (i.e. more modern houses).
4. Better health facilities, including a maternity ward and more and better health workers.
5. Better school with good and committed teachers. Currently, the teachers can leave anytime and often do not return for months. This affects the education of their children and the quality of education in the village has dropped because of this.

Notes on individual interview with the village councillor

The town councillor was interviewed individually to scope his views on the potential establishment of a 'field school' in the lodge, to take in students and scientists when the lodge is not being used by sport fishers (e.g. out of season). This is a potential Black Bass project output that has been under discussion this year on the suggestions of some of the villagers. He said he would be happy for that to happen as long as scientists and students do not conduct activities that are destructive to the environment. He specifically wants them to come and conduct studies on the village vulnerability to rising sea level and king tides. He noted that visits up to twice a year would be okay.

The town councillor also mentioned several plans for infrastructure development in the village. These include plans to set up wells in each of the villages and the plans of the provincial government to build classrooms in the school.

We also asked him about his future vision for the community and he listed the following items:

1. The establishment of a tuna cannery.
2. Establishment of aquaculture.
3. A market in the village.
4. Fishing project (e.g. cooperative) so they can fish and sell. They already obtained a generator and freezer from NFA but they have not received any boat yet.
5. He would like the provincial government to purchase a vehicle for the village so they can use it to travel out and sell their catch and produce.

Somalani Focus Group, *August 15 2016*

A. Participatory Mapping

Description of Fishing

Somalani villagers fish 15 – 20 km up the Via river (March – September is the best time of year to fish in the river); fuel is the limiting factor. They also fish at the mouth of the river and about 1 -2 km out from there. They fish most of the year except November and December when they have bad weather.

They catch Black Bass in the river to eat, including lots of other species such as trevally. Black Bass and spot-tail bass tend to be caught further up the river. They catch many other species in the sea including (but not limited to): mackerel, red emperor, marlin, tuna, coral trout, trevally, mullet, rainbow runner, Black Bass, mangrove jack, finger mark. They use lines in the river and gillnets around the mouth of the river (2-5 inches). When they go out to sea they also use purse seines on the reef, although mostly line. They also use spear (Hawaiian sling), which they use to catch mackerel. They use a spear for to kill Black Bass after they have hooked it (Fig. 6).

Figure 6. Spear used to kill Black Bass, Somalani

The women glean mainly around the reef areas (e.g. clam shells) and in mangrove areas (kina shells, crabs, oysters, crayfish, other edible marine shells.) They also go out about 20 – 30 km from the village (north) to collect edible calm shells and other marine shells from the reef.

Overlap with Tourism

Tourists are allowed to go wherever they want in the surrounding sea and up the river. The locals stop around 15-20 km because of fuel constraints (note that this might be tenure related as well). Two other communities own part of the river (paid royalties by the SFT operator as well), although Somalani owns the most. Tourists will go as far as the fuel will take them and they are also taken blue water fishing. There has never been any debate or discussion about where tourists are allowed to go. They are free to go wherever they want and catch whatever they want.

Access to Market

Somalani villagers take their fish to market in Kimbe town; they go when they have fish, maybe 2 – 3 times a week. It is mostly the women who go. They the take a boat to Garu and then PMV to Kimbe. They pay the passenger fare and weight of esky on the motorboat. It involves a lot of expenses including fuel, boat passage, freight. The biggest problem is they don't make ice and they don't have an established market they can go and sit in at Kimbe. This means they have to sell fish openly on the street. They would like an established market. If they make money they sell fish 2 or 3 times a week, if not then only once a week. They have to buy ice in Kimbe, bring it back to the village, keep it cold with the generator and then bring it back to town. On a typical trip one or two women go to market and it takes two or three days to get there. Maybe 3 days selling product, then come back. The whole process takes about a week.

The total cost of going to market (includes return trip and money they spend on ice) is 450 kina for two people.

Infrastructure

Health: There is a medical centre about 1 km from town on the mainland. It has one health extension officer and one nurse and can accommodate about 5 people. If there is an emergency they go there first and then the medical centre calls for help. They are taken to Garu by boat and then catch the ambulance to Kimbe from there.

Education: The primary school is also about 1km from town on the mainland and accommodated about 350 kids ages 5 – 13. There are 7 teachers.

Transport: They do not have good road access; only the logging road and that needs upgrading, so they go everywhere by boat and this is expensive.

Other: There is no fresh water supply so villagers collect rain and water from the Via River. They do not know if it is clean and water is an issue they would like help with. There is no electricity but there are seven freezers in town for personal use and a couple of generators.

B. Future vision

The five items listed by the men were (Note: They first said that education transcends all of their needs ("all are educational messages"), so they represented their vision of all stemming from there (Fig. 7). They also believed all the items were equally important.

1. Permanent market needed because at the moment they have such high expenses to go to Kimbe and they have no specific place to sell. If they had a fixed fish market it would cost less. They would guarantee sales (like a wholesaler) and they would only need to stay for a short while.

2. Sustainable development. Tourism is one aspect of this. It doesn't threaten the environment. It will save this generation and the future generations will benefit.

   "*We don't expect expenses from them. It's one way. We don't spend money to get it back. They just use facilities and give back to the community*."

   As shown at the end of this section, the villagers are building a lodge to accommodate sportfishing tourists and they also get money from the use of the river. There is an agreement already in place to get a proportion of the money from the operator when they use the lodge. It has changed their living standards already.

   We asked if they would like to expand tourism development. They said they are using bush materials on the lodge for now but plan to upgrade. We asked if they were interested in other types. They said they are dreaming of expanding into diving and trekking. They will start with the sportfishing and see how they go and then if other people come in and want to do other types of tourism they will be welcome. The only ones for now are sportfishers. They emphasised that they can come any time so long as they request.

3. Change fishing techniques. They do not want to damage their environment using traditional techniques like poison ropes. They kill all kinds of small fish. They are thinking of doing away with it. Another destructive technique they have been using recently is dynamite. That is really bad. They want people to come in and educate them more about fishing. Also, if they catch bigger fish they have to put it back again as it will produce more. They would like to do that in the future – they don't really do it now. They just want to catch fish and eat. I asked if they understood which fish needed to go back at what size. They said they are just using trial and error – they really want more education to improve their fishing technique and get more fish. We asked what the alternative was to these fishing techniques. They said if dynamite and poison aren't used properly then people can die. It's not that they need more fish – they are not hungry. The want techniques to save more fish for future populations but still be able to catch enough for them to have a meal. The called it "preservation".

4. Environmental impacts. They are not thinking of letting oil palm in. If they plant it up the Via River all the waste will damage the environment and the life chain. If they spoil the river the Black Bass will go, then whatever depends on the Black Bass will go, and the chain of life will be impacts. The impacts of these big companies are really damaging – so they don't accept any of these big companies (logging, mining, oil palm). They have already experienced it through people from the eastern coast who know they made wrong decisions and future generations will be affected a lot. They secure things here for their future generations. The more they save their environment the more they sustain tourism. It's not destructive – they just get money from our resources - "*They just get fish and put it back again*".

5. Improved transportation. The sea transport is ok but they don't have a good road. There is an old logging road from 20 years ago that really needs upgrading. They are asking government for help. This road links to Kimbe and it would be more cost saving than going by sea (via PMV on land). If they had a better road then they could get a permanent market closer than Kimbe.

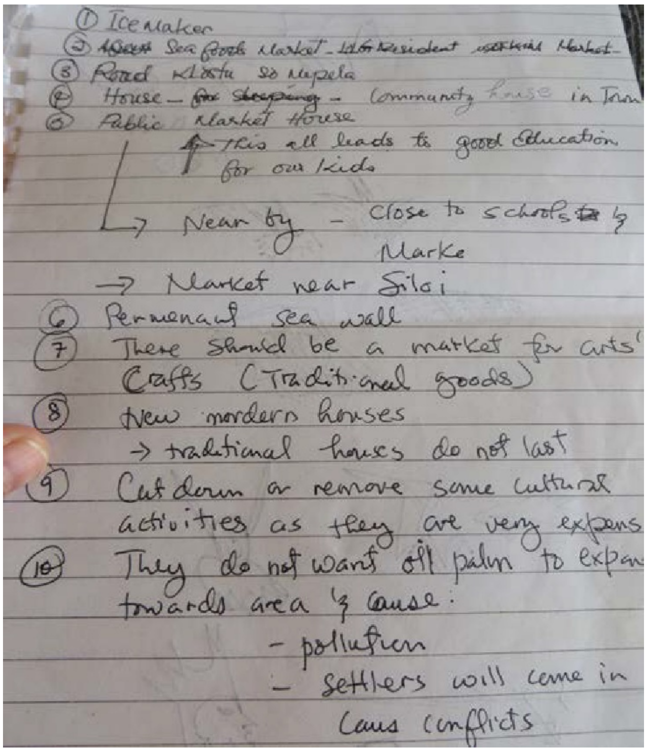


Figure 7. Men's Future Vision, Somalani

They finished up again by emphasising education a lot. They said they are more educated than in other villages; but if they have more facilities and more kids educated then they can educate the rest of the community. Here they don't have proper support from the government. There is no way out unless their government comes up with a solution. They have the highest percentage of educated people in the village. They have a person with a PhD and he lives in the village, not in town. They need more people like that to help them know how to protect their environment and so they know what is going on. So foreigners don't come in and just tell them they want to do this and that with their environment.

The six items (they listed one extra) listed by the women were:

1. An icemaker for the village so they can make ice to preserve the fish and take them to town for market. At the moment, they have to travel all the way into town to buy ice and bring back to the village, which is an extra expense.
2. A seafood market in Kimbe as currently they do not have one. They also want to have a market established by the Local Level Government at Silo (logging company camp) so instead of going all the way into town, they can go there to sell their produce. Also, they think it's best if their community can build a small market on the mainland (close to the school and clinic) so they can sell food to the teachers, the school children and workers and patients at the health clinic

nearby. Further, they want the community to purchase land in town and build a house for the community, which can accommodate them when they go into town to sell their produce and fish.

3. A permanent sea wall around the island to prevent erosion of the land.
4. A craft market in the village so they can sell traditional arts and crafts to visiting tourists.
5. Better houses, especially modern houses. Traditional houses do not last long.
6. Cut down on traditional practices/activities that are costly (e.g. bride price).

They also do not want oil palm near their land, as it will cause destruction to the environment and pollute the river system. They use the big river for drinking water. An incident occurred near Vesse where a heavy rainfall washed chemicals into the sea. It can cause massive mortality to the marine lives. Oil palm will bring in settlers from other areas and cause conflicts and create an unsafe environment for the locals.

Notes on New Sportfishing Lodge up the river

There is currently a sportfishing lodge being built (with support from the operator) upon request by Somalani residents (Figs. 8 & 9). The operator is helping them with the building materials but they are building it themselves. Some of the participants say that guests are coming there in preference over the other lodge (near Vesse) as they think it is too expensive. The place is not complete though and they have been using it as a camp until now. So, they bring the freezer, generator, everything with them. Eventually it will have 4 - 6 cabins for 2–3 people each, a kitchen and dining room area, toilet and shower. From there they can take them to two other rivers owned by other villages.

Figure 8. Sportfishing Lodge, view from Via River

Figure 9. Sportfishing Lodge Kitchen Area

Vesse Focus Group, *17 August 2016*

A. Participatory Mapping

Description of Fishing

The villagers said they do not fish in freshwater but all around the blue-water in every direction out to a distance of 50 – 60 km (out as far as Bali & Vitu island). Sometimes they sleep at sea. They mainly use purse seines and lines. Sometimes they set nets near the river mouth. They fish most of the year (even in November – December when the weather is bad). They catch all kinds of fish including mackerel, red emperor, trevally and tuna.

The women glean mostly on the reef or around mangrove areas; crabs, kina shells and oysters. The dotted line through the sea shows the tenure boundary for the other clan. It only applies to the reef so the men can still go deep fishing there. But the women can't glean.

Overlap with Tourism

They only take tourists 2km up the Kapluk River because it is very shallow. They also take them to Kulu River (it splits so in one direction the go as far as 10 – 15km and in the other they go 7km) and Via River (about 15km as far as the waterfall). Kandoka village owns Kulu River but they let them take the fishers there. Kapluk belongs to Vesse. The Via River belongs to Somalani but some guys who work for the operator are allowed up there. There is no overlap between local fishing practices and tourist activities.

Note: Observation and personal communication indicated that there is some tension in the village in association with the lodge at Uluai. Although the owner is originally from there, some have expressed concern that the benefits are only being shared with her family and not the rest of the village.

Access to Market

The villagers sell most of their fish in Kimbe but sometimes at Silo. The cost of fuel is K28 from village to town and from the town to village it costs K15 kina since fuel is cheaper in Kimbe. Thus, the total money spent on fuel on return trip K43. The PMV from Garu to town is K8.

The eski costs K10 on the boat and they usually bring 1 or 2 depending on how much they catch. Ice is K5 in Kimbe and K10 in Sili. They send money with family/friends going into town to buy ice. If not, they go to Silo and buy ice. They buy 1-4 ice packs, depending on the quantity (K5-K40)

They go to the market once/twice in a week. They sell all their fish in just one day and normally one to two women go to the market.

Expenses for the market comes from other goods they sell in the village such as mats, baskets, shells, food or store goods.

Infrastructure

Health: There is one health centre and it is 20 litres of fuel one-way to get there (around K280). There are 3 nurses there who work there from 7 – 4pm each day. It can accommodate up to 6 people (Fig. 10). If there is an emergency they take a boat to Garu and then catch the ambulance from there to Kimbe.

Education: There is one elementary school on the island; there is 1 teacher and 30+ students. The other school is primary and is on the peninsula to the west. It accommodates 200+ kids and has 4 teachers (Fig. 10).

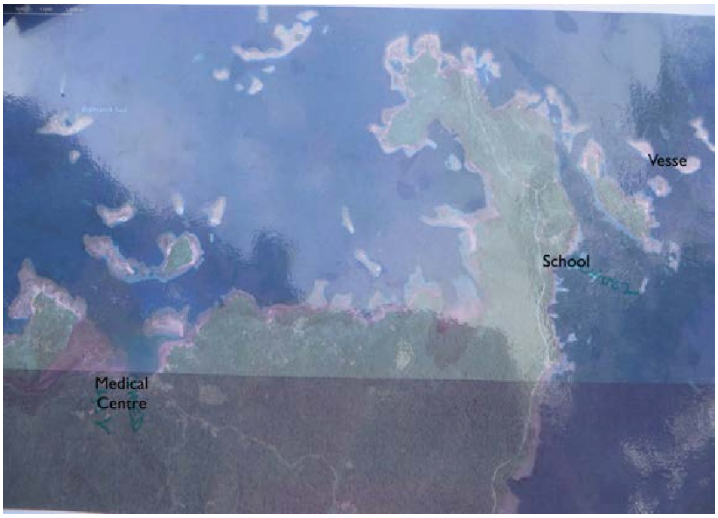


Figure 10. Location of the primary school, Vesse Village

Transportation: They would like more boats to make it easier for them to get to the mainland (Garu).

Other: No electricity or freezers. They have mobile coverage but there is no running water; they collect it from the mainland rivers.

B. Future Vision

The five items listed by the men were:

1. Development – sea walls. They want to build an extension of the island so they can build more houses and accommodate more people.
2. Building more houses (solar light). They want to build more modern houses on this extension and have solar light for them.
3. Sea transport – they would like for every family to have a boat with an outboard motor. Right now there are only 9 and they belong to individuals. People need to go where they want when they want. This will help them go to town when they need to.
4. Fishing cooperative. They want to be able to fish more extensively by forming a cooperative. This will give them the right to get support from the government (e.g. eskies, fishing materials etc.). That means they can fish more and sell more.
5. School, aid post, church.

The five items listed by the women were:

1. A sea wall around the island.
2. More boats for ease of transportation.
3. A water piped supply for the village.
4. If they expand the island, they want a clinic to be built in the village.
5. They want to build new modern houses and a new church (that is, after they expand the island).

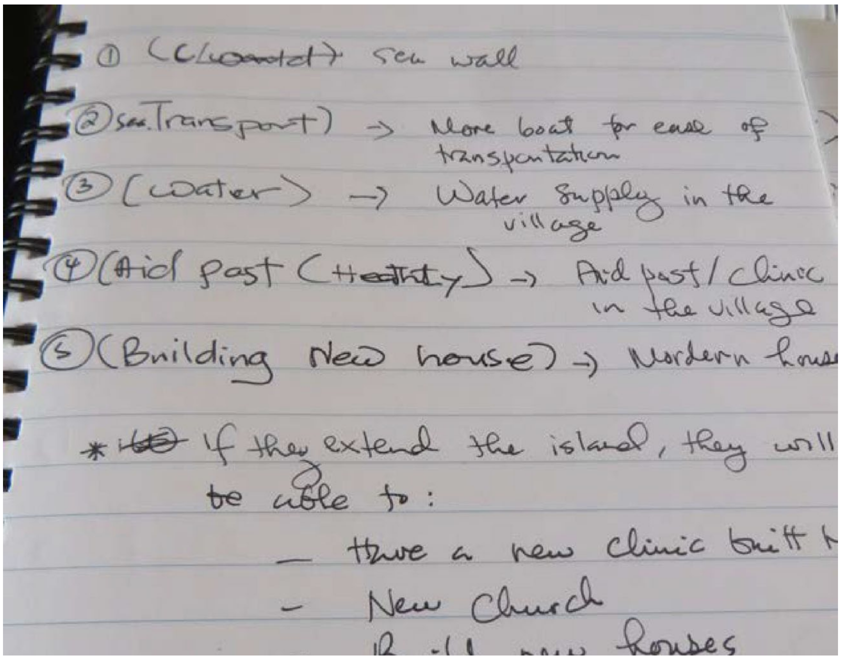


Figure 11. Women's Future Vision, Vesse

Conclusions and next steps

The results of the participatory mapping exercise showed a diversity of fishing grounds and target species for the villages. The main species listed by the focus group participants are reflected in the results of the survey data collected previously, which supports the accuracy of these results (see Farr et al. 2016). This diversity of grounds and target species, the fact that Black Bass is not a primary target, and confirmation from the villagers that they do not consider there to be any conflicts with SFT, are all positive results with respect to future SFT development. However, there was a significant lack of basic infrastructure across the villages, which could act as an impediment to future tourism development. Access to markets is also limited, particularly in Vesse and Somalani, which impedes the efficiency of fishing for sustainable livelihoods. These villages are highly dependent on fishing (Diedrich et al. 2016), so their ability to be able to maintain this practice in a sustainable way is critical. Improving market access and improving infrastructure, if combined with appropriate training, could contribute to improving the efficiency of fishing and supporting further tourism development.

The future visions of the community members were particularly interesting. They share similarities in their focus on the need for basic infrastructure and development, but differ quite significantly with respect to sustainable livelihood pathways. For example, Somalani residents expressed a well-articulated and strong desire to develop sustainable tourism, avoid other less sustainable options (e.g. oil palm, logging), and learn how to fish more sustainably. Vesse residents, on the other hand, expressed a desire to fish more, obtain more boats and develop more houses on the island. In Baia, the village leader supported the prospect of establishing a 'field school' in the lodge to bring in more income when SFT is not occurring. This school would run over the low tourism season, and accommodate researchers and university students that come to stay as part of a learning experience. It would generate income because people would pay to stay at the lodge the same way as sport fishers do. Participant observation and informal accounts from villagers suggested that logging practices are severely impacting their river systems, which could potentially impact their ability to maintain SFT. Identifying alternative livelihood options to extractive industries such as logging could be critical for ensuring a sustainable future for the villages.

The focus groups established two important results: (1) SFT currently does not compete with local fishing practices either spatially or with respect to target species, and (2) the communities have distinct visions for their future development with varied implications for sustainable livelihoods. This latter point warrants more insight into the potential trade-offs and impacts of different livelihood options. These, in turn, will impact the potential for SFT and other sustainable livelihood options to be further established. This point was also raised at the recent project review meeting in Port Moresby earlier this year.

In order to address this need, the Black Bass Project team will conduct a systematic review of the scientific literature relevant to key livelihood options in PNG and the documented impacts and trade-offs among them (e.g. logging, oil palm, tourism, etc.). These results are expected to further contribute to the overall project objective of facilitative sustainable livelihood pathways through SFT in West New Britain.

References

Diedrich A., Farr M., Stoeckl N., Larson S., Pandiahu L., Prideaux M., Kuilber A., Moscardo G. (2016) Sustainable Management of Communities in Papua New Guinea: Report on Western New Britain Survey Results for the Socio-cultural Component. *Report number: FIS/2013/015*, James Cook University, Townsville.

Farr M., Stoeckl N., Larson S., Diedrich A., Prideaux M., Kuilber A., Moscardo G. (2016) Sustainable management of sportfisheries and communities in Papua New Guinead: Economic aspects. *Report number: FIS/2013/015*, James Cook University, Townsville.

11.7 Appendix 7: Household level survey questions

1. **Where are you originally from? Circle one./*As ples b'long yu long we?***

This village/ *Displa ples*	Other village in the region/ *Narapla ples*	Other part of PNG/ *Narapla hap long PNG*	Other country/*Narapla country*
	Which one? /*Wanempla ples?*	Where?/*Wanem hap?*	Which one? /*Wanempla country?*
	______________	____________	____________

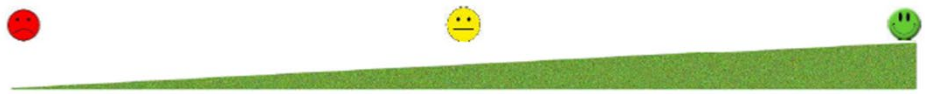
2. **How long have you lived in this village?** ___ all my life OR ______ years
Hamaspla krismas olgeta yu stap long displa ples? *___ laif taim blo mi OR ______ krismas*

If the respondent is not originally from the village ask:

Why did you move to this village?/*Bilong wanem yu kam lo displa ples?* ______________

PART A: LIFE SATISFACTION

3. **Think about your life as a whole – your home, your family, your work, the food you eat, the people you spend time with everything. How satisfied are you with your overall quality of life?** *(Please circle)*
Tingting go bek lo olgeta samting lo laip blo yu – ples/haus blo yu, famili blo yu, wok blo yu, kaikai yu sa kaikai, ol lain yu sa stap wantaim. Yu peelim [bel isi na hamamas] wantaim long gutpla sindaun bilong yu?



0 1 2 3 4 5 6 7 8 9 10

Very unsatisfied
Nogat bel isi na hamamas stret

Very satisfied
I gat bel isi na hamamast stret

4. **Now please <u>think back</u> to what life was like 10 years ago. Was your quality of life better or worse than it is now?** *Please show us on the diagram above, write 'P' (short for past), so we can tell if it is better or worse, and how much better or worse it is.*
Inap yu tingting I go bek long laip bilong yu olsem 10 pla krismas I kam go pinis. Yu ting wanem nau, sindaun bilong yu I kampa gutpela or I no kamap gutpela. *Plis inap yu soim mipla long piksa antap (raitim P) na mipela I ken save sapos laip b'ong yu I kamap gutpela or ino kamapt gutpla*

5. **What could be done to improve the quality of life in your village?/*Wanem kain samting I ken kamap long wokim kamap gutpla sindaun lo ples?***

____

____

6. **Please think about each item on the left hand side of the page (one item at a time) and answer the following questions (if not relevant, write 'not relevant'; if don't know, write DK").** ***Inap yu tingting long lo displa samting long sait bilong pepa (wanpla samting long wanpla taim) na bekim ol askim***

	How important is this to your overall quality of life? *(circle a number please)* *Yu ting wanem? Dispela I bikpla samting long kamapim gutpla sindaun insait long laip blong yu?*	How satisfied are you with this aspect of your life? *(circle a number please)* *Yu ting wanem, yu bel isi na hamamas long displa sait blong laif blo yu?*
Your health & the health of your family. *Helt blo yu na family blo yu*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
The relationships you have with your family and friends *Sindaun blo yu wantaim family na ol poroman blong yu (tokples, pasin tumbuna, kastom, singsing)*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
The relationships you have with others in the village *Sindaun blo yu wantaim ol narapla lain lo ples*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
Leadership within the village *Psain lida long ples*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
The preservation of your culture (language, art, traditions, ritual, music). *Holim strong pasin belong tumbuna (tok ples, pasin tumbuna, tastom, singsing)*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
Your education, the education of your children & the ability to access education Save yu kisim long skul, na save pikinin blo yu kisim long skul	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
The food you are able to collect from the sea, rivers and land (e.g. the amount (and size) of fish you are able to catch, the number of turtles). *Ol kaikia yu inap long kisim lo solwara, long wara na long giraun (kain oolsem ol hamas pis yu inap long kisim na namba bilong ol torosel)*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
The amount (and quality) of other food you & your family are able to grow or farm locally *Hamaspla gutpla kaikai yu na family blo yu inap long planim ples*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
The health of your local environment (e.g. the health of local rivers, forests, plants and animals). *Gutpla blo bus graun blo yu (olsem gutpla blong wara, bus na ol gras,diwai na binatan na abus)*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
The material/physical things you own (clothes, mobile, cooking utensils etc.) *Ol kago yu gat (kolos, momil fon, sospen na ol samting bilong kuk)*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied
Your ability to find a paid job/employment *Rot blo yu long painim wok moni*	0 1 2 3 4 5 6 7 8 9 10 Very unimportant … Very important	0 1 2 3 4 5 6 7 8 9 10 Very unsatisfied … Very satisfied

7. **What is the biggest change that has occurred within your village in the last 10 years?/ *Wanem kain bikpla senis stret is bin kamap long ples blo yu olsem tenpla yar I kam go pinis?***

Change (*Senis*) ____

What do you think has happened to cause that change?/ *Wanem kain samting yu ting I bin kamap long wokim kamap displa kain senis?*

Causes/reasons for the change /*Ol as bilong displa senis*

____
____
____

Overall, please tell us whether the changes have been mainly good, mainly bad or a mixture of good and bad. /*Lukluk igo bek, inap yu tokim mipla sapos displa ol senis I bin gutpla stret , I nogut stret or igutpla na nogut wantaim.*

Mainly bad *Gutpla stret*	A mixture of good and bad *Gutpla na nogut wantaim*	Mainly good *Nogut stret*

What aspects of your life have changed the most?/ *Wanem kain samting lo laif blo yu I bin senis bikpla stret?*

Aspects of life that have changed most/*Samting lo laif blo yu we bikpla senis stret I bin kamap*

____
____
____

8. **What is the biggest change that you think is likely to happen in the village in the next 10 years?/ *Wanem kain bikpla sensis we yu ting I bai kamap insait long peles lo tenpla yar time?***

Change/Senis____

____

What do you think will cause/drive that change?/ *Yu ting wanem samting bai kamapim dispela senis?*

Causes/reasons for the change/ *Ol as b'long displa senis*

____
____
____
____

Overall, please tell us whether you think the changes will be mainly good, mainly bad or a mixture of good and bad. /*Olgeta yet, inap yu tokim mipla sapos displa ol senis I bai gutpla stret , I nogut stret or igutpla na nogut wantaim*

Mainly bad *Gutpla stret*	A mixture of good and bad *Gutpla na nogut wantaim*	Mainly good *Nogut stret*

What aspects of your life are likely to change the most?/*Wanem samting lo laip blo yu, yu ting bai I gat bikpla senis?*

____

____

9. What type of leadership is practiced in in your community? /*Wanem pasin bilong lida yupla I save behainim insait long dispel ples?*

-
- Chieftain/Big-man/Counsel/Inheritance/Others *Chif/bik-man/kansol/narapla*

10. I now have a few questions about you and the people in your village. Please tell us how much you agree or disagree with the following statements/*Nau mi gat sampla askim lo mekim lo yu na ol lain lo ples. Inap yu tokim mipla sapos yu wanbel o ino wanbel wantaim ol toktok bai me we wokim*

I trust the people in my village / *Mi bilip long ol lain long ples blo mi*

0 1 2 3 4 5 6 7 8 9 10

Strongly disagree / *I no wanbel stret* — Strongly agree / *Wanbel stret*

People in this village are generous and share what they have with other people / *Ol lain lo displa ples ol gutpla lain na I save skelim gut ol samting wantim ol narapla lain*

0 1 2 3 4 5 6 7 8 9 10

Strongly disagree / *I no wanbel stret* — Strongly Agree / *Wanbel stret*

-

11. Do you belong to any community organisations/committees? YES / NO
You stap insait long wanpla grup or komiti insait long ples? YES/NOGAT

If "YES" please list/ *Sapos 'yes', plis kolim hamaspla*:

____

____

PART B: The following questions are about the activities that you and the members of your household do to bring food and money into the house? /*Ol askim mi bai mekim nau em long ol samting yu na ol lain lo haus blo yu I save mekim lo kisim kaikai na mani I kam long haus?*

12. Please respond yes or no to each activity and then fill out more information if needed (at household and individual level). At the end, ask the respondent to rank the activities in order of how important they are in their household. /*Plis bekim yes o nogat long ol wanwan samting yupla sa mekim*

6. ACTIVITY *Samting yupla sa mekim*	Household *Olgeta lain lo Haus* Yes or No (household)/ *Yes or nogat (ol lain lo haus)*	If yes ...... How many people/ *Sapos yes--hamaspla lain*	Individual *Wanwan* Do you do it? Yes/No *Yu save wokim? Yes/nogat*	Rank of Importance to household (1 most important)
Fishing/ *Painim pis*				
Collecting aquatic species (e.g. clams)/ *Painim ol narapla samting lbilong solwara na wara olsem ol kina sel*				
Growing crops/ *Plainim ol kaikai*				
Collecting bush products outside garden/ *Painim ol samting long bush, ino lo gaten*				
Salaried employment/ *Wok moni?* What/*Wanemkain?* ____________				
Other/*Narapla*: ____________				

13. How much of the food that your household catches and grows do you sell in one year? ***/Hamaspla kaikai yu planim lo garden na save kisim long bush, wara na solwara yu save salim insait lo wanpla ya?***

0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10

Nothing *Nating* — About one half *Tasol* — Almost all *Klost olget yet*

Other response/*Narapla ol bekim* :____________________________

14. Which two products (e.g. crops, fish) or activities (e.g. paid employment) brought in the most money for your household last year? Please list the one that brings in most money first. ***/Wanempla tupla samting (kain olsem ol gaden kaikia, pis) or rot blo kisim money (wok moni) I kisim mo mani I kam insait long haus family bilong yu long yar I kam go pinis. Plis putim displa sa kisim mo mani kam I go pas.***

i. ________

ii. ________

15. Would you be interested in selling more of your products? Yes__ No__
Bai yu I gat laik lo salim planti mo b'long ol displa samting I save bringim mo mani?
Yes__Nogat__

If "yes", what would you need to be able to do this/ *Sapos "yes", wanem samting bai yu nid lo mekim lo wokim em I isi lo yu long wokim displa?* ____________________________

____

For FISHING households only

16. How often do you fish (approximately) ____ days per week OR ____days per months
Hamaspla taim yu save go painim pis*___dei long wanpla wik (enap 7 days) Or.........dei long wanpla mun*

17. I would like to know a bit about your fishing. I realize that some days you catch a lot of fish, other days you may not catch many fish./ ***Mi laik save mo long sait b'long yu long go painim pis. I luk olsem sampla dei yu sa kisim planti pis, sampla dei yu no sa kisim planti pis***

	Fish to feed family	Fish to sell in the market
Daily effort	People/ *Hamaspla lain*: Hours/ *Hamaspla haua*:	People/ *Hamaspla lain*: Hours/ *Hamaspla haua*:
Catch (let them define the unit)/ *Hamaspla pis*		
Estimate of how much you could get if you sold this in a local market/ *Hamaspla mani bai yu ksim sapos yu salim ol displa pis (even if for family only)*		

18. In general, what are the two most important species of fish that you catch in your household (important for food or for other reasons) / ***Lo ogleta pis yu save kisim, wanem displa tupla pis I mo gutpla (blo kaikai, blo salim, or blo wok kastom)?***

i. ________
ii. ________

19. What fishing equipment do people in your household use to catch fish? *(please list all of them)/* ***Wanem kain smating bilog ketsim pis ol lain lo haus blo yu I save usim lo go painim pis***

____

20. If you were to get only half of you usual catch <u>all year</u> what would you do?/ ***Long question 14 yu bin tok olsem yu save kisim xx number blo pis. Sapos long wanpla yia namaba blo pis yu save kisim I go daun olsem haf (1/2 blo xx), bai yu mekim wanem?***

Fish same / fish harder / fish less / move fishing area / change fishing method / stop fishing / don't know
Bihainim wankain wei blo kisim pis /traim hat lo painim mo pis / noken go painim pis tumas/go lo narapl hap na painim pis/senisim wei blo painim pis/ stop lo go painnim pis/ mi no save

Other/*Narapla*:____

For FARMING households only

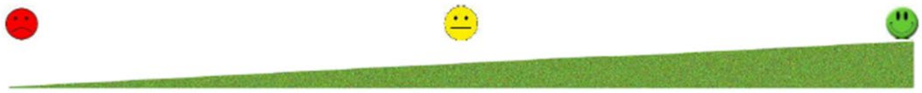
21. If you were to get only half the crop you usually get <u>all year</u> what would your household do?/ ***Sapos ol kaikai yu planim lo garden, half blo ol kaikai I no kamap or karmim kaikai insait lo wanpla ya, wanem samting bai yu wantaim ol lain lo haus b'long yu I wokim?***

Farm same / farm more / farm less / move farming area / change crop / stop farming / don't know
Planim wankain kaikai/ planim mo kaikai/ planim liklik kaikai/ go plainim kaikai lo narapla hap/senisim ol kaikai lo garden na planim nupla kaikai/ stop wokim gaden/ mi no save

Other/*Narapla*:____

For ALL households

22. **Are there more or less fish around your village than there were 5 years ago? Circle one.** ***/Inap yu tingting go bek lo 5 pla yia Igo pinis. Lo lukluk blo yu nau, yu ting igat mo pis lo wara/solwara klostu lo ples or ino gat mo planti pis***



0	1	2	3	4	5	6	7	8	9	10
A lot less					About the same					A lot more

Ino planti tumas *Wankain tasol* *Planti mo*

23. **What can affect the number of fish? If you don't know write "don't know"/** ***Yu ting wanem samting I mekim ol namba blo ol fish I stap olsem?, Sapos yu no save orait yu ken I tok, 'yu no save'.***

____

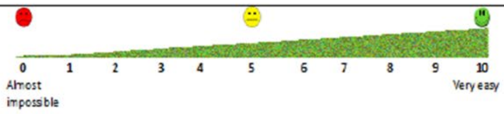
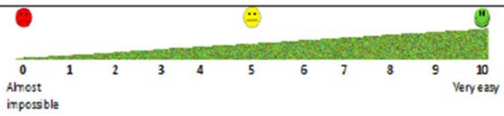
____

PART D: Tourism

24. **Would you or someone in your household be interested in becoming more involved in tourism?** ***/Bai yu o sampla lain lo haus blo yu I gat laik long wok mo long ol turis wok o laik wok wantim ol samting bilong kiraoim laik bilong ol turis na kisim ol I kam?***

-

Yes ___ No ____ Don't know ___ If yes, please fill out the table below
Yes_____nogat_____Mi no save____ Sapos yes, pulapim tabol tamblo

7. *(e.g. you, daughter)/ Husait? (kain olsem yu, pikinini meri)*	What would you/they like to do?/ *Bai yu o ol displa lain long haus bai laik lo wokim wanem kain wok?*	How easy or difficult would this be?/ *Yu ting em bai esi or hat long wokim samting or wokim wok blo turist?*
		 *I hat stret* *I esi stret ?* If difficult, what makes it difficult?/ *Sapos I hat, wanem samting it wokim em I hat?*
		 *I hat stret* *I esi stret ?* If difficult, what makes it difficult?/ *Sapos I hat, wanem samting it wokim em I hat?*

PART E: FINAL QUESTIONS – DEMOGRAPHICS

25. Age/ *Krismas* ___

26. Gender/ *Man/Meri* M / F

27. Number of people in Household/ *Hamaspla lain save stap long haus blo yu* ______

28. What is your role in the household (e.g. father, mother)/ *Hap wok b'long yu long displa haus I olsem wanem (kain olsem mama, papa)?* ____________________

29. What grade were you in when you finished school/ *Yu bin pinis skul lo wanem grade?* _____________

30. In the last year, roughly how many times have you traveled out from your village? ________times

Insait lo last yia, hamaspla taim yu bin lusim ples na go raun na kam?___________taim

31. If at least once, where do you usually go/ *Sapos yu bin go out wanpla taim, yu go we stret?* _____________________________

What is your main reason for going/ *Lo wanem as yu bin go aut na raun?* _______________________

FINAL SECTION FOR INTERVIEWER TO COMPLETE WITH SUPPORT OF THE RESPONDENT

32. Household items & facilities. Please tick if present; if more than 1, write the number (* if shared with village or other families

-

Generator	Electricity	Car battery	Air Conditioning
TV	DVD	Satellite dish	Refrigerator
Electric fan	Radio/cassette/CD	Piped water	Mobile phone
Internet access			

Lighting

Nothing	Kerosene wick	Candle	Hurricane lamp	Light bulb

Transport

Boat With motor? Y / N	Other vehicle: Please list: ______ Type:

Cooking

Firewood	Charcoal	Kerosene	Gas/electric

Roof material

Thatch	Metal	Tile	Other

Floor material

Dirt/soil	Bamboo/palm	Plank Wood	Cement	Finished (tiles, etc.)

Wall material

Bamboo/ thatch	Wood (plank)	Stone block	metal	Cement	Other

33. Finally, if we come back in the future, would you mind if we asked you more questions related to this project?

If yes, ask for name and cross reference with number in notebook

11.8 Appendix 8: Community data summary sheets

Sustainable Management of Sportfishing Communities in Papua New Guinea: Community Data Summary Sheets

ACIAR Project Number FIS/2013/015

August 2016

In August 2016 Lina Pandihau from the PNG National Fisheries Association and Amy Diedrich from James Cook University returned to the three communities that participated in the socio--economic surveys (Baia, Somalani, Vesse) to provide feedback of the survey results to the communities and conduct follow up focus group interviews to match future visions with targeted groups of men and women. The attached information sheets comprise the materials (verbally and in hard copy) that were presented to the study communities.

Summary of Survey Results for Baia, Silaleve and Loiloi

- In August 2015 a social science team from James Cook University and PNG National Fisheries Authority worked with local volunteers to interview 34 households in Baia, Silaleve and Loiloi Villages.
- We spoke with 22 men and 12 women from all age groups (18 – 50 + years old).
- We wanted to learn more about how satisfied you and the people in your household were with your lives and what you thought was most important to your overall quality of life. We also wanted to know what you thought about the changes that had happened in your village in the last 10 years, and to learn more about how your family spends its time – fishing, farming, working for someone else, and what your interest is in becoming more involved in tourism.

This is what the people in your village said:

Satisfaction with Quality of Life

- Overall, people were very satisfied with their quality of life.
- Most people had seen a big improvement in quality of life over the last 10 years.
- Villagers placed the highest importance on the food they were able to collect from the sea, rivers and land; on their own health and health of their family; and on the health of their local environment.

What can be done to improve quality of life in the village?

- The most important aspect for improving quality of life was cooperation, sharing, and trust among people.
- People also thought it was important to have more income opportunities, better education, infrastructure, and health facilitates.

What have been the biggest changes in the village in the last 10 years?

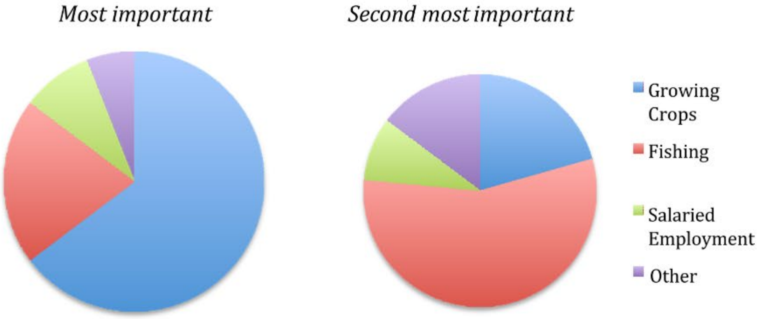
- Nearly two--thirds of the households said that changes in the village in the last 10 years were mainly good; less than 5% said they were mainly bad.
- The most positive changes were better school and education, better health services, new church, better transportation and roads, water tanks, and increased income.
- The villagers said that most of these positive changes came from sportfishing tourism and from support from the Provincial Government.
- Some people thought there were negative changes to the natural environment from logging.

Has the quantity of fish around the village changed in the last five years?

- Overall, people believed the number of fish has decreased a bit in the last five years.
- Some people believed this was because of use of poison vines and dynamite, overfishing and logging.

What are the most important activities in the households?

- Growing crops and fishing are the most important activities from bringing food and income into the households.



- Fish and sago are the most important activities for income, followed by gardening.
- Villagers are very adaptable in their fishing and farming activities; they are willing to try new techniques and locations if there were changes in the availability of natural resources.

Which are the most important fish for money?

- Red Emperor was the most important fish for most people followed by trevally, tuna, ruby snapper, mackerel and mullet.

Trust and sharing in the village

- Villagers are very trusting of each other and believe that other people in the village are generous and share what they have with others.

What do villagers think about tourism?

- Almost all (more than 80%) of the people interviewed said one or more members of their household would like to be more involved in tourism.
- Most men were interested in become fishing guides or skippers (and some women as well!).
- Many women were interested in housekeeping and cooking.
- Overall, people thought it would be easy to become more involved in tourism, although many people said some additional training would be helpful.

What does all of this mean?

- These results show a community that is developing in a positive way.
- They show a community with good conditions for future positive change; trust, sharing, flexibility, interest in improved education and health, interest in getting involved in new activities such as tourism.
- The results show the community is benefiting from sportfishing tourism and -through more collaboration with this project, we hope you will continue to grow these benefits.

For more information contact:
Amy Diedrich amy.diedrich@jcu.edu.au or Lina Pandiahu lpandihau@fisheries.gov.pg

Summary of Survey Results for Somalani

- In August 2015 a social science team from James Cook University and PNG National Fisheries Authority worked with local volunteers to interview 68 households in Somalani.
- We spoke with 51 men and 17 women from all age groups (18 – 50 + years old).
- We wanted to learn more about how satisfied you and the people in your household were with your lives and what you thought was most important to your overall quality of life. We also wanted to know what you thought about the changes that had happened in your village in the last 10 years, and to learn more about how your family spends its time – fishing, farming, working for someone else, and what your interest is in becoming more involved in tourism.

This is what the people in your village said:

Satisfaction with Quality of Life

- Most people were satisfied with their quality of life, although about 40% felt it could be improved.
- Overall, people saw some improvement in quality of life over the last 10 years.
- Villagers placed the highest importance on education and the ability to access education.

What can be done to improve quality of life in the village?

- The most important aspect for improving quality of life was more opportunities for generating income.
- People also thought it was important for there to be cooperation, trust and sharing among people in the village, along with better infrastructure, transport, education, and a better market.

What have been the biggest changes in the village in the last 10 years?

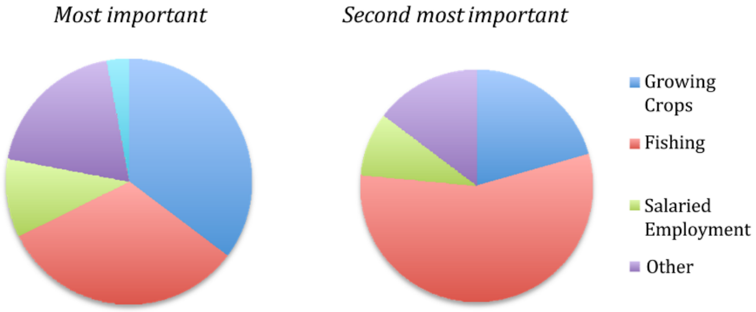
- Nearly everyone said that changes in the village in the last 10 years were mainly good.
- The main benefits were modern houses, better transportation and better telecommunication services.
- Most of the benefits were thought to be due to the hard work of individuals, educated family members, and the timber logging company.
- Some benefits were also seen as being due to community efforts to progress (i.e. in telecommunications and tourism).

Has the quantity of fish around the village changed in the last five years?

- Overall, people believed the number of fish had increased a bit in the last five years.
- Some people believed this was because of a healthy environment, rich river and sea resources, local involvement in conservation, and lack of oil palm plantations.
- Those who did report a decrease thought it was due to overfishing from diversification of methods, the use of poison vines and changes in weather.

What are the most important activities in the households?

- Growing crops, fishing, and other types of activities (making mats, sago, baskets, shell money and selling betel nut) are the most important activities from bringing food and income into the households.



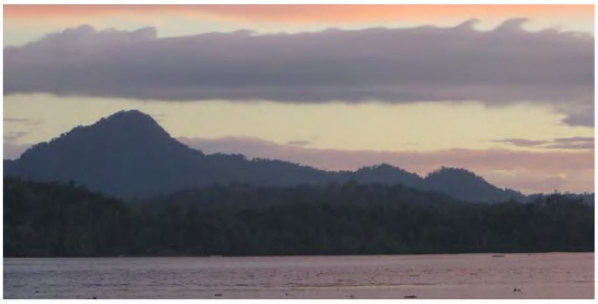
- Fish and sago are the most important income generating products, followed by gardening, paid employment and mat making.
- Villagers are very adaptable in their fishing and farming activities; they are willing to try new techniques and locations if there were changes in the availability of natural resources.

Which are the most important fish for money?

- Red Emperor and mackerel were the most important fish for most people followed by mullet, tuna, and trevally.

Trust and sharing in the village

- Villagers are very trusting of each other and believe that other people in the village are generous and share what they have with others.



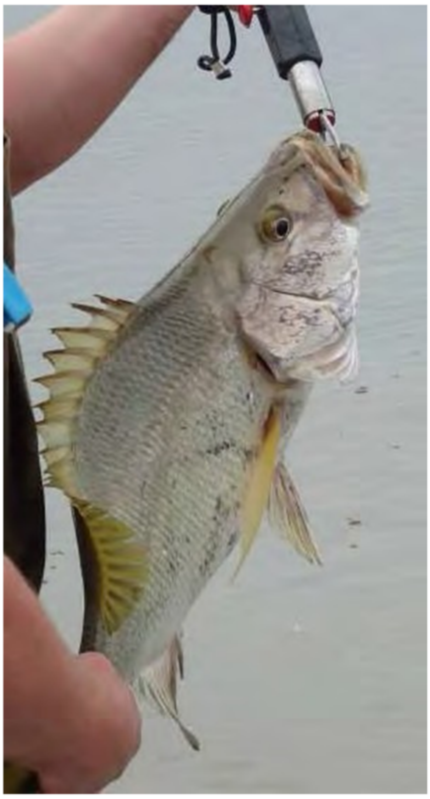
What do villagers think about tourism?

- Almost all (close to 80%) of the people interviewed said one or more members of their household would like to be more involved in tourism.
- Most men were interested in become fishing guides or skippers and women were mainly interested in housekeeping and cooking.

- A number of people also said they were interested in building some accommodation for tourists.
- Overall, people thought it would be easy to become more involved in tourism, although many people said some additional training would be helpful.

What does all of this mean?

- These results show a community that is developing in a positive way but where some people would like to see improvements in quality of life.
- They show a community with the capacity to engage in new business ventures and to continue to improve standards of living in the community.
- The results show the community could benefit from engaging more with tourism and -through more collaboration with this project, we hope you be able to grow these benefits.



For more information contact:
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Summary of Survey Results for Vesse

- In August 2015 a social science team from James Cook University and PNG National Fisheries Authority worked with local volunteers to interview 55 households in Vesse.
- We spoke with 42 men and 13 women from all age groups (18 – 50 + years old).
- We wanted to learn more about how satisfied you and the people in your household were with your lives and what you thought was most important to your overall quality of life. We also wanted to know what you thought about the changes that had happened in your village in the last 10 years, and to learn more about how your family spends its time – fishing, farming, working for someone else, and what your interest is in becoming more involved in tourism.

This is what the people in your village said:

Satisfaction with Quality of Life

- Most people were satisfied with their quality of life, although about 40% felt it could be improved.
- Overall, people saw some improvement in quality of life over the last 10 years.
- Villagers placed the highest importance on education and the ability to find a paid job.

What can be done to improve quality of life in the village?

- The most important aspect for improving quality of life was more opportunities for generating income.
- People also thought it was important for there to be cooperation, trust and sharing among people in the village, along with better infrastructure, transport, education, and a more access to fish and garden resources.

What have been the biggest changes in the village in the last 10 years?

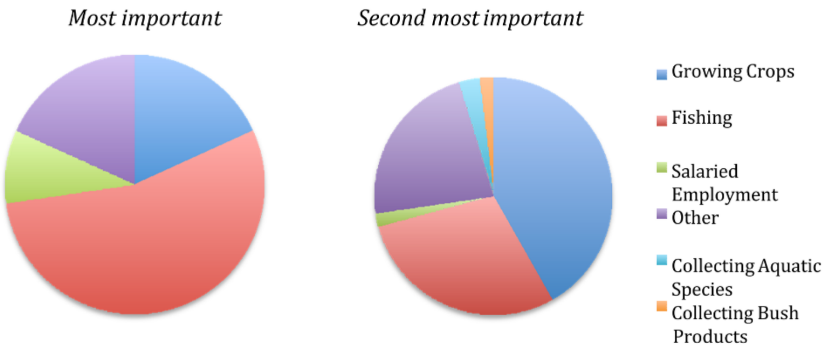
- Nearly everyone said that changes in the village in the last 10 years were mainly good.
- The main benefits were an increase in income and other monetary benefits, better transportation and better education services.
- Benefits were believed to be due to the presence of the oil palm company, the timber logging company and sportfishing tourism; which led to the ability to sell fish and products.
- More than a quarter of people said there had been no change in the last 10 years. Oil palm and logging industries were also thought by some people to be bringing negative changes such as population pressure and deterioration of the natural environment.

Has the quantity of fish around the village changed in the last five years?

- Overall, people believed the number of fish had not changed in the last five years.
- Those who did report a decrease thought it was due to overfishing (with a diversification of methods), changes in weather/seasons and the use of poison vines and dynamite.

What are the most important activities in the households?

- Fishing and growing crops are the most important activities from bringing food and income into the households.
- Other activities such as making baskets, shell money, making lime and selling betel nut were important.



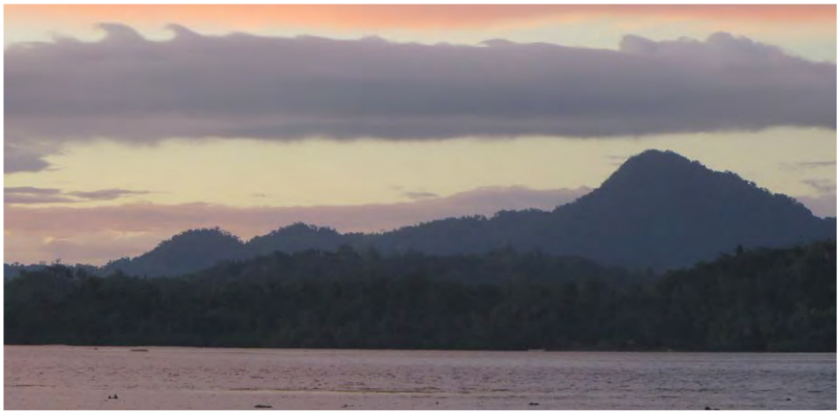
- Fish, mats and garden crops are the most important income generating products in the village.
- Villagers are very adaptable in their fishing and farming activities; they are willing to try new techniques and locations if there were changes in the availability of natural resources.

Which are the most important fish for money?

- Red Emperor and mackerel were the most important fish for most people followed by tuna, and trevally.

Trust and sharing in the village

- Villagers are very trusting of each other and believe that other people in the village are generous and share what they have with others.

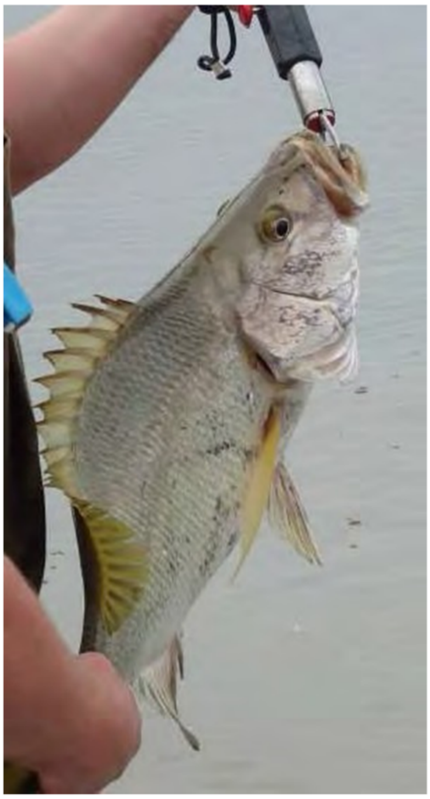


What do villagers think about tourism?

- Almost all (close to 90%) of the people interviewed said one or more members of their household would like to be more involved in tourism.
- Most men were interested in become fishing guides or skippers and women were mainly interested in housekeeping and cooking.
- A few people also said they were interested in building some accommodation for tourists.
- Overall, people thought it would be easy to become more involved in tourism, although many people said some additional training would be helpful.

What does all of this mean?

- These results show a community that is developing in a positive way but where some people would like to see improvements in quality of life.
- They show a community with the capacity to engage in new business ventures and to continue to improve standards of living in the community.
- The results show the community could benefit from engaging more with tourism and -through more collaboration with this project, we hope you be able to grow these benefits.



For more information contact:
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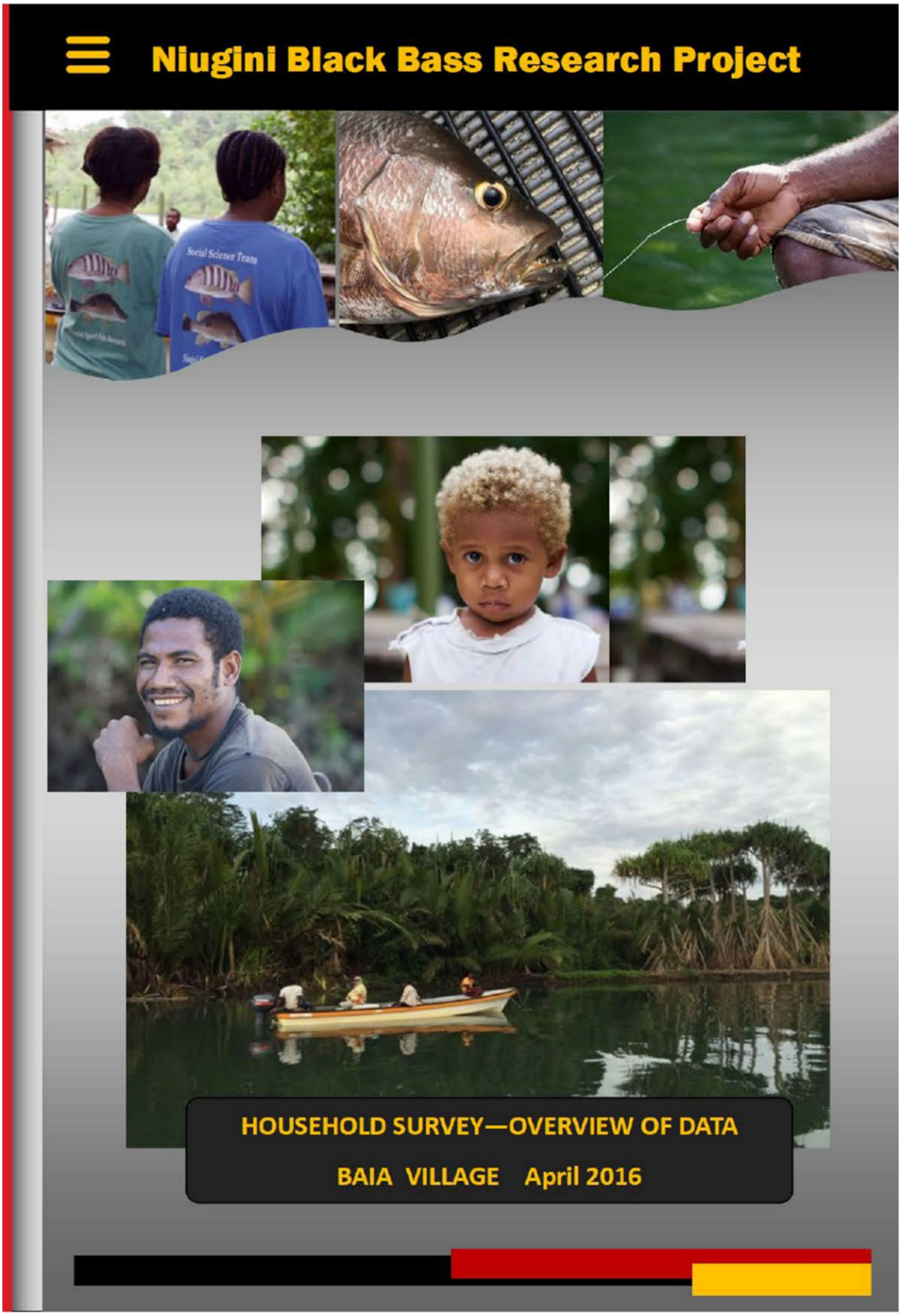
11.9 Appendix 9: Economic survey factsheets



Household Survey — overview of data

SNAPSHOT

- In June 2015 we interviewed 34 people from 34 households. 65% of participants were males and 40% were aged between 20-30 years old
- 40% of participants had not left the village during the last year
- 85% of participants said that they or someone from their household would like to be more involved in the tourism industry

We asked people how satisfied they are with their overall quality of life (QOL) now and 10 years ago .

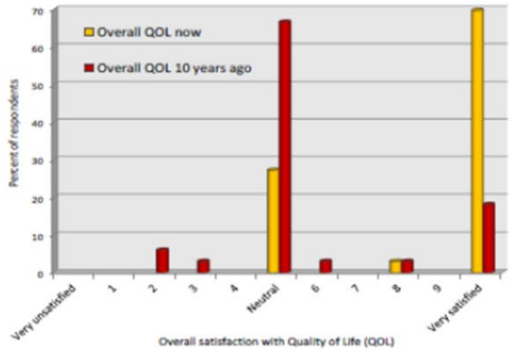


Figure 1. Overall satisfaction with quality of life now (yellow) compared to 10 years ago (red)

And we asked them to tell us what grade they completed at school.

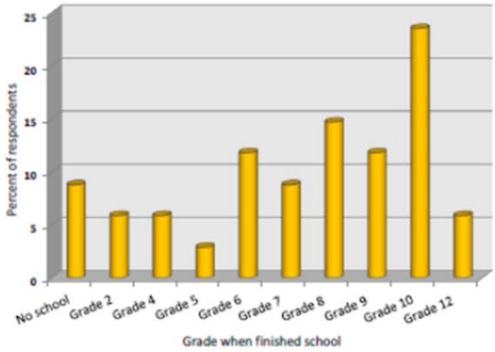


Figure 2. Grade when finished school

IMPORTANCE OF AND SATISFACTION WITH DIFFERENT ASPECTS OF LIFE

We asked people to tell us how important different things were to their overall quality of life (red lines in Figure 3), and how satisfied they were with them (yellow lines). The closer a red line is to the centre of the circle, the less important it is. The closer a yellow line is to the centre of the circle, the less satisfied people are. If people feel something is very important to them and they are dissatisfied with it, then there may be a cause for concern—in this graph it seems that most concern relates to the health of the local environment.

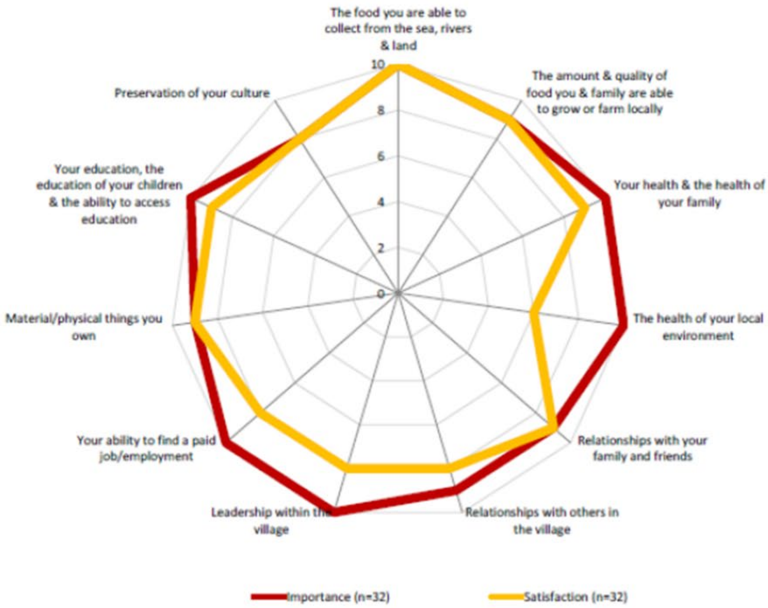


Figure 3. How important are different factors to your overall QOL (red lines) and how satisfied are you with those factors (yellow lines) (0 if very unimportant/very unsatisfied; 10 if very important/very satisfied)?

Household Survey — overview of data

CHANGES IN THE LAST 10 YEARS

We asked people to tell us about the biggest change they had experienced in the last ten years— what it was (Figure 4 shows the most frequent changes mentioned), and whether the change was mainly good, mainly bad or a mixture of good and bad. Changes to the right of the black line are 'mainly bad' changes, and those to the left are the good ones. Nearly two-thirds of households indicated that changes were mainly good; less than 5% said they were mainly bad. We then asked people to tell us what they thought had caused the changes. Most attributed changes to sportfishing tourism (shown in red) and to the West New Britain (WNB) Provincial Government (yellow).

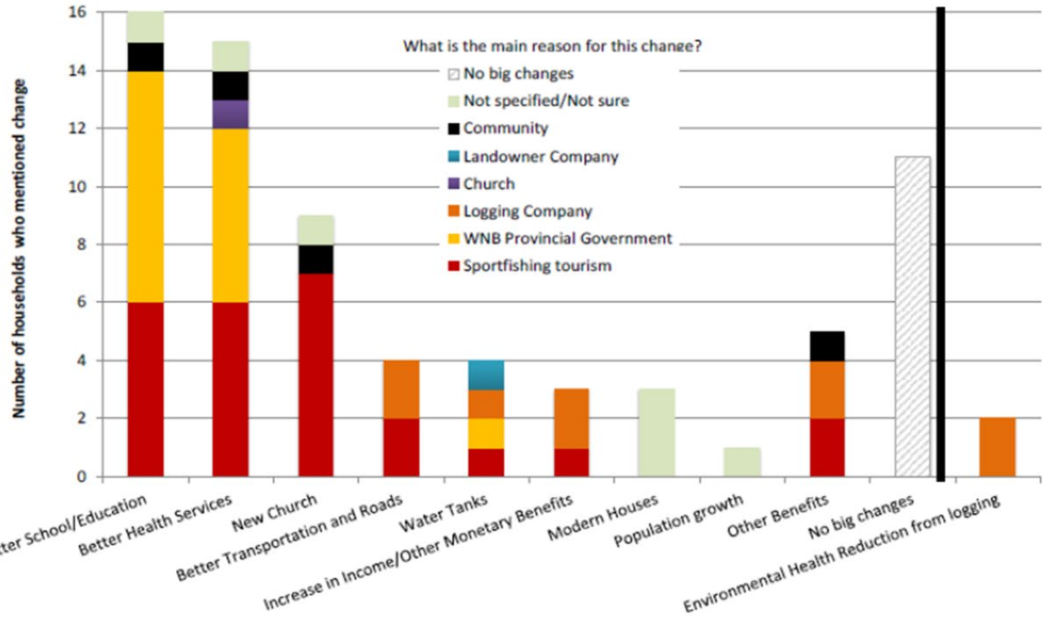


Figure 4. The biggest changes that have occurred in the village in the last 10 years and reasons for that change

CHANGES IN THE FUTURE

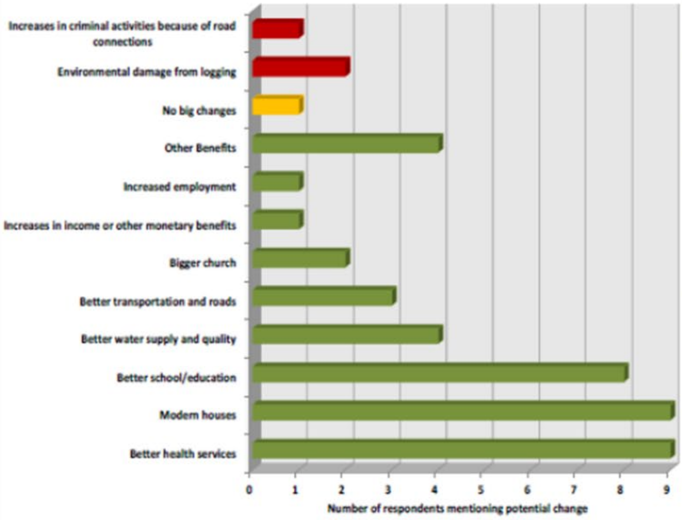


Figure 5. Changes that might occur in the village in the next 10 years

We also asked people to tell us about changes that might happen in the village in the next 10 years. 68% thought that changes would, overall, be good; others thought the changes would likely be a mixture of good and bad.

Better health services, more modern houses, better education and better water supply were the most frequently mentioned changes and these were seen to be mainly 'good' (shown in green, Figure 5). Some people were concerned about the potential for environmental damage from logging ('bad' changes shown in red).

Household Survey — overview of data

THE IMPORTANCE OF FISH AND FISHING FOR INCOME AND LIVELIHOODS

We asked people to rank various activities according to how important they were as a way of getting food (Figure 6) and to tell us which two activities/products were most important as a source of income (Figure 7).

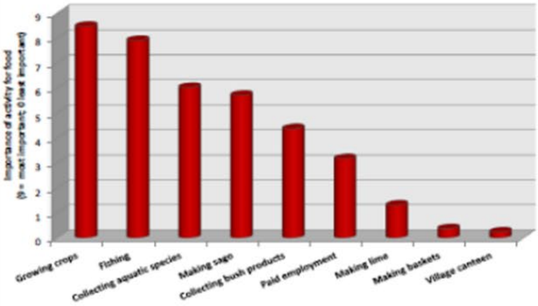


Figure 6. Most important ways of getting food

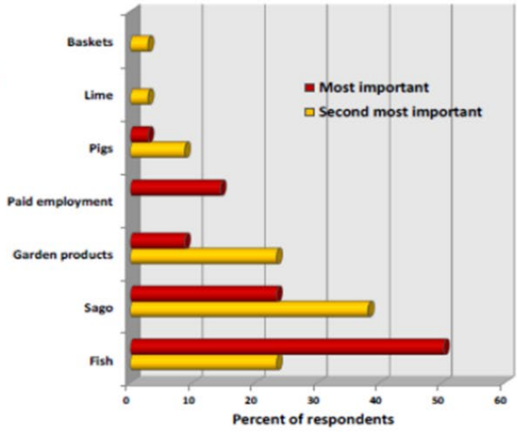


Figure 7. Most important ways of earning money

We asked people to tell us which two species of fish were most important to them (for food or for other reasons) and what fishing gear they used to catch fish.

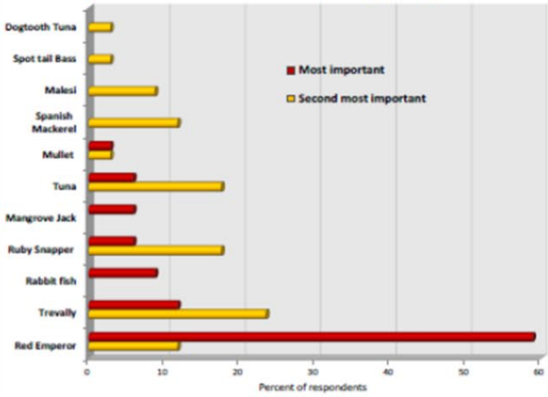


Figure 8. Most important species of fish

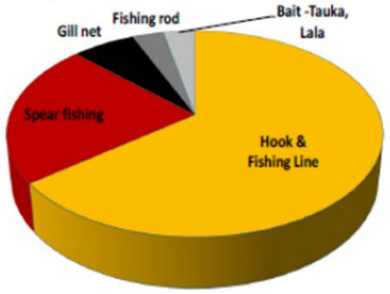


Figure 9. Fishing equipment

CHANGES TO FISH AVAILABILITY IN LAST 5 YEARS

Households were asked to tell us if they thought there were more or less fish near the village now compared to five years ago. If different, we asked what they thought had caused the change (Figure 10). Use of poison and dynamite, and overfishing were seen as main reasons for reduced availability of fish near the village.

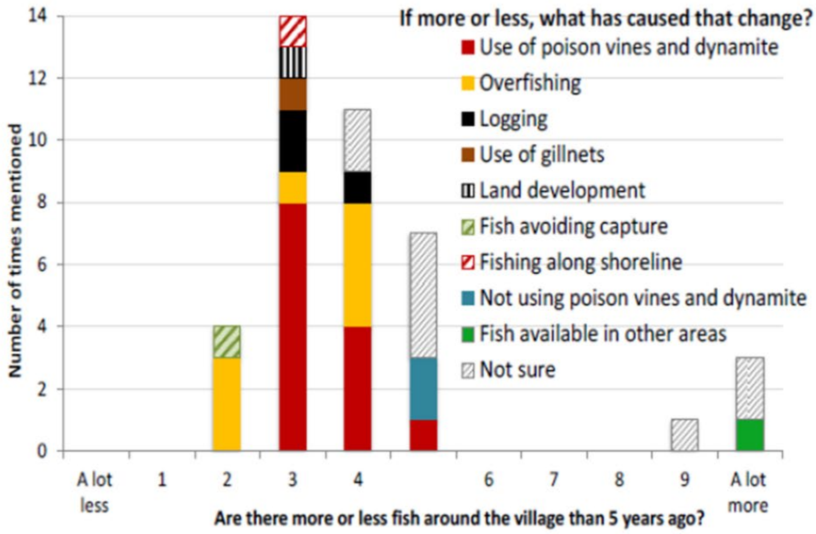


Figure 10. Number of fish now, compared to five years ago and reasons for change

Niugini Black Bass Research Project

HOUSEHOLD SURVEY—OVERVIEW OF DATA

SOMALANI VILLAGE April 2016

We would like to acknowledge Otto B. Christensen & Natalie Stoeckl for providing photographs &
Somalani Island Residents

Household Survey — overview of data

SNAPSHOT

- In September 2015 we interviewed 68 people from 68 households. 75% of participants were males; 20% were aged between 20-30 and 25% were aged between 30-40 years old
- 13% of participants had not left the village during the last year
- 79% of participants said that they or someone from their household would like to be more involved in the tourism industry

We asked people how satisfied they are with their overall quality of life (QOL) now and 10 years ago .

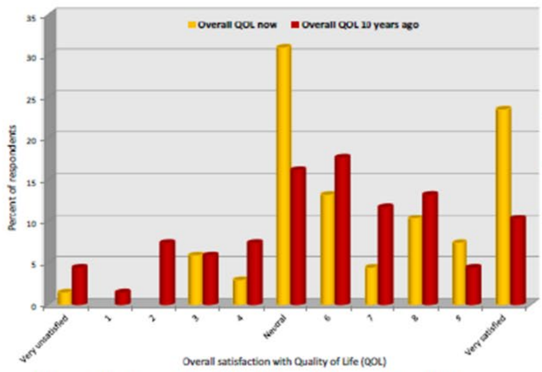


Figure 1. Overall satisfaction with quality of life now (yellow) compared to 10 years ago (red)

And we asked them to tell us what grade they completed at school.

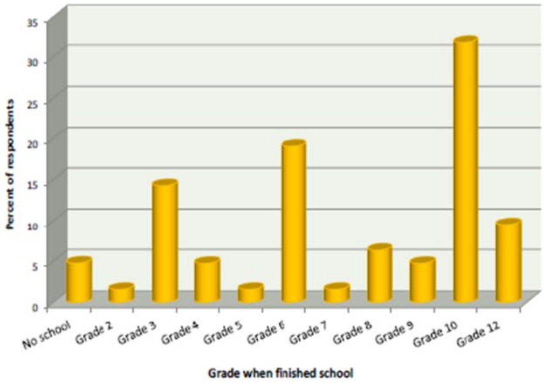


Figure 2. Grade when finished school

IMPORTANCE OF AND SATISFACTION WITH DIFFERENT ASPECTS OF LIFE

We asked people to tell us how important different things were to their overall quality of life (red lines in Figure 3), and how satisfied they were with them (yellow lines). The closer a red line is to the centre of the circle, the less important it is. The closer a yellow line is to the centre of the circle, the less satisfied people are. If people feel something is very important to them and they are dissatisfied with it, then there may be a cause for concern—in this graph it seems that most concern relates to the education, employment, and leadership in the village.

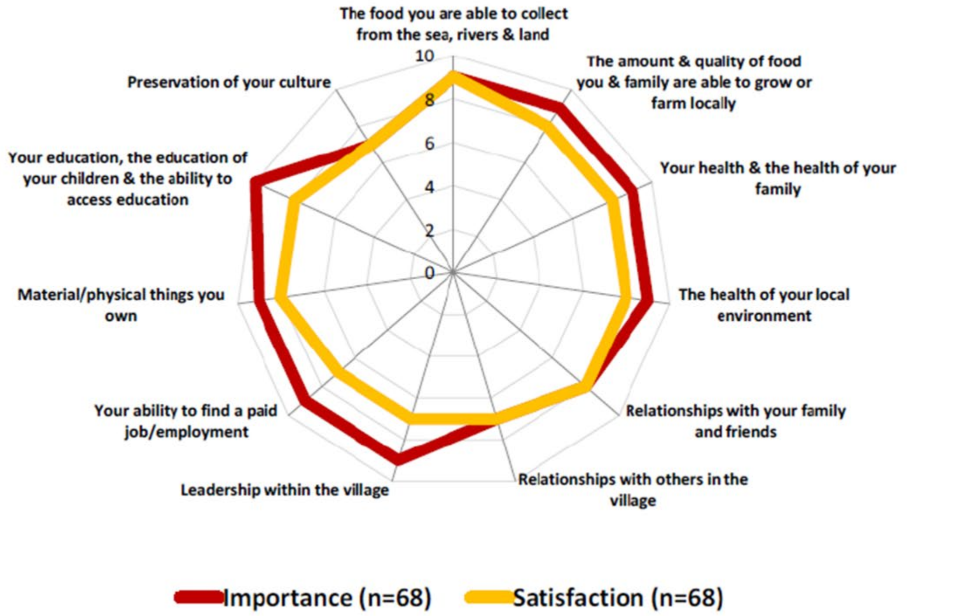


Figure 3. How important are different factors to your overall QOL (red lines) and how satisfied are you with those factors (yellow lines) (0 if very unimportant/very unsatisfied; 10 if very important/very satisfied)?

Household Survey — overview of data

CHANGES IN THE LAST 10 YEARS

We asked people to tell us about the biggest change they had experienced in the last ten years— what it was (Figure 4 shows the most frequent changes mentioned), and whether the change was mainly good, mainly bad or a mixture of good and bad. Changes to the right of the black line are 'mainly bad' changes, and those to the left are the good ones. 46% of households indicated that changes were mainly good; less than 8% said they were mainly bad. We then asked people to tell us what they thought had caused the changes. Most attributed changes to hard work of individuals (dark blue) and to help of educated working family members (pattern blue).

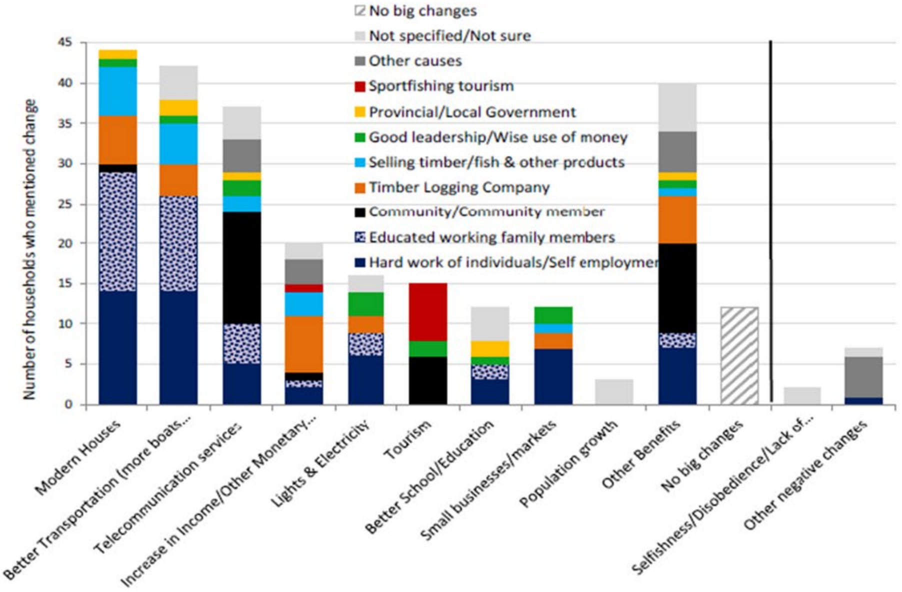


Figure 4. The biggest changes that have occurred in the village in the last 10 years and reasons for that change

CHANGES IN THE FUTURE

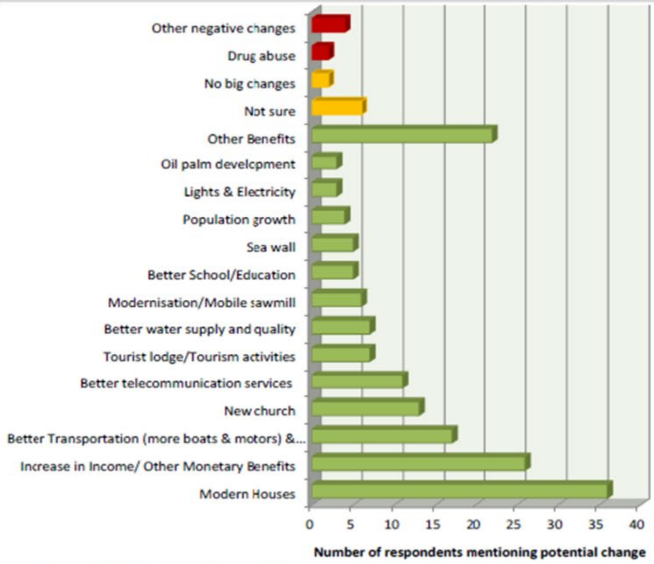


Figure 5. Changes that might occur in the village in the next 10 years

We also asked people to tell us about changes that might happen in the village in the next 10 years. 58% thought that changes would, overall, be good; and 4.8% indicated that changes would be bad.

More modern houses and Increase in income or other monetary benefits were the most frequently mentioned changes and these were seen to be mainly 'good' (shown in green, Figure 5). Some people were concerned about drug abuse, lost of culture and language ('bad' changes shown in red).

Household Survey — overview of data

THE IMPORTANCE OF FISH AND FISHING FOR INCOME AND LIVELIHOODS

We asked people to rank various activities according to how important they were as a way of getting food (Figure 6) and to tell us which two activities/products were most important as a source of income (Figure 7).

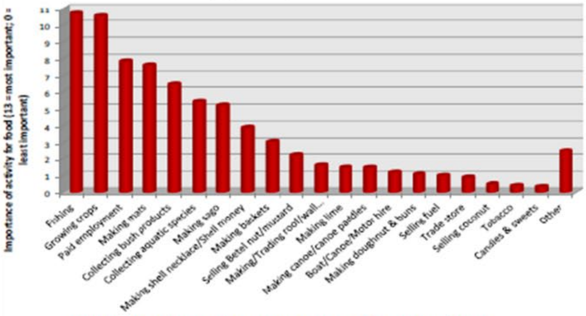


Figure 6. Most important ways of getting food

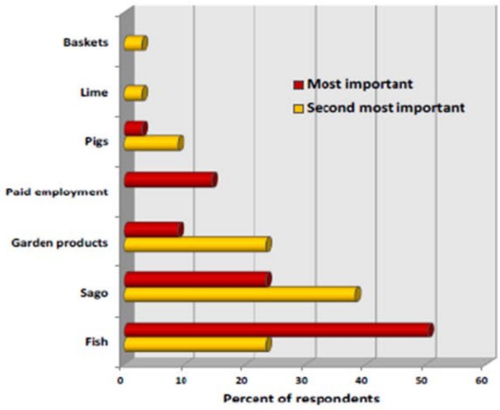


Figure 7. Most important ways of earning money

We asked people to tell us which two species of fish were most important to them (for food or for other reasons) and what fishing gear they used to catch fish.

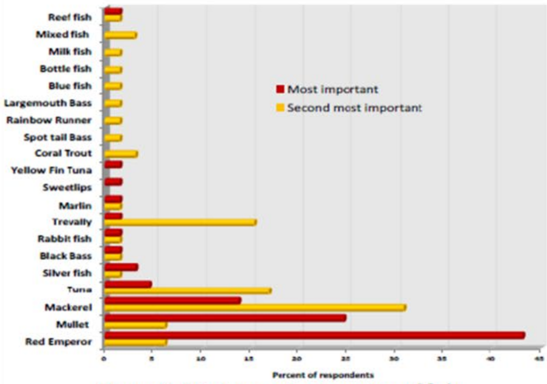


Figure 8. Most important species of fish

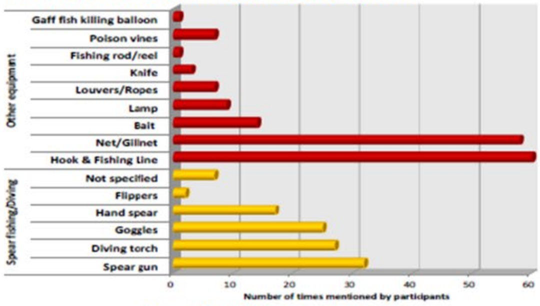


Figure 9. Fishing equipment

CHANGES TO FISH AVAILABILITY IN LAST 5 YEARS

Households were asked to tell us if they thought there were more or less fish near the village now compared to five years ago. If different, we asked what they thought had caused the change (Figure 10). Healthy environment was seen as a main reason for increase in fish around the village, while overfishing due to diversification of methods, use of poison vines and change in weather/seasons were perceived as reasons for decrease in fish.

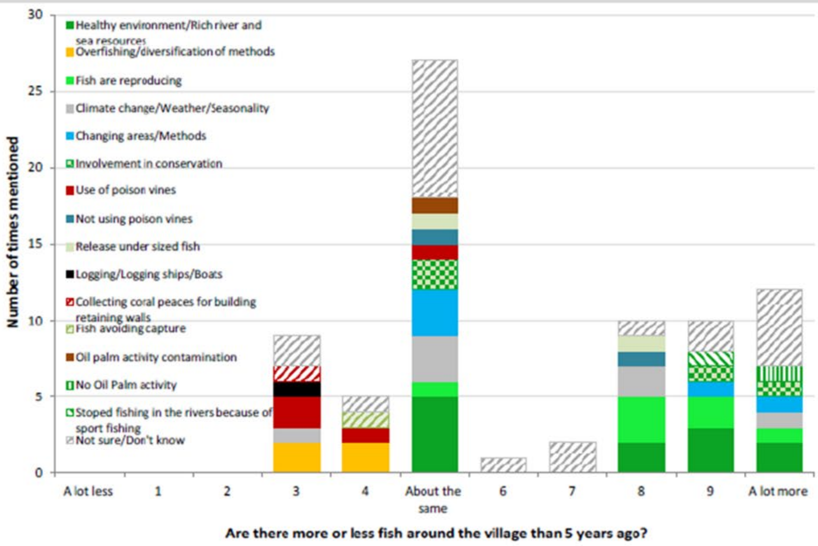


Figure 10. Number of fish now, compared to five years ago and reasons for change

We would like to acknowledge Otto B. Christensen for photographs & Vesse Island residents

Household Survey — overview of data

SNAPSHOT

- In September 2015 we interviewed 55 people from 55 households. 76% of participants were males and one third were aged between 30-40 years old
- 26% of participants had not left the village during the last year
- 87% of participants said that they or someone from their household would like to be more involved in the tourism industry

We asked people how satisfied they are with their overall quality of life (QOL) now and 10 years ago .

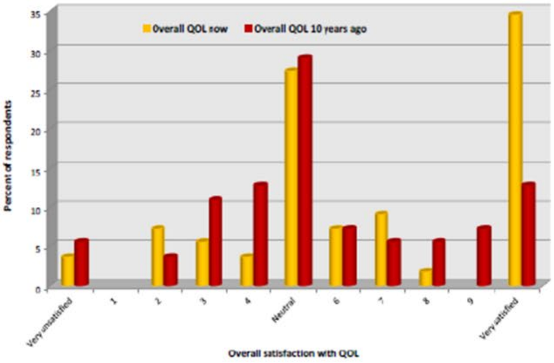


Figure 1. Overall satisfaction with quality of life now (yellow) compared to 10 years ago (red)

And we asked them to tell us what grade they completed at school.

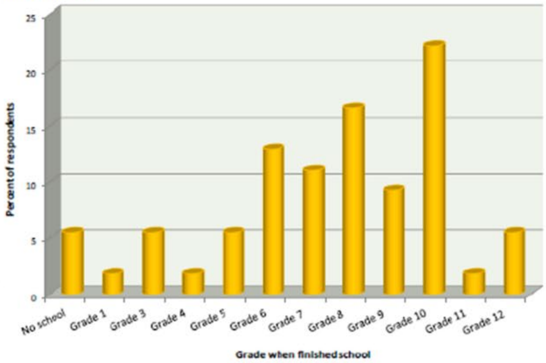


Figure 2. Grade when finished school

Importance of and satisfaction with different aspects of life

We asked people to tell us how important different things were to their overall quality of life (red lines in Figure 3), and how satisfied they were with them (yellow lines). The closer a red line is to the centre of the circle, the less important it is. The closer a yellow line is to the centre of the circle, the less satisfied people are. If people feel something is very important to them and they are dissatisfied with it, then there may be a cause for concern—in this graph it seems that most concern relates to the ability to find a paid job/employment and the health of the local environment.

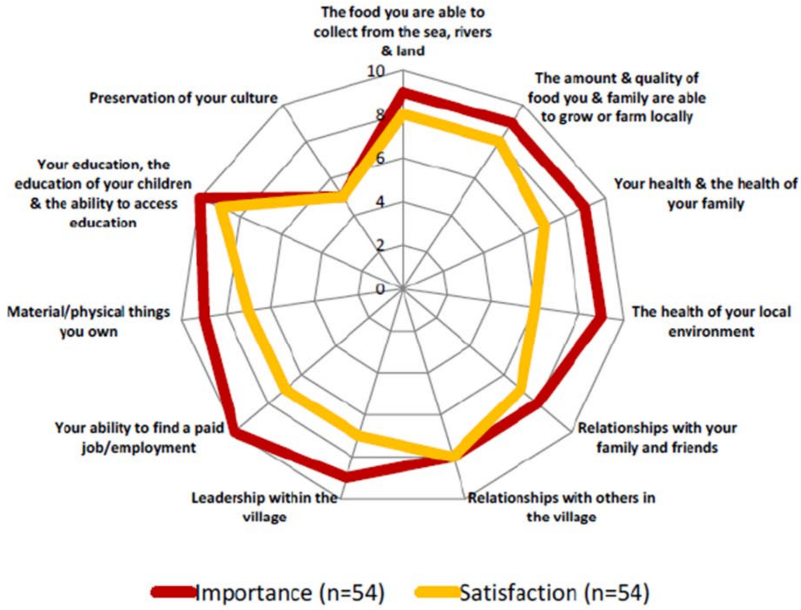


Figure 3. How important are different factors to your overall QOL (red lines) and how satisfied are you with those factors (yellow lines) (0 if very unimportant/very unsatisfied; 10 if very important/very satisfied)?

Household Survey — overview of data

CHANGES IN THE LAST 10 YEARS

We asked people to tell us about the biggest change they had experienced in the last ten years— what it was (Figure 4 shows the most frequent changes mentioned), and whether the change was mainly good, mainly bad or a mixture of good and bad. Changes to the right of the black line are 'mainly bad' changes, and those to the left are the good ones. Nearly 24% of households indicated that changes were mainly good; just over 25% said they were mainly bad. We then asked people to tell us what they thought had caused the changes. Most attributed changes to Oil Palm and Timber Logging companies (shown in dark blue and orange respectively).

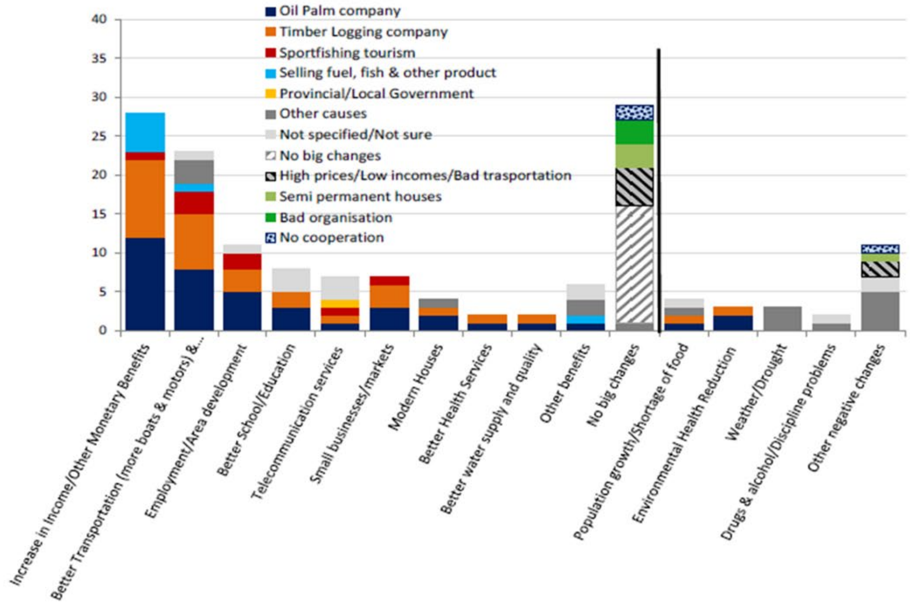


Figure 4. The biggest changes that have occurred in the village in the last 10 years and reasons for that change

CHANGES IN THE FUTURE

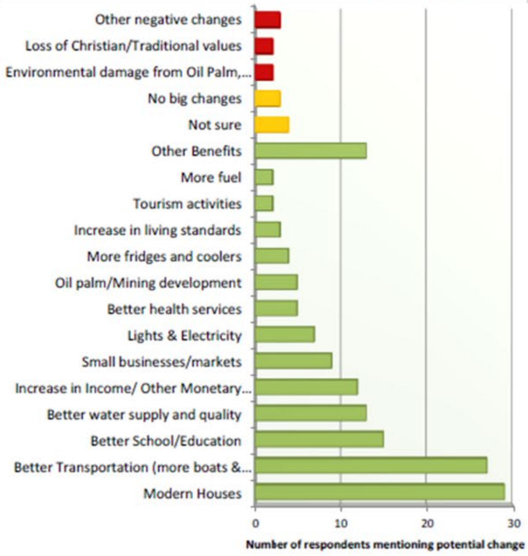


Figure 5. Changes that might occur in the village in the next 10 years

We also asked people to tell us about changes that might happen in the village in the next 10 years. 52% thought that changes would, overall, be good; 42% thought the changes would likely be a mixture of good and bad.

More modern houses, better transportation and better education were the most frequently mentioned changes and these were seen to be mainly 'good' (shown in green, Figure 5). Some people were concerned about the potential for environmental damage from logging, palm oil and mining ('bad' changes shown in red).

Household Survey — overview of data

THE IMPORTANCE OF FISH AND FISHING FOR INCOME AND LIVELIHOODS

We asked people to rank various activities according to how important they were as a way of getting food (Figure 6) and to tell us which two activities/products were most important as a source of income (Figure 7).

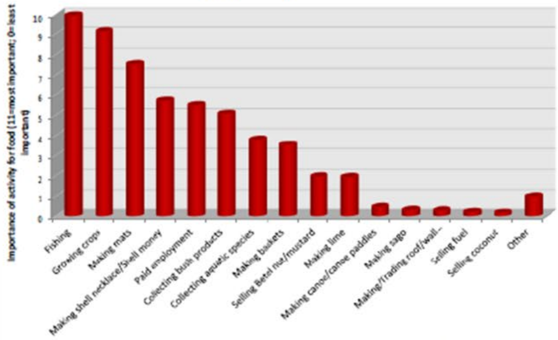


Figure 6. Most important ways of getting food

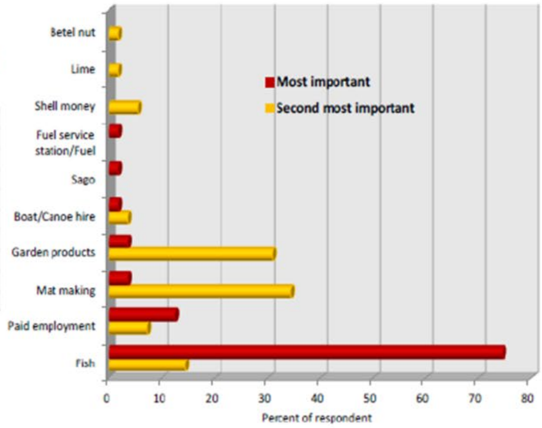


Figure 7. Most important ways of earning money

We asked people to tell us which two species of fish were most important to them (for food or for other reasons) and what fishing gear they used to catch fish.

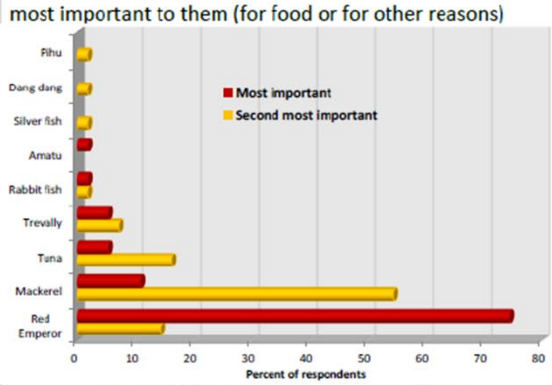


Figure 8. Most important species of fish

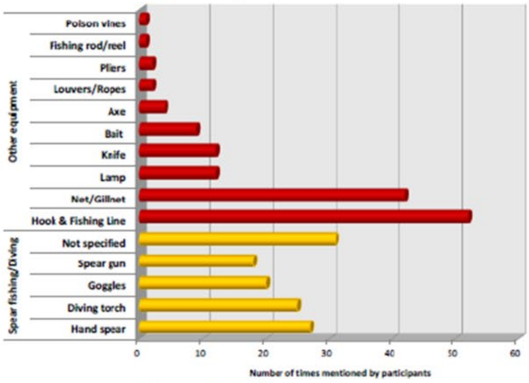


Figure 9. Fishing equipment

CHANGES TO FISH AVAILABILITY IN LAST 5 YEARS

Households were asked to tell us if they thought there were more or less fish near the village now compared to five years ago. If different, we asked what they thought had caused the change (Figure 10). Overfishing due to diversification of methods, changes in weather/seasons and use of poison vines and dynamite were seen as main reasons for reduced availability of fish around the village.

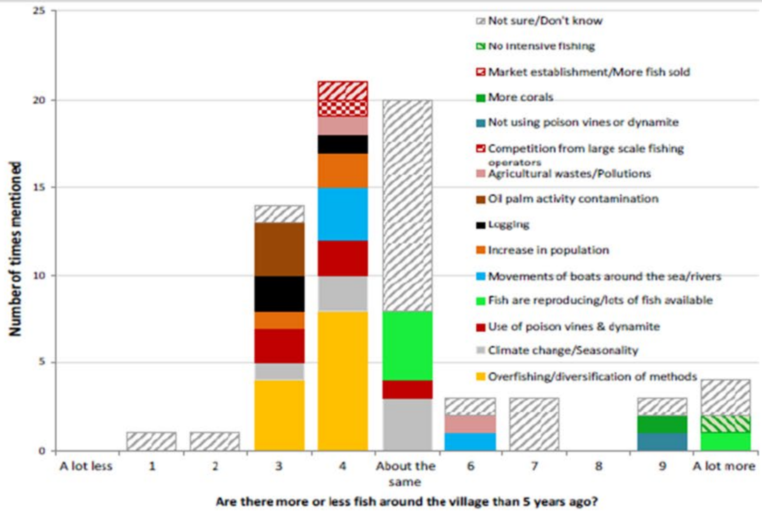
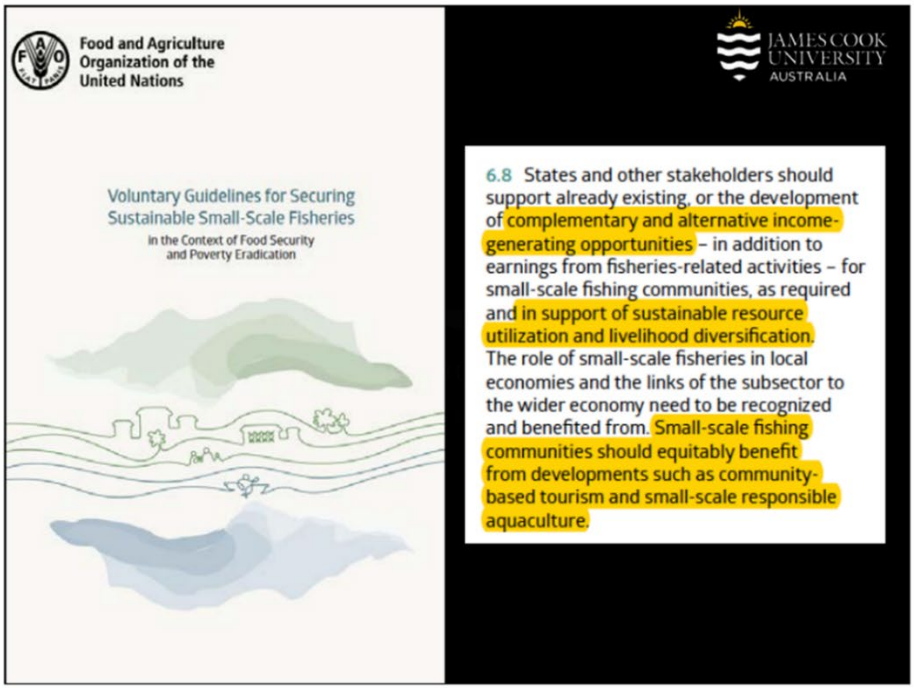


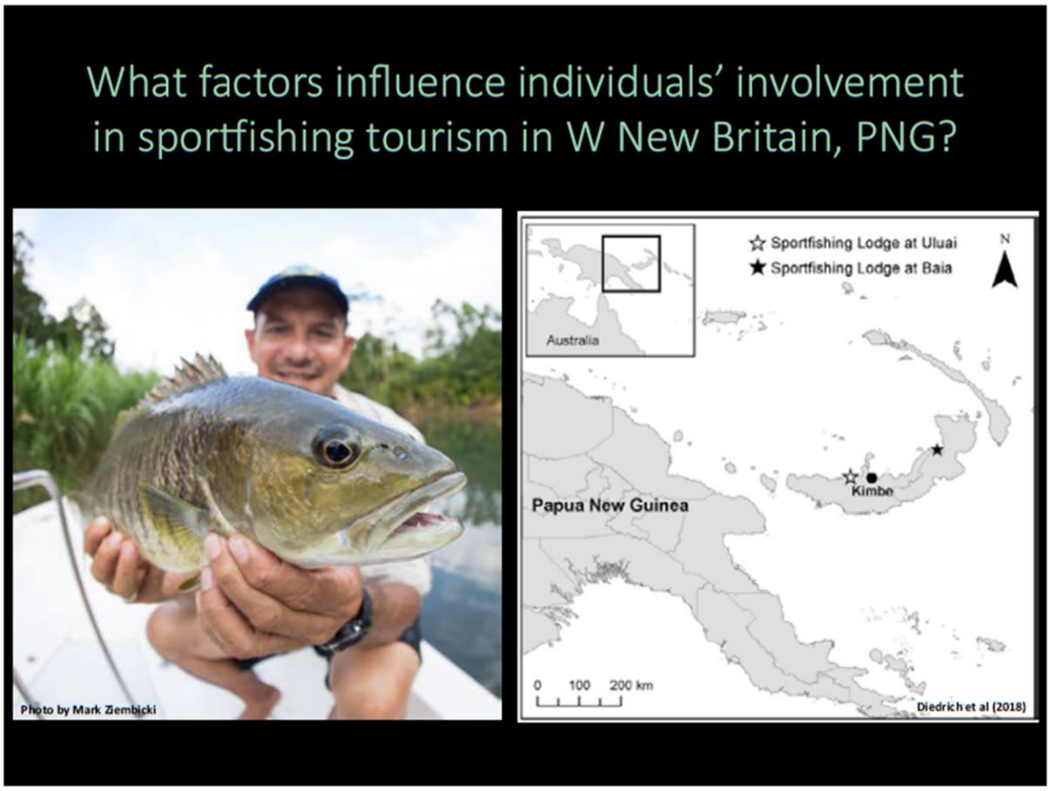
Figure 10. Number of fish now, compared to five years ago and reasons for change

11.10 Appendix 10: Role of social capital in transitions to sportfishing tourism in PNG (Diedrich et al. 2018)

Here, we present the slides of a conference presentation on the role of social capital in transitions to sportfishing tourism in PNG (3rd World Small-Scale Fisheries Congress, Chiang Ma Thailand, 22-26 October 2018).




(World Bank2017)
Pacific Possible
Long-term Economic Opportunities and Challenges for Pacific Island Countries
In 2040, transformational tourism opportunities could bring an additional US$1.7 billion in revenue and 116,000 jobs to Pacific Island Countries
Opportunity
Additional Impact
Increasing the Chinese Market
660,000 tourists
65,200 jobs
US$947m receipts
$36.9m airport taxes
Home-basing 4 Cruise Ships
266,000 tourists
4,700 jobs
US$67m receipts
$9.2m port fees
Expanding the High-end Resorts Market
139,000 tourists
32,500 jobs
US$487m receipts
$7.8m airport taxes
Capturing the Retiree Market
10,000 retirees
13,800 jobs
US$200m receipts
$0.56m airport taxes


What factors influence individuals' involvement in sportfishing tourism in W New Britain, PNG?
Photo by Mark Ziembicki
Sportfishing Lodge at Uluai
Sportfishing Lodge at Baia
N
Australia
Papua New Guinea
Kimbe
0 100 200 km
Diedrich et al (2018)

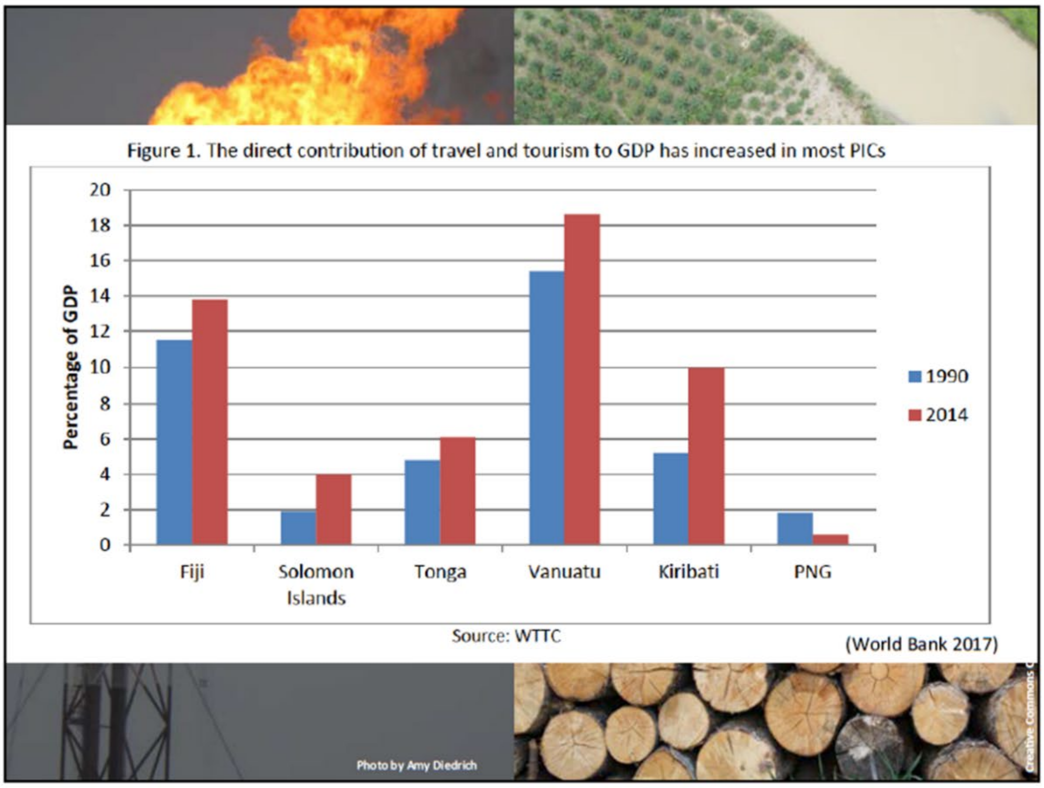
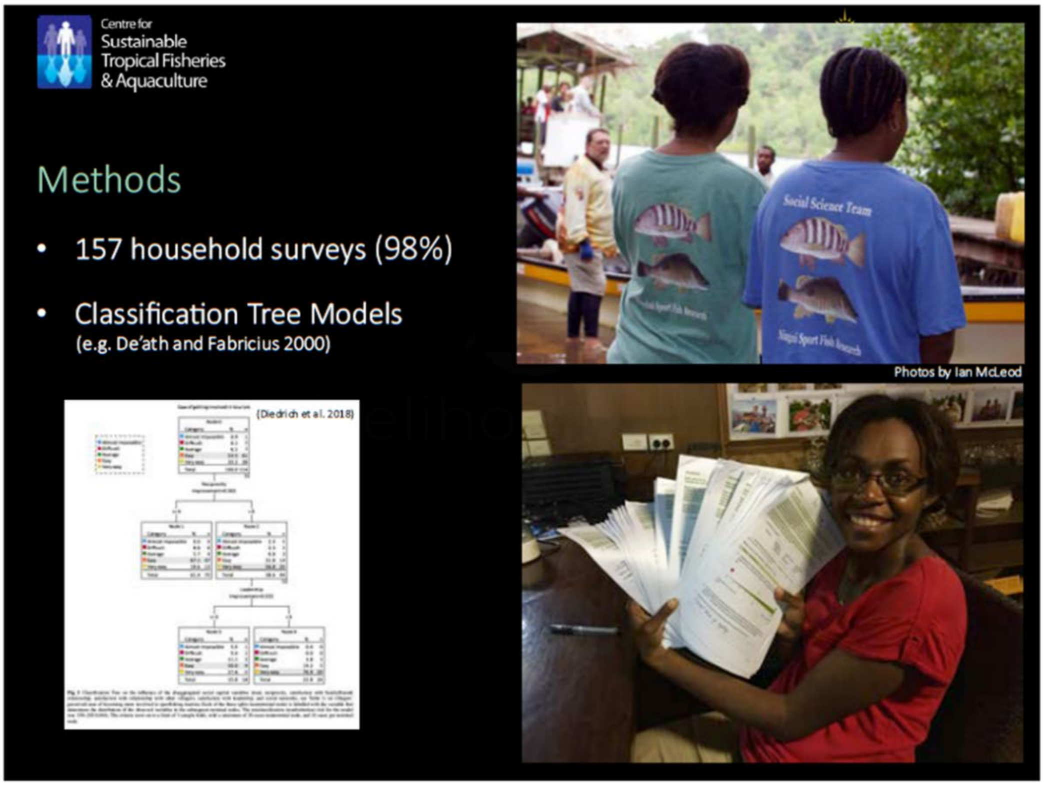
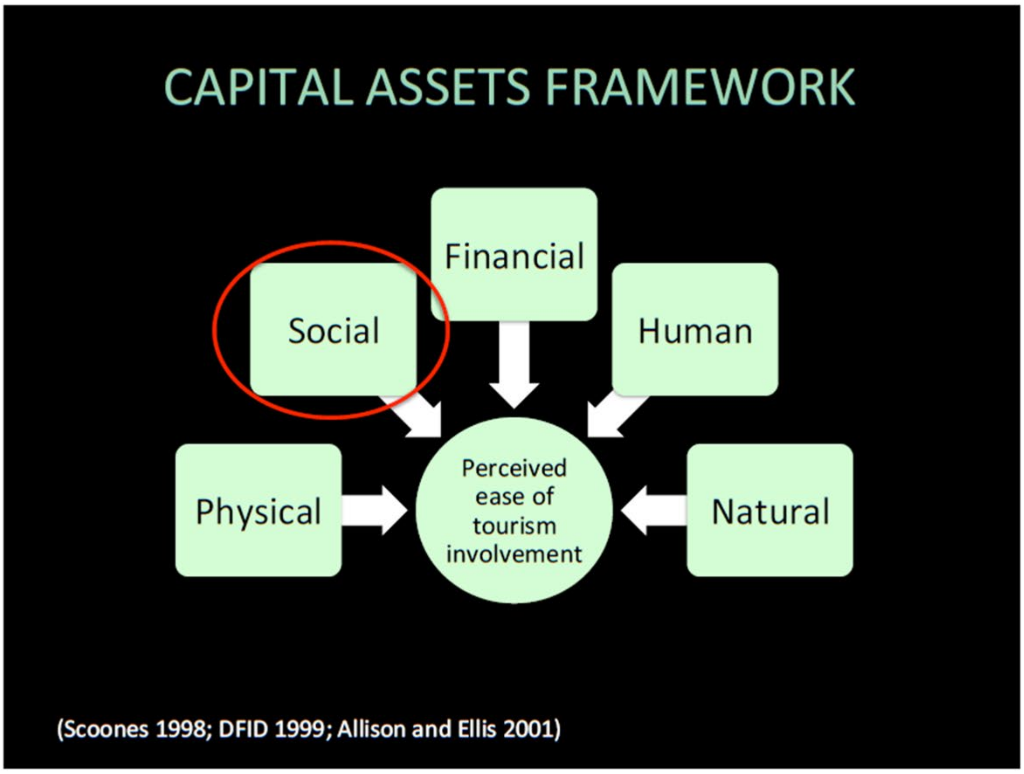
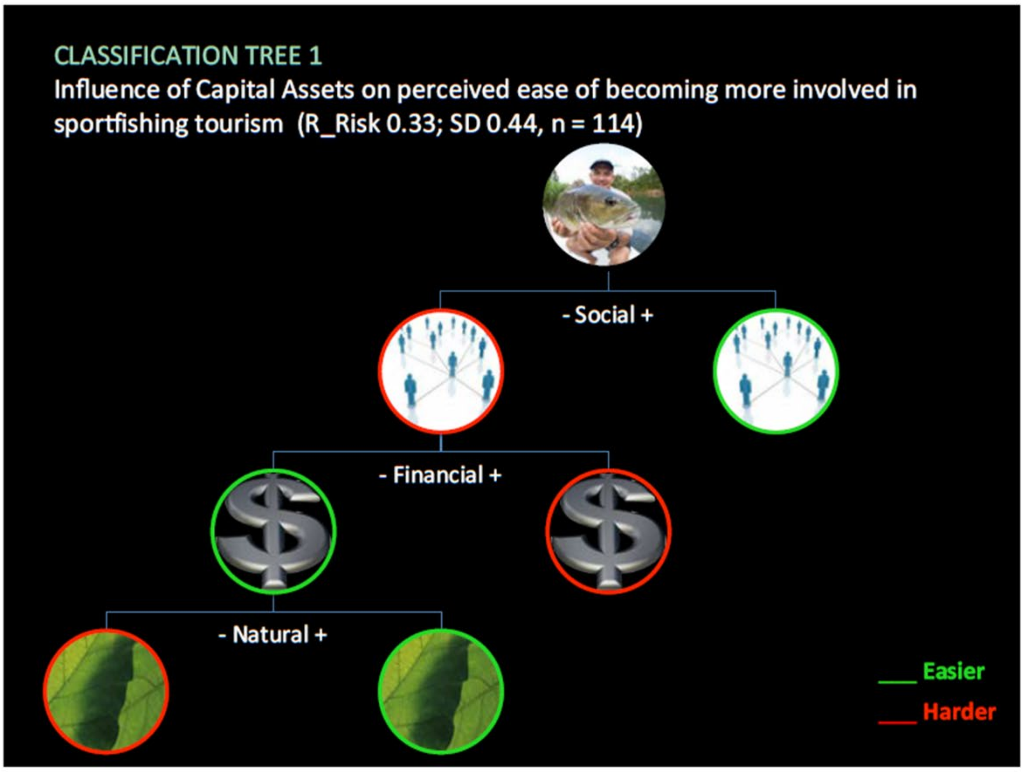


Figure 1. The direct contribution of travel and tourism to GDP has increased in most PICs
Percentage of GDP
20
18
16
14
12
10
8
6
4
2
0
Fiji
Solomon Islands
Tonga
Vanuatu
Kiribati
PNG
1990
2014
Source: WTTC
(World Bank 2017)
Photo by Amy Diedrich


Centre for Sustainable Tropical Fisheries & Aquaculture
Methods
• 157 household surveys (98%)
• Classification Tree Models
(e.g. De'ath and Fabricius 2000)
(Diedrich et al. 2018)
Social Science Team
Photos by Ian McLeod


CAPITAL ASSETS FRAMEWORK
Financial
Social
Human
Physical
Perceived ease of tourism involvement
Natural
(Scoones 1998; DFID 1999; Allison and Ellis 2001)


CLASSIFICATION TREE 1
Influence of Capital Assets on perceived ease of becoming more involved in sportfishing tourism (R_Risk 0.33; SD 0.44, n = 114)
- Social +
- Financial +
- Natural +
Easier
Harder

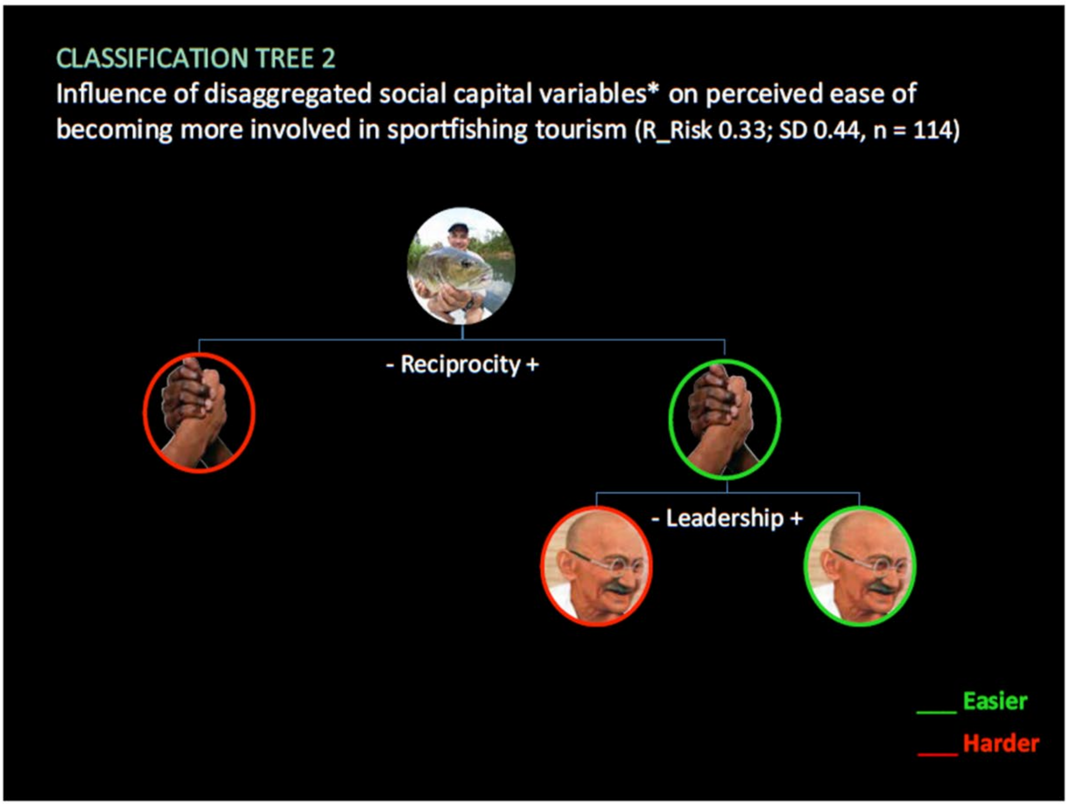
CLASSIFICATION TREE 2

Influence of disaggregated social capital* variables on perceived ease of becoming more involved in sportfishing tourism (R_Risk 0.33; SD 0.44)

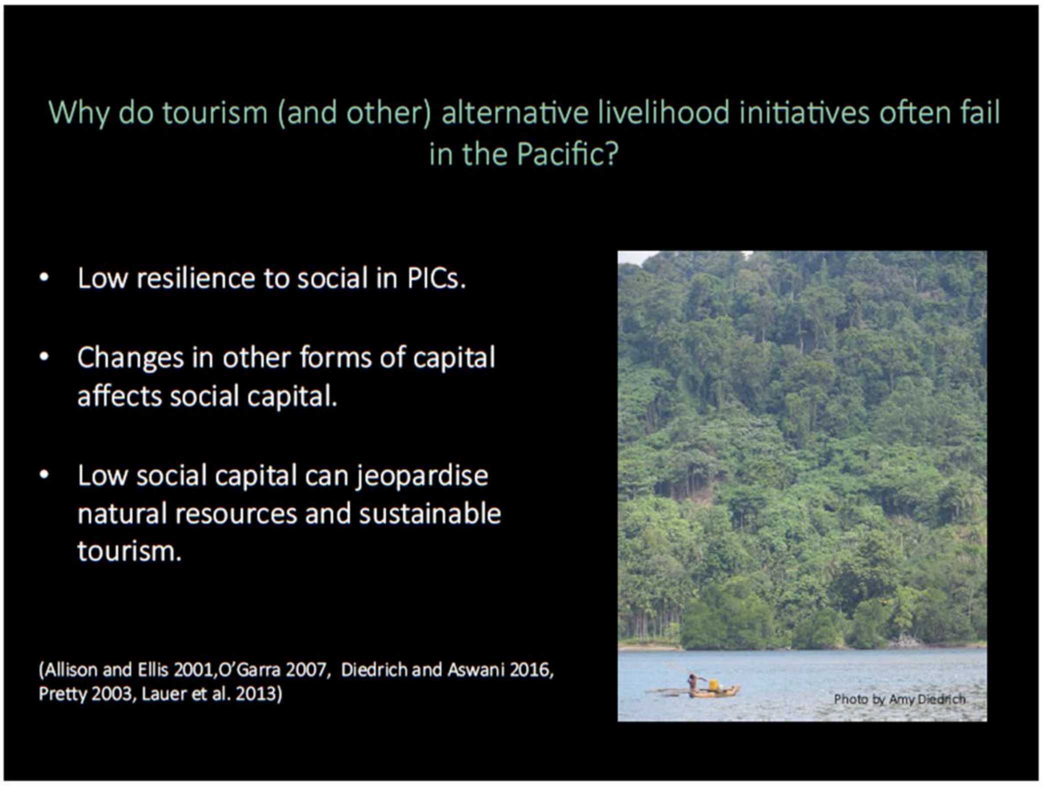
*

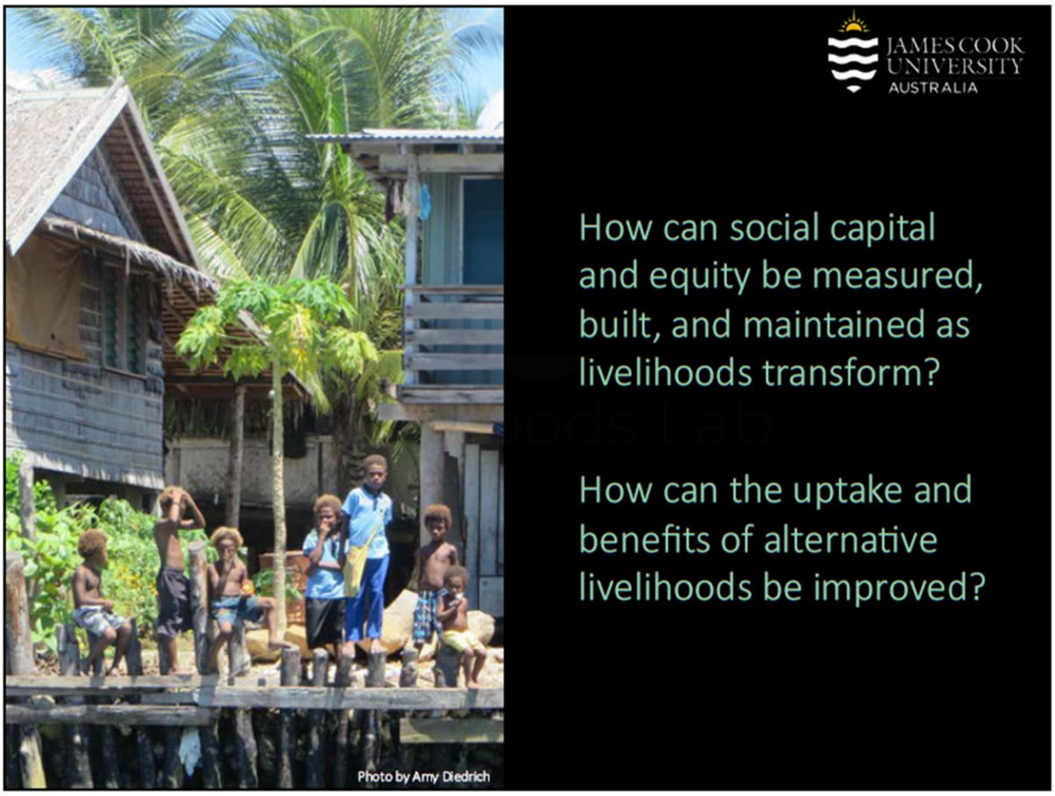
- Trust
- Reciprocity
- Satisfaction with family/friends
- Satisfaction with relationship with other villagers
- Satisfaction with leadership
- Social Networks

(Portela et al. 2013; Diedrich et al. 2017)




Why do tourism (and other) alternative livelihood initiatives often fail in the Pacific?
• Overly simplistic expectations.
• Social dynamics play a crucial role in determining development outcomes.
• Social capital considerations can take a back seat to other forms of capital.
(O'Garra 2007, Gillet et al. 2008, Govan 2011, Curry and Koczberski 2013, Butler et al. 2014)
Photo by Amy Diedrich


Why do tourism (and other) alternative livelihood initiatives often fail in the Pacific?
• Low resilience to social in PICs.
• Changes in other forms of capital affects social capital.
• Low social capital can jeopardise natural resources and sustainable tourism.
(Allison and Ellis 2001,O'Garra 2007, Diedrich and Aswani 2016, Pretty 2003, Lauer et al. 2013)
Photo by Amy Diedrich


JAMES COOK
UNIVERSITY
AUSTRALIA
How can social capital and equity be measured, built, and maintained as livelihoods transform?
How can the uptake and benefits of alternative livelihoods be improved?
Photo by Amy Diedrich


Centre for
Sustainable
Tropical Fisheries
& Aquaculture
Acknowledgments
• Papua New Guinea National Fisheries Authority (NFA)
• ACIAR (Project FIS/2013/015)
• Baia Sportfishing
• Communities of Baia, Vesse and Somalani
Photo by Mark Ziembicki

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11.11 Appendix 11: Draft Niugini Black Bass Management Plan

Draft Niugini Black Bass Management Plan

Draft: 1 July 2017

Background of the Plan

The Niugini Black Bass Sportfishery is a high value recreational industry focused on the iconic, endemic Niugini Black Bass, *Lutjanus goldiei*, and associated sportfish. These are principally river and estuarine species, and this is where the sportfishery is principally conducted. The sportfishery is mainly conducted on a catch-and-release basis and interacts with a local capture fishery.

Licencing is designed to allow the industry development while protecting the business of individual operators who require some surety of access to sportfishing resources, and village resource owners who require security of determination over the use of their resources and reasonable recompense for access to their resources.

Designated Fishing Activity

Niugini Black Bass Management Plan (the Plan) relates to the conduct and management of the sportfishing industry targeting Niugini Black Bass, *Lutjanus goldiei*, and associated sportfish, Spot-tail Bass, *Lutjanus fuscescens*, Mangrove Jack, *Lutjanus argentimaculatus*, and Fingermark Snapper, *Lutjanus johnii*, in the waters of Papua New Guinea.

Substantive Matters Addressed

Management arrangements for the Black Bass sportfishery are aimed at simultaneously (i) controlling overall harvest to ensure the sustainability of both the high-value sportfishing resource and continued, sustainable harvest by local people, (ii) ensuring protection of key habitats and resources that the fishery relies on, (iii) regulating the number of operators in any one area to ensure fishery and business sustainability, (iv) ensuring sustainable conduct of the fishery, and (v) ensuring operators have appropriate training to conduct operations sustainably in accordance with the requirements of the industry.

As such, the Plan addresses:

- Sportfishing harvest levels
- Conduct of the sportfishery
- Gear allowed to take fish in the fishery
- Access to the fishery
- Habitat protection
- Protection of key resources
- Regulatory controls
- Training requirements for operators
- Certification and Licencing
- Data collection requirements

- Monitoring requirements
- Further research required to update and validate the Management Plan

Draft Niugini Black Bass Management Plan

1. Objectives:
    1.1. The objective of the Management Plan is to provide the regulatory framework to support the orderly development a long-term sustainable Niugini Black Bass sportfishery in Papua New Guinea. The Plan aims to provide (a) initial directives for management based on current knowledge, and (b) criterial for directing the collection of relevant information to allow the Plan to be reviewed and updated to increase its validity and value.
2. Designated area the plan applies to:
    2.1. The plan applies to the waters of Papua New Guinea where the target species are found.
3. Who the Plan applies to:
    3.1. The Plan applies to those fishing for or collecting the target species as (a) sportfishing operators, (b) recreational fishers, (c) commercial fishers, (d) accredited researchers (see 7.5.1 below for definitions).
4. Target species:
    4.1. The primary target species for the Management Plan are:
        4.1.1. Niugini Black Bass, *Lutjanus goldiei*,
        4.1.2. Spot-tail Bass, *Lutjanus fuscescens*,
        4.1.3. Mangrove Jack, *Lutjanus argentimaculatus*,
        4.1.4. Fingermark Snapper, *Lutjanus johnii*,
5. Designation of the fishery:
    5.1. The Niugini Black Bass sportfishery, as conducted by licensed sportfishing operators or recreational fishers, is designated as primarily a catch-and-release fishery, with limited take for food or record certification purposes.
    5.2. The plan bans commercial take of Niugini Black Bass, *Lutjanus goldiei*, and Spot-tail Bass, *Lutjanus fuscescens*, from the designated areas.
    5.3. This plan does not specifically regulate the capture fishery aimed at local usage, although it recognizes that such catches need to be monitored to ensure they do not increase to a level that would compromise the integrity and sustainability of the sportfishery.
6. Duration of the Management Plan.
    6.1. The Management Plan will be implemented for an initial three (3) year period (the Development Phase) during which aspect of the plan and its implementation will be developed and fine-tuned.
7. Rights of users to take fish:
    7.1. Licenced sportfishing operators:
        7.1.1. Sportfishing operators should endeavour to ensure fish are handled to maximise survival and health and to release target species wherever possible.

7.1.2. Only a limited take (seem 7.3.1 below) is allowed for food.

7.1.3. Fish should only be kept for record certification if the operator has good reason to believe the fish in question is likely to be a record catch. To this end operators should carry up-to-date record lists with them at all time as part of standard equipment.

7.2. Recreational sportfishers:

7.2.1. Recreational fishers have the same rights to take fish as sportfishing operators.

7.3. Local capture fishermen:

7.3.1. Local capture fishermen can take target species for their own use and that of their family and village using legal non-destructive techniques.

7.4. Commercial fishers:

7.4.1. Commercial fishers are banned from taking of Niugini Black Bass, *Lutjanus goldiei*, and Spot-tail Bass, *Lutjanus fuscescens*, for sale.

7.5. Accredited researchers:

7.5.1. Researchers accredited by the Papua New Guinea National Fisheries Authority (PNG NFA) are permitted to take target species for *bona fide* research purposes.

8. Conditions relating to the handling of fish

8.1. Fish to be released should be handled so as to minimise unnecessary stress or injury. Suitable guidelines are available for responsible sportfish handling from: https://spccfpstore1.blob.core.windows.net/digitallibrary-docs/files/af/afc18ea88107172442af2ac618efb96b.pdf?sv=2015-12-11&sr=b&sig=X0iBLqxrBYkpx0kDbIkwXluTOy7d%2BZnIPi7LIPkyt1U%3D&se=2017-12-17T03%3A50%3A34Z&sp=r&rscc=public%2C%20max-age%3D864000%2C%20max-stale%3D86400&rsct=application%2Fpdf&rscd=inline%3B%20filename%3D%22Anon_10_GiantTrevally.pdf%22

9. Permitted fishing gear

9.1. Customers of licenced sportfishing operators:

9.1.1. Customers of licenced sportfishing operators are permitted to use one fishing rod or hand-line at a time.

9.1.2. Each baitfishing line is limited to a single hook (barbless or with barb crushed).

9.1.3. Each lure or fly fishing line is limited to a single lure or fly, with each lure limited to no more than three (3) treble hooks. All hooks must be barbless or have their barbs crushed.

9.2. Recreational sportfishers:

9.2.1. Recreational sportfishers are allowed the same gear as the customers of licenced sportfishing operators.

9.3. Local capture fishermen:

9.3.1. Local capture fishermen are permitted to use all legal non-destructive techniques.

10. Mimimum and Maximum size limits for target species.

  10.1. It is important to protect both the spawning stock and maintaining a stock of large fish that make up the primary target for sportfishing. Consequently, there is a need for both a minimum size limit, aimed at ensuring fish reach breeding size, and a maximum size limit, to ensure the removal of large long-lived fish from the population is limited.

  10.2. Licenced sportfishing operators, their clients and recreational sportfishers are required to release all fish under 45cm. Fish over 70cm can only be retained if the has good reason to believe the fish will qualify for a record (see 7.1.3 above).

11. Certification and Permitting

  11.1. Certification of sportfishing operators

    11.1.1. Current sportfishing operators who can demonstrate at least two (2) years continuous operation in the industry in PNG will be provided an initial licence on implementation of the Management Plan.

    11.1.2. After three years of operation (i.e. the Development Phase) and data collection (see xxx below), licences will be reviewed and a call made for expressions of interest for new licences.

    11.1.3. During that three year period criteria for certification, and an approach for evaluation will be developed in consultation with a Consultative Committee representing management, operators already in the industry and researchers.

  11.2. Number of Licences.

    11.2.1. The key issue in building a sustainable industry is balancing effort to maintain healthy stocks and catch rates.

    11.2.2. Initially, the aim is to limit licences to one per province, with this to be reviewed after three years.

12. Training of operators and staff.

  12.1. A sustainable sportfishing industry depends on the quality of operators and staff and their ability to develop, manage and conduct a professional and productive business.

    12.1.1. During the first three year Development Phase training needs for operators and staff at all levels will be assessed and a training plan, training course and training material developed. This will be under direction of the Consultative Committee.

13. Protection of key habitats.

  13.1. The Niugini Black Bass Sportfishery depends on high habitats and environmental quality. This particularly includes, but is not limited to, (a) high water quality, (b) in-tact and substantiative riparian zones around the streams, rivers, lakes, estuaries and other waterways that the target species rely on, (c) high quality management of the catchments surrounding target species' waterways, (d) unimpeded connectivity pathways between the habitats required by the target species over their life-histories, and (e) in-tact and high quality food webs and food resources that support populations of target fish species. Part of the attraction for anglers of PNGs Black Bass sportfishery is the wild, pristine environments in which the fishery is conducted. Consequently, protection needs to extend to maintaining high visual quality of surrounding environments.

13.2. Initially, habitat protection will be based on the Papua New Guinea Logging Code of Practice (1996). The value of this instrument and its fitness for purpose will be reviewed during the three year Development Phase, with a view to developing environmental guidelines specific to the needs of the Niugini Black Bass Sportfishing industry.

14. Selection, constitution, development and conduct of the Consultative Committee.

14.1. The Consultative will be developed under the direction of PNG NFA, with appropriate structure and operating protocols developed by senior PNG NFA staff.

15. Review process.

15.1. The review process is aimed at testing the details of the initial plan, including the collection of relevant information to allow the Plan to be reviewed and updated to increase its validity and value.

15.2. The Consultative committee with review all aspects of the plan.

15.3. The review will include, but not be limited to:

15.3.1. Surveys of operators about the strengths and weaknesses of the plan.

15.3.2. Surveys of local people about the strengths and weaknesses of the plan, in particular about the flows of benefits from the industry.

15.3.3. Surveys of operators about the training needs of staff.

15.3.4. Evaluation of monitoring data (see xxx.xx below).

15.3.5. Identification of key knowledge gaps by a sub-committee of NFA staff and researchers. This review will include, but not be limited to:

15.3.5.1. A review of existing data including its comprehensiveness, its spatial scope.

15.3.5.2. Identification of emerging treats to the sustainability of the industry.

15.3.6. An assessment of any need to extend the scope of the plan.

15.3.7. The development of Performance Indicators and monitoring, to access whether the objectives of the plan and ecologically sustainable development are being attained.

16. Monitoring.

16.1. All operators will be required to keep a log book detailing (i) locations fished (GPS locations), (ii) the number of anglers fishing at each location, (iii) the total angler hours fished at each location, (iv) numbers and sizes of each species caught, (v) numbers and sizes of fish retained, (vi) the condition of each fish released, and (vii) observations on conditions of the fishing sites (water quality, health of bankside vegetation etc.).

17. Definitions

17.1. Sportfishing operator: an individual who holds certification to operate a recreational sportfishery.

17.2. Sportfishing worker: an individual trained as a sportfishing guide.

17.3. Recreational fisher: an individual who fishes for pleasure without receiving financial gain.

17.4. Commercial fisher: an individual who operates a fishing operation aimed at taking fish for sale (Local capture fishermen, as defined in 17.5, are excluded).

17.5. Local capture fishermen: Local capture fishermen are individuals fishing within their traditional village land boundaries capturing target species for their own use, or that of their family and village, using legal non-destructive techniques.

17.6. Accredited researcher: a researcher with relevant training, conducting research relevant to the Management Plan, and accredited by NFA.

11.12 Appendix 12: Published output briefs

Published Output Brief 1: The conservation status of Niugini Black Bass: A world-renowned sport fish with an uncertain future (Sheaves et al. 2016)

Sustainable Management of Sport Fisheries for Communities in Papua New Guinea

Published Output Brief 1

Fisheries Management and Ecology

Fisheries Management and Ecology, 2016

The conservation status of Niugini black bass: a world-renowned sport fish with an uncertain future

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Papuan Black Bass (*Lutjanus goldiei*), is the focus of a growing sport fishing industry with the potential to provide long lasting benefits to local communities. However, management is hindered by a fundamental scientific knowledge gaps, putting future of the fisheries at risk.

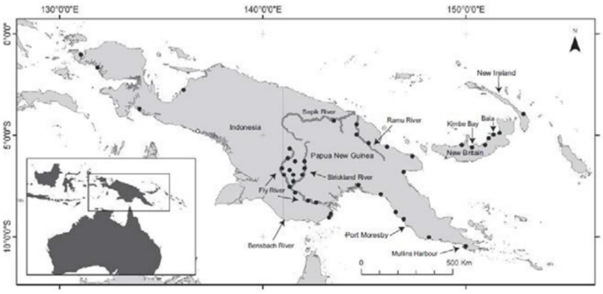
Knowledge gaps

Systematic literature search found only 11 records relating to *L. goldiei*, of which 7 were peer reviewed. These contained very little specific data, meaning there is limited information about most aspects of the biology, ecology and distribution of *L. goldiei*. Some of the critical gaps include:

- Habitat preferences;
- Spawning season and sites;
- Nursery sites;
- Movement;
- Resistance and resilience to habitat perturbations.

Distribution

- Distribution confirmed around the islands of New Guinea, New Britain and New Ireland;
- Unconfirmed reports from Borneo.



Geographic distribution of Lutjanus goldiei. Filled circles indicate reliable records (Source: Sheaves et al. 2016)

Current threats

- Development, including plantation agriculture, logging and mining that impact habitat quality;
- Overfishing as a result of population increase.

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Published Output Brief 2: Sportfisheries, conservation and sustainable livelihoods: A multidisciplinary guide to developing best practice (Barnett et al. 2016)

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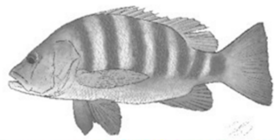

Published Output Brief 2

FISH and FISHERIES

FISH and FISHERIES, 2016, 17, 696–713

Sportfisheries, conservation and sustainable livelihoods: a multidisciplinary guide to developing best practice

Adam Barnett[1,2], Kátya G Abrantes[1,2], Ronald Baker[1,2,3], Amy S Diedrich[1,2], Marina Farr[2,4,5], Alf Kuilboer[4], Tracey Mahony[4], Ian McLeod[1,2], Gianna Moscardo[4], Murray Prideaux[1,2,4], Natalie Stoeckl[2,4,5], Ariella van Luyn[6] & Marcus Sheaves[1,2]

Ecotourism is a viable alternative for developing countries aiming to enhance livelihood sustainability without compromising traditional ways of life.

Sportfishing ventures are an increasingly attractive option. Papua New Guinea's endemic sportfish, Niugini Black Bass (*Lutjanus goldiei*) is a prime candidate for locally-based ventures that can benefit local communities' economies while maintaining traditional ways of life and promoting environmental stewardship. There are simple broad guidelines that, if followed, greatly increase the likelihood of long-term success. Barnett et al. (2016) summarizes the best practice guidelines for the development of a sportfishing industry.

Best practice guidelines: summary

- Sociocultural
  - Understand and respect the cultural values of local communities;
  - Inform, consult and involve local communities and leaders on decision;
  - Provide location-specific guidelines for tourists.
- Environmental
  - Develop a detailed understanding of the biology and ecology of target species and align research with sportfishing development;
  - Identify and minimize threats to the target species and their natural habitat;
  - Develop best handling practice.
- Economic
  - Employ local people whenever possible;
  - Negotiate offsets before impacts occur if negative side effects are unavoidable;
  - Implement a sustainable livelihood approach (i.e. short term coping mechanisms and long term capacity building).

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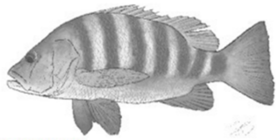
Published Output Brief 3: Sport fisheries: Opportunities and challenges for diversifying coastal livelihoods in the Pacific (Wood et al. 2013)

Sustainable Management of Sport Fisheries for Communities in Papua New Guinea



Published Output Brief 3

Marine Policy 42 (2013) 305–314

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Marine Policy

journal homepage: www.elsevier.com/locate/marpol

ELSEVIER

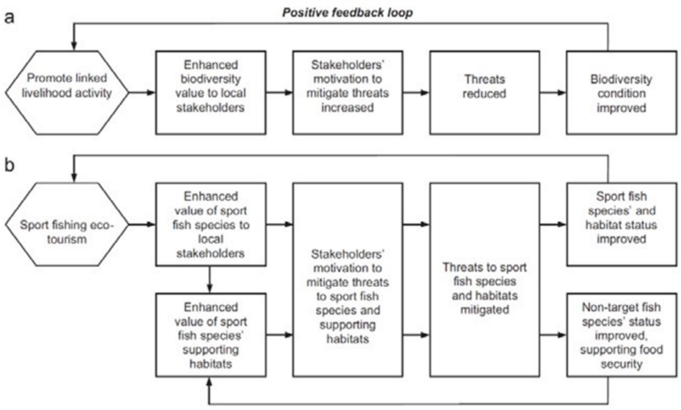
Sport fisheries: Opportunities and challenges for diversifying coastal livelihoods in the Pacific

Apanie L. Wood[a,*], James R.A. Butler[b], Marcus Sheaves[a], Jacob Wani[c]

Rural communities in the Pacific regions often rely on fishing as a source of protein and income. However, high population growth rates and climate change are placing high stress on local fish stocks. Therefore, developing alternative livelihood strategies is becoming a necessity.

Sportfishing as alternative livelihood

Sportfishing is the recreational catch and release for particular species of predatory game fish, and has the potential to be a successful livelihood strategy. Unlike other industries, sportfishing can provide income for locals while protecting the ecosystem.



Conceptual representations of (a) the enterprise approach to integrated conservation and development, and (b) the double linkage between conservation of target sport fish and non-target species and their habitats, and livelihoods development created by a community-based sport fishing ecotourism (Source: Wood et al. 2013).

Principles for success:

- Adequate local capacity and co-management
- Clearly delineated resource-ownership
- Governance arrangements which ensure even dispersal of benefits
- Social, biodiversity and ecosystem service co-benefits
- Monitoring and evaluation within an adaptive co-management framework

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