Title
Socioeconomic and Ecological Analysis of Artisanal Fishery in Yanuca, Fiji

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Introduction

Many coastal communities rely heavily on artisanal fisheries for income and food security, but this reliance can negatively affect the ecosystems they depend on. (FAO 2010, Hawkins and Roberts 2004, Peckham 2007) Though artisanal fisheries are small, research has determined that they are the driving force behind declines in reef fish populations, and rising prices for fish and fish products have only further contributed to such declines. (Newton 2007, Raj and Evans 2004) It is impractical, however, to expect small fishing communities to partake in permanent fisheries closures, given the socioeconomic situation of many coastal communities, which depend on the fisheries for employment, protein, and wealth generation. (Greboval 2002, Johannes 2002, Bene et al. 2007, Ruddle and Hickey 2008) Furthermore, these coastal communities often have strong cultural ties to the fishery that cannot be easily replaced. (Ruddle and Hickey 2008)

The challenge then with artisanal fisheries, Salas *et al.* (2007) explains, is finding a balance between the use and conservation of marine resources. Many artisanal fishers use traditional management practices, which have been in place for centuries. In some cases, such as *tabus* created in Fiji, traditional management practices were intended to stockpile fisheries for celebratory harvests in the near future, not necessarily to provide long-term fisheries management (Foale and Manele 2004). Even if some traditional management practices are geared toward maintaining fisheries for the long-term, the efficacy of these practices may be compromised by increases in population density and/or increased demand for fish products, since the fishery would be providing resources for a larger population. Without empirical data, however, it is difficult to determine the effectiveness of traditional management and the state of the fishery. The fishery must be assessed and monitored in order to determine the health of the fishery and the extent of a community's fishing impact. This poses yet another challenge, since artisanal fisheries are still not well understood and communities often lack the funds to conduct effective assessments. (Ruddle and Hickey 2008, Salas et al. 2007)

The Pacific Blue Foundation, a nonprofit that strives to promote biological and cultural diversity in coastal regions, addressed this challenge by hiring a local woman on the island of Yanuca in Fiji to collect village catch data. The costs of recording daily fish catch are relatively low compared to the costs of conducting extensive biological surveys and interviews, and the data collected may give better quantifiable insight of the state of the fishery than traditional practices provide. The ability to provide quantifiable assessments of the fishery is important because the state of its health can have major implications for local fishers – critical information decision-makers can use when creating policies. For example, highlighting the fishery's economic value can encourage governments, which usually overlook artisanal fisheries, to recognize and consider small-scale fisheries in national policy. (Barnes-Matheau et al. 2013) This paper looks at the effectiveness of Pacific Blue Foundation's method for data collection, preliminary analysis of the data and possible ways to make improvements.

Study Area

The island of Yanuca (pronounced Yanutha) lies in the Beqa Lagoon, just south of Viti Levu, the largest island of Fiji. The village relies on the fishery for protein and income and is located on the southeast side of the island right next to the beach. As of 2007, Yanuca Island had a total of 34 households and a total population of 241, consisting of 125 males and 116 females. (Calamia *et al.* 2010)

Map 1. Yanuca Fishing Sites

An exclusive fishing rights area (*qoliqoli)* surrounds the island, 77 kilometers of which Yanuca villagers have customary rights to fish. About eight square kilometers of the *qoliqoli* held by the Yanuca community has been set aside as a no-take zone. Yanuca villagers share fishing rights to the *qoliqoli* in the Beqa Lagoon with villagers from the nearby Beqa Island. (Calamia *et al.* 2010)

The Beqa Lagoon is 352 square kilometers and holds ten major fishing sites that Yanucan fishers frequent: Cakau Nisici, Dakurukua, Daga, Malua, Waidaiga, the Beach, Naisoga, Cawalevu, Nayamotu, and Kavukavu. (*See* Map 1) Though Lovell *et al.* (2004) states the Beqa Lagoon's reef has a medium overall threat level, with low levels of threat from pollution and destructive fishing, and medium levels of threat from coastal development, the Beqa Lagoon was noted for having a high threat level from overfishing. This is striking given the fact that Yanuca is reliant on its fishery, which could potentially have grave implications for the Yanuca community.

Data Collection

In order to evaluate the state of the Yanuca fishery, Pacific Blue Foundation hired a local woman, Mere Kago, from the Yanuca Island community to collect artisanal fisheries data for the past four years. Kago records the name, number and size (using a meter stick) of fishes; the number of fishers actively fishing; the number of hours spent fishing; the fishing location; and the cost of the boat ride and name of the boat driver (if applicable). This data set is very unique, with fishing catch reported daily (with some exceptions), and low costs associated with the data collection.

Though it is possible that fishers misreported information, having a local in charge of data collection reduces the likelihood of fishers relaying false information about their fishing location, since locals feel more comfortable speaking with her. (Kittinger 2014) It is, however, likely that Kago did not record all catch information, including catch from night fishing trips and/or catch from boats that did not return to the village after the fishing trip. There is also conflicting data, such as catch total not corresponding to the total number of fish recorded under various lengths; missing information, including trip costs and location sites; as well as a five-week gap in the data, from November 2012 to December 2012.

Even so, Barnes-Matheau *et al.* (2013) notes that self-reported data is often less accurate than observed data – especially when researchers are trying to reconstruct estimates about fishing activities that happened in the past. Many researchers attempt to make up for less reliable reports by carefully constructing surveys, though fishers have a tendency to over-estimate catch under such circumstances. (Kuster et al. 2006) The data recorded by Kago is therefore likely to provide just as good of an accuracy of catch data, if not higher, as estimates provided by fishers through interviews.

Furthermore, time-series data that provides information to calculate catch per unit effort is less common among coral reef fishery data. One study looked at trends in coral reef fisheries research and reported a decline in the number of studies that focused on time-series data, fish catch biomass and catch per unit effort. Instead, coral reef fisheries research is focusing more and more on bycatch and stakeholder interview data. (Johnson et al. 2013) Such trends highlight the uniqueness of this artisanal fishery data set and the potential need to focus on time-series data and catch per unit effort information.

Overall Challenges

There are a number of challenges one faces when working with artisanal fisheries data from small coastal communities. One of the major challenges is determining which species corresponds with the name local Fijians use to describe the fish. At times different names were used to describe the same species. In many cases, the local name encompassed several species within one or more genuses. When one name covers a number of species, it becomes difficult to assign specific characteristics, such as size at maturity or trophic level, to the fish. This, however, is a common issue researchers face when assessing small-scale fisheries. When asked about one of the local fish names, James Comley, Project Manager and Research Advisor for the Institute of Applied Sciences at the University of the South Pacific, promptly responded: "I just spoke to one of my colleagues here who is from Beqa island (right next door to Yanuca) and the name Toyaya drew a complete blank with him!... This is a common problem (unfortunately) with using local dialects." In this instance, the Toyaya was never identified, which highlights yet another challenge. Lack of proper identification made it difficult to quantify the total weight of harvested fish and complicated attempts to identify trophic level changes.

Methods

Though Kago had been collecting data since 2009, there were many gaps in the data in years 2009 and 2010, and the format of the collected data changed in 2011. Data analysis therefore uses data collected between August 2011 and June 2013.

While multiple fishing trips could occur daily, Kago did not identify individual fishing trips. The fishing location and the type of fishing gear used, however, was only recorded once, with fish names and lengths listed underneath, which denoted the start of an individual fishing trip. The recording of the fishing location and the type of fishing gear was therefore used to identify individual fishing trips. The catch per unit effort was calculated for each trip, but it excluded trips that lacked necessary information to calculate catch per unit effort, such as hours, fishers, and/or number of fish. Of the 1004 total trips identified, 27 trips were discarded due to insufficient data. Statistically significant catch per unit effort data was identified using the Stata program.

The Fishbase database was used to determine which species/genus corresponded to the local Fijian fish name. Literature reviews and the Fishbase database were used to obtain size maturity estimates of specific species or genuses of fishes. If a local Fijian fish name corresponded to several species across several genuses, the average size maturity was used. However, if a local Fijian fish name corresponded to several species and there was a large range for the reported maturity size among the species, the smaller size was used to be conservative. It was also noted if several species corresponded to a local Fijian fish name but only one species had a known size at maturity.

Due to time constraints, simple analysis was used to conduct an initial assessment of the Yanuca fishery. Preliminary analysis could then be used to guide where more robust statistical analysis should be conducted to better evaluate the state of the fishery and its economic value.

Catch Per Unit Effort

Artisanal fishers are often pressed by socioeconomic needs in the present, such as the need for food and/or income, limiting their ability to minimize present catch for potential increase in future stock. (Ruddle and Hickey 2008) As a result, artisanal fishers discount the future, placing more value in the present catch than in the future productivity, which makes it difficult to implement effective fisheries management without taking into consideration other avenues of revenue for artisanal fishers. Establishing other employment opportunities, however, can be difficult without initial governmental assistance.

Unfortunately, governmental and national policies often neglect artisanal fisheries, in part, due to a lack of data. (Andrew *et al.* 2007, FAO 2010, Barnes-Matheau *et al.* 2013) Even so, very little economic data exists that provide the value of artisanal fisheries. (Harris 2011) Pacific Blue Foundation's data collection can be used to evaluate the economic value of the Yanuca fishery. An economic evaluation of the fishery can be shared with local villagers and the government in order to promote sustainable management practices and a healthy fishery that will ultimately benefit the community.

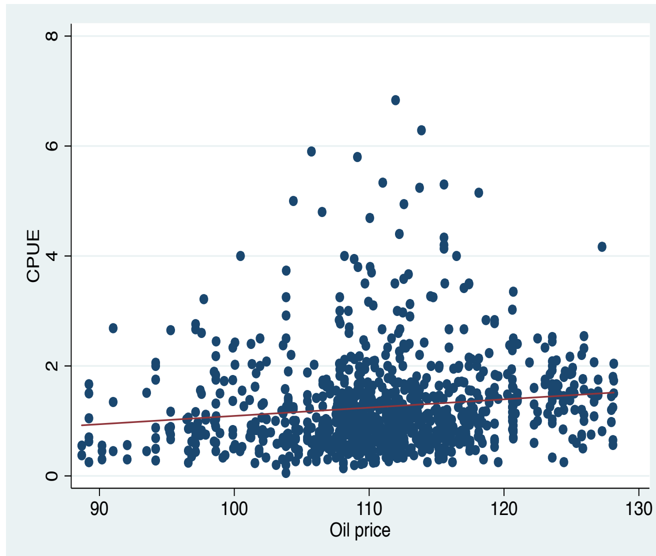


Figure 1. Catch Per Unit Effort plotted against oil price for each individual fishing trip. A positive correlation suggests fishers find ways to fish more efficiently when the price of oil increases.

Upon preliminary analysis of the collected data, a positive correlation between the catch per unit effort and the price of oil was found. As oil prices increased, catch per unit effort also increased, suggesting artisanal fishers tried to fish more efficiently as the price of oil climbed. (*See* Figure 1) While oil prices may not have a direct affect on fishers (Fijian fishers may have their fuel subsidized by the Fijian

cpue	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
brentoil	.0187979	.0052274	3.60	0.000	.0085397	.0290562
_cons	-.791395	.5816011	-1.36	0.174	-1.932727	.3499375

Table 1. Catch Per Unit Effort increases by 0.019 per dollar. The t-statistics (3.6) indicates a statistical significance of 1%. While there is much noise and variation, the increase is still significant.

government), the price of oil may be affecting overall costs, such as import prices – macroeconomic changes which can still be observed in the Yanuca fishery. (*See* Table 1)

Similarly, hours spent fishing per trip decreased as the cost of oil increased, suggesting oil costs affect the fishing behavior of Yanuca fishers. (*See* Figure 2) The number of hours spent fishing decreases by almost 4% for every $1 increase in oil. A $10 increase in oil prices therefore reduces an hour-long fishing trip by 23 minutes. (*See* Table 2) As the cost of oil increases, fishers may be inclined to reduce the number of hours spent fishing, either by fishing closer to home or for shorter periods of time. Again, regardless of the macroeconomics at play, oil prices seem to affect fishing behavior.

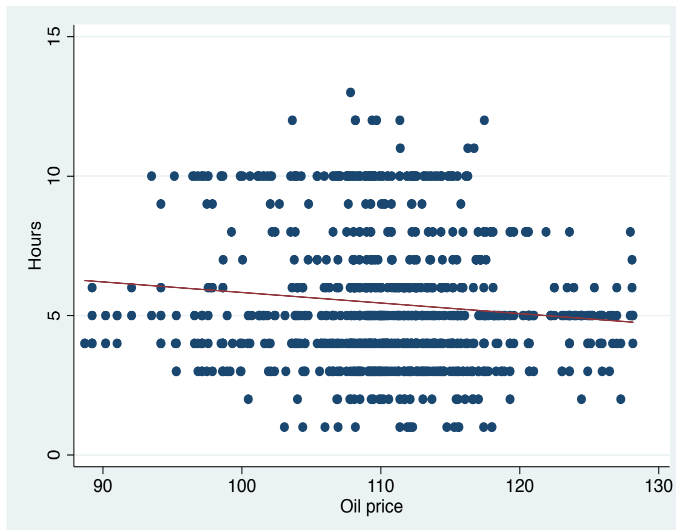


Figure 2. Hours spent fishing per trip is plotted against oil price. A negative correlation is found, suggesting fishers limit their fishing trips as the price of oil increases.

hours	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
brentoil	-.037869	.0102211	-3.70	0.000	-.0579263	-.0178117
_cons	9.615027	1.137412	8.45	0.000	7.383031	11.84702

Table 2. The hours of fishing are changed by -.037869 for each $1 increase in the price of oil. The t-statistics (-3.7) indicates a statistical significance of 1%.

This may explain why certain fishing locations were frequented when oil prices increased. Yanuca fishers spent significantly more time fishing at the beach; a reasonable choice given its proximity to the village. Fishing trips at the beach rarely had any recorded associated costs, suggesting fishers could access the fishing location cheaply and easily, either by walking or swimming to the desired fishing location. Kavukavu was also fished more frequently as oil prices increased. Since Kavukavu is the furthest fishing location from the island, it is less intuitive as to why fishing increased in this location when oil prices increased. It is likely that catch per unit effort is higher in this location, possibly due to a higher fish biomass, but this is just speculation and the correlation needs to be investigated further.

It is important to recognize how various economic factors can impact the Yanuca community's fishing behavior and, most likely, resulting catch and revenue. Further interviews and information is needed, however, to determine to what extent fishers depend on the artisanal fishery.

Yanuca Fishery

The Yanuca fishery is very diversified, comprising over 100 local fish names, and even more species when taking into account the fact that one fish name may include several species. (*See* Figure 3) Such diversity, however, is common in tropical artisanal fisheries. Ruddle and Hickey (2008) observe that nearshore fisheries in the tropics have more species than their temperate counterparts, which can make management more complex for those unaccustomed to working with so much diversity. Many scientists and fisheries managers in temperate regions only have to manage one species of fish. Hughes (1994) notes that diversity can make management all the more difficult due to the trophic level interactions that occur among the many different species. For the purposes of this project, I will be looking at the fishes that have 100 or more reported landings (17 fish names in all), which constitutes 73% of the entire fishery.

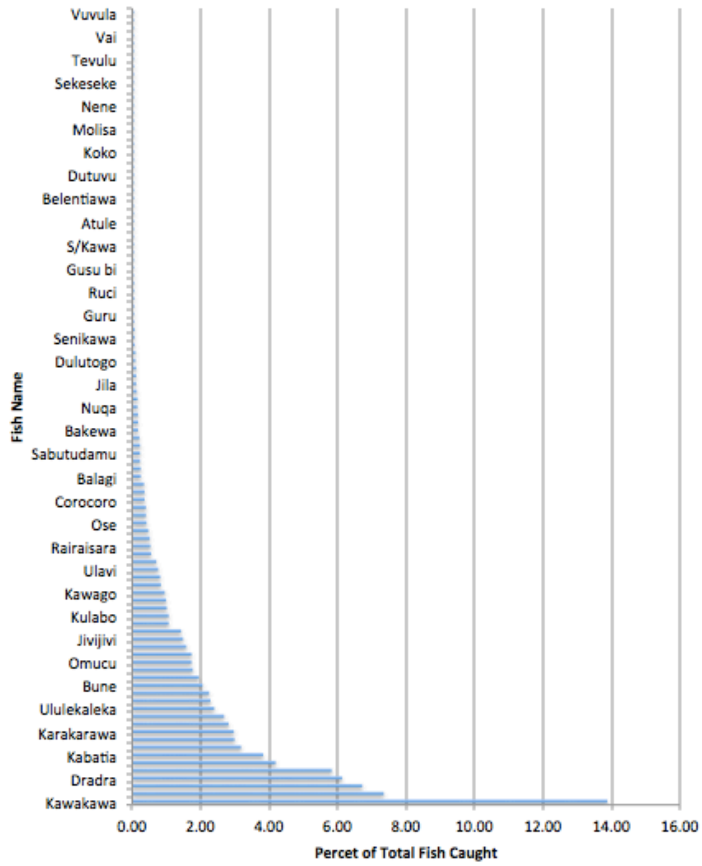


Figure 3. The Yanuca fishery is very diverse, comprise of over 100 fish names. Most fish constitute only a small portion of the entire fishery, with the *Kawakawa* accounting for 14% of the fishery.

Fish Size

Fishery collapse is often associated with “recruitment failure,” or “recruitment overfishing,” as described by Cushing (1983). When too many adult species are harvested from a fishery, it becomes more difficult for the remaining adults to reproduce, and subsequently the stock can crash. Therefore, in order to ensure a fishery is maintained for the future, fishers must maintain enough adults to replenish the fishery. Preliminary analysis of the size of fish caught on Yanuca suggests there are some species that are being harvested at an unsustainable rate.

The Fijian fish name, *senikawakawa*, corresponded to a single species, *Epinephelus merra*, or the honeycomb rock grouper, which made it easier to analyze the species. *E. merra* is a shallow-water coral reef species listed on the IUCN Red List of Threatened Species. However, it is listed as "Least Concern" due to its "widespread distribution, abundance, and presence within a number of marine protected areas," and, though heavily fished, it matures relatively early and can therefore be resistant to low to moderate levels of fishing. (IUCN Red List of Threatened Species 2014) There are, however, concerns about targeted fishing during spawning aggregations, which is proposed to be outside of their shallow habitats. Such concerns arise due to the increased vulnerability species face when forming spawning aggregations: They are more likely to be overfished since their spawning habits are often predictable. (Sadovy de Mitcheson and Erisman 2011) To gain a better understanding of whether the fish was caught outside its shallow-water habitat, *E. merra* catch locations were identified.

Simple analysis found that Yanucans caught a majority of *E. Merra* on the beach or in the nearby fishing site, Malua, which can be expected given the species' shallow-water preference. (*See* Figure 4) The shallow location of the catch suggests Yanuca fishers are not targeting the species' spawning aggregation site, though it does not exclude the possibility that outside fishers are targeting the species' spawning site. Species size was then analyzed to determine whether the fish caught were adults or juveniles. The length of the catch is recorded in increments of 10 cm, with size ranges of 0 to 10 cm, 11 cm to 20 cm, 21 cm to 30 cm, etc. Simple analysis determined that almost 40% of *E. merra* catch was reported to be 10 cm or smaller – smaller than its reported size at maturity at 11 cm. (Murty 2002) (*See* Figure 5) Eliminating juveniles from the fishery not only reduces the number of fish that can reproduce and replenish the fishery, but also means fish

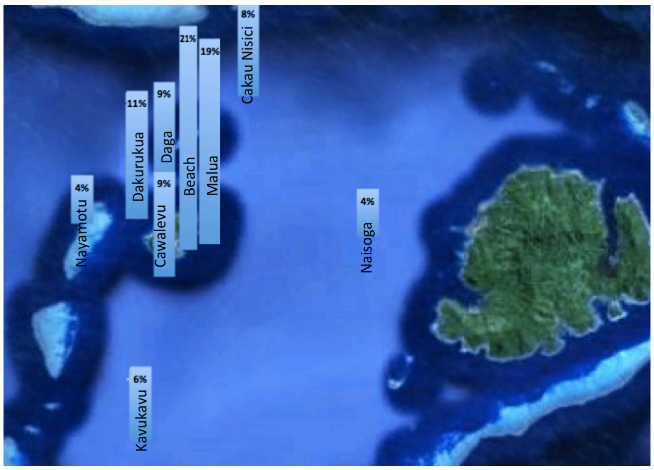


Figure 4. Percentage of *E. Merra* caught at different fishing sights. The majority of fish were caught at the Beach or Malua, shallow water fish locations.

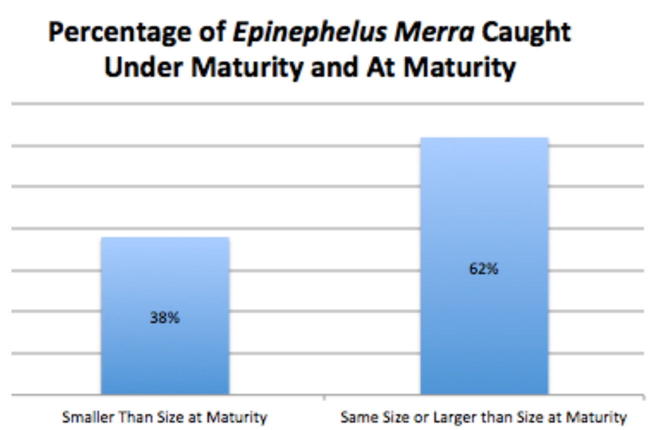


Figure 5. Percentage of *E. Merra* caught smaller than the size at maturity versus the percentage of *E. Merra* caught at the same size or larger than the size at maturity.

were harvested before having the capability of reproducing, which could potentially result in the crash of the stock. Since *E. merra* only constitutes less than 3% of the fishery, limiting catch size of this species may not have major socioeconomic implications for the community.

The *Kawakawa*, on the other hand, is the most commonly caught fish on the island and accounts for almost 14% of the Yanuca fishery. The Fijian name *Kawakawa* encompasses nine species across two genuses (*Epinephelus* and *Cephalopholis*), both of which are types of groupers. The Fishbase database and literature review only provided the size at maturity for 7 of the 9 species, and the reported size at maturity ranged between 26.5 cm and 61.1 cm. (Pears et al. 2006, Sadovy 1998, Shakeel and Ahmed 1996) The average size at maturity for these groupers was 37.6 cm, using conservative estimates. Of the 730 *Kawakawa* caught, 28% were recorded to be 30 cm or less – which conservatively excludes species caught between 30 cm and 40 cm. (*See* Figure 6) Additional research must be done to determine if a specific *Epinephelus* species is predominantly caught on the island. For instance, if *Epinephelus miliaris* is the

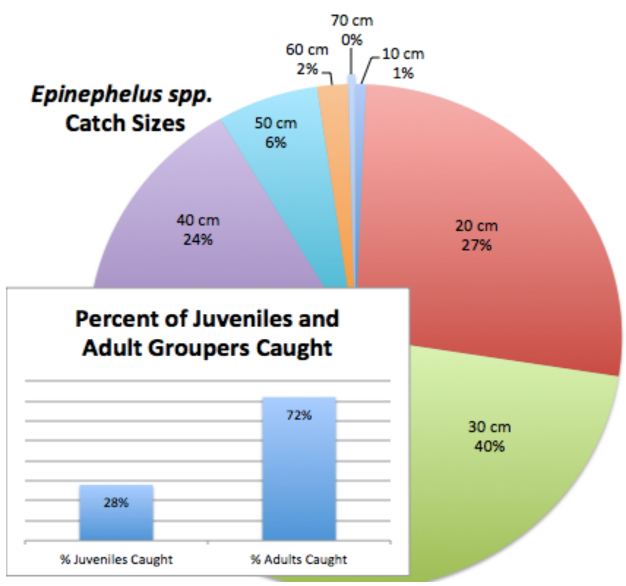


Figure 6. 28% of *Epinephelus* species caught are recorded to be 29 cm or less.

predominant species found in the fishery, there is less cause for concern since maturity is reached at 26.5 cm. (Shakeel and Ahmed 1996). However, if *Epinephelus tauvina* is the main species caught, there is more reason for alarm because the species only reaches maturity at 61.1 cm, meaning almost every fish caught would have not yet reached maturity.

James Comley's colleague at the University of the South Pacific identified Yanuca's *Dradra* as *Lutjanus argentimaculatus*, which has a maturity size of 57 cm. Based on this information, all of the *L. argentimaculatus* catch is harvested before reaching maturity. (*See* Figure 7) While this seems rather worrisome, species verification should be conducted before making management suggestions.

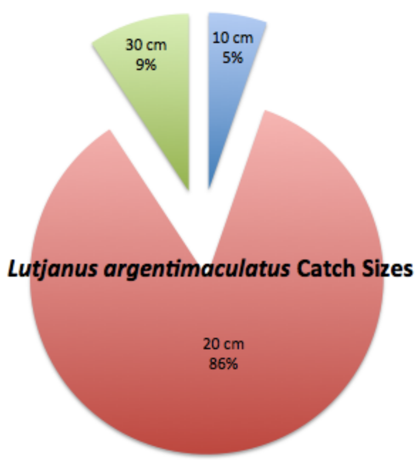


Figure 7. Fishers catch *L. argentimaculatus* before it reaches maturity, based on the identification of the local fish name, *Dradra*.

Similar trends can be seen in a number of the top species found in the Yanuca fishery. However, without knowing which specific species are caught at Yanuca and lacking sufficient maturity size data, it is difficult to confirm whether fish catch is, in fact, harvested before reaching maturity. The data, however, suggests there are a number of red flags that should be further investigated to determine whether or not the fishery is being harvested at a sustainable rate.

The ability to recognize such red flags highlights the benefits of this type of data collection. The cost effectiveness of the data collection scheme implemented on the island of Yanuca enables a robust data set to be collected over a long period of time and simple analysis can provide managers, researchers and other interested parties with a picture of what is happening with the local marine resources. Should potential concerns with the fishery stand out, interested parties can invest more time and resources to identify whether or not there is a large issue at hand and provide management suggestions according to their findings.

Looking Forward: Next Steps

Immediate steps include verifying the predominant species caught in Yanuca, in order to confirm whether species are harvested prior to reaching maturity. This information should be shared with the Yanuca community, conveying clearly the impacts of harvesting juvenile species. Drawing management suggestions from the community is important, not only for encouraging community involvement, but also for developing creative solutions. (Foale and Manele 2004) If species are, in fact, caught as juveniles, species-specific closures or size limitations may be necessary. However, it is most important to take into account the social and economic needs of the village. (Ruddle and Hickey 2008) A species-specific closure may be a reasonable solution for the *Senikawakawa*, which only makes up 3% of the entire Yanuca fishery. A closure may not be reasonable for the *Kawakawa*, which accounts for a much larger portion of the fishery, and size limitations may be used to manage the fishery instead. While conveying catch information to the community is necessary to promote sustainable management of the fishery, potential assistance from the government is likely to be based on a more thorough socioeconomic evaluation.

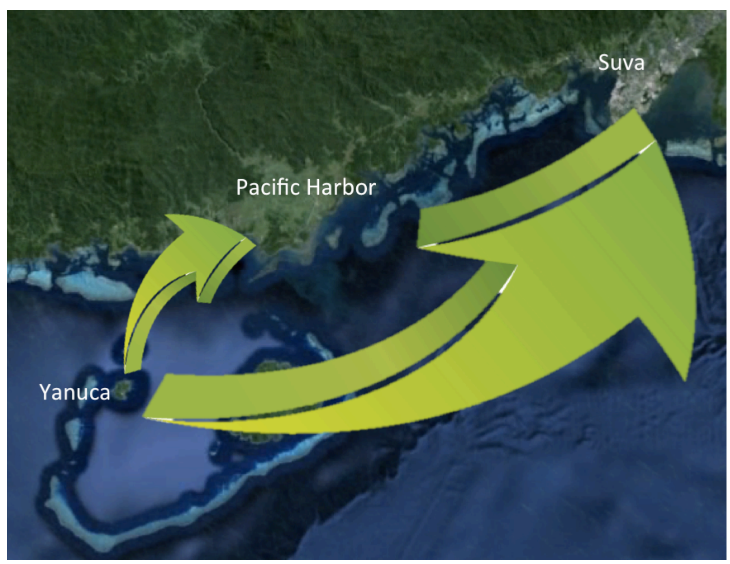
The socioeconomic value of the fishery can be determined with more up-to-date information regarding the village's size and local interviews. By establishing how much of each species is consumed, one can calculate the nutritional value derived from the fishery. Local interviews can be used to estimate the amount of fish consumed versus the amount of fish sold. Coupling interview data with market values for each species can be used to quantify the economic value of the fishery. Such economic data can draw national attention to artisanal fisheries, which is important when requesting governmental support.

In order to determine the true impact of the artisanal fishery, ecological field studies need to be conducted, which would compare the standing-stock biomass of the Yanuca fishery with the pristine biomass of a similar ecosystem. (McClanahan *et al.* 2012) Being aware of the reef's biomass would enable researchers to evaluate harvest rates and can help with the creation of fishery catch targets.

Statistically significant fluctuations in catch size were found, but marine populations are known to be unstable and can change drastically over time due to natural events. While the data set may be useful for the future, it would be difficult, over a short-term period, to identify changes caused by human impacts as opposed to changes that result from poor recruitment, storms, El Niño cycles, etc. (Hodgson *et al.* 2006) The Pacific Blue Foundation data set is an important foundation for the creation of a long-term time-series data set, in which natural fluctuations may be more easily distinguished.

Looking Forward: Improvements for the Future

Post-landing or final use information, which notes where the catch is likely to end up, gives great insight into the extent fisheries resources are distributed. (Kittinger 2013) Artisanal fishers may take the catch home to consume, share with friends and relatives, trade with others, or sell at the market. (Barnes-Matheau *et al.* 2013) Post-landing data, however, is currently not captured in Pacific Blue Foundation's catch survey. Including post-landing data would allow researchers to evaluate the importance of the Yanuca fishery in terms of food security and poverty alleviation – not just within the Yanuca community, but wherever the catch is distributed. (Barnes-Matheau *et al.* 2013) For example, a local Yanucan estimated fishers take home 20% of the catch and sell the remainder in the



market. This means approximately 80% of the catch is distributed in the nearby markets of Suva and Pacific Harbor, providing protein for these communities as well. (*See* Figure 7) Understanding final use information of an artisanal fishery may also reveal whether current management practices are sufficient for the fishery's reach. The data can be used to highlight the extent of the fishery's economic reach and impact on marine resources, which may finally draw attention to the value of sustainably managing artisanal fisheries.

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