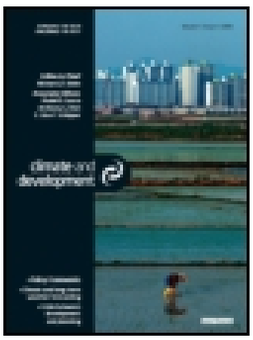

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Impact of Tropical Cyclone Winston on women mud crab fishers in Fiji

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ABSTRACT

Communities dependent on natural resources for food and livelihoods are extremely vulnerable to climate change and its impacts. Tropical cyclones are a frequent occurrence in the Pacific and can have devastating impacts on coastal communities, particularly in remote or isolated areas. However, most post-cyclone studies focus on damages and losses to infrastructure and services, and do not quantify the impact on fishers or community fisheries. We conducted a study to assess the social and economic effects of Category 5 Tropical Cyclone Winston on mud crab fishers in Bua Province, Fiji. The study methodology was one-on-one surveys with mud crab fishers, mostly women, in 16 villages who had previously participated in a 2015 value chain analysis survey. Post-cyclone, 52% of the fishers had stopped harvesting crabs because many were focussed on repairing their homes and had difficulties accessing collection sites and markets. Fishers that continued reported less frequent collection, and fewer and smaller crabs. To obtain income for house repairs, 65% of the fishers still harvesting sold the crabs to local traders, rather than consuming them. Understanding mud crab fishers' vulnerability to natural disasters, the barriers to adaptation and how their livelihoods are affected is key to effective mitigation and adaptation.

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Adaptive capacity; Pacific; Mangroves;-Fisheries; Gender; Natural disasters; Climate Change

1. Introduction

Climate change has caused an increase in the frequency and intensity of extreme weather events (IPCC, 2013; Meehl & Tebaldi, 2004), which can result in significant and long-lasting effects to ecosystems (Easterling et al., 2000; Jentsch & Beierkuhnlein, 2008) and the human communities that depend upon them (Jentsch, Kreyling, & Beierkuhnlein, 2007; Mirza, 2003). For example, tropical cyclones and associated floods can result in the loss of human life and large economic losses (Gray, Landsea, Mielke, & Berry, 1994; Henderson-Sellers et al., 1998; Tonkin, Landsea, Holland, & Li, 1997), including damage to boats, fishing gear (e.g. nets), and fish landing centres, as well as educational, health, housing, and other community infrastructure (Adger, Hughes, Folke, Carpenter, & Rockstrom, 2005; Jallow, Toure, Barrow, & Mathieu, 1999; Westlund, Poulain, Bage, & van Anrooy, 2007). Sectors that constitute the livelihoods of rural populations in developing countries, such as agriculture and fisheries, are among those most vulnerable to climate change (Adger, Huq, Brown, Conway, & Hulme, 2003; Howden et al., 2007; Webster & Jian, 2011) and its impacts.

Vulnerability has been defined as 'the state of susceptibility to harm from exposure to stress associated with environmental and social change and from the absence of capacity to act' (Adger, 2006, p. 268). The vulnerability of natural resource-based livelihoods is determined by a mixture of biological and socio-economic factors including dependency on natural resources for livelihoods, availability of alternative livelihoods and natural resources, lack of financial and human capital (to pursue alternative livelihoods), isolation, gender, unstable sources of income, and poor infrastructure (Ding et al., 2014; Islam, Sallu, Hubacek, & Paavola, 2014b; Orchard, Stringer, & Quinn, 2016). Although sensitivity and vulnerability determine potential impacts, adaptive capacity (the ability to adapt to a change in circumstances) is a major influence on determining what effects actually occur (Marshall, Tobin, Marshall, Gooch, & Hobday, 2013). Adaptive capacity may be limited by a lack of physical, natural, and financial capital, and/or limited diversification of livelihoods. Barriers to adaptation may include poor technology, lack of access to credit or unfavourable credit schemes, low income, attachment to place and/or occupation, lack of education, skills and livelihood alternatives, lack of access to markets, and limited local environmental knowledge (Islam, Sallu, Hubacek, & Paavola, 2014a; Marshall & Stokes, 2014; Morzaria-Luna, Turk-Boyer, & Moreno-Baez, 2014). Understanding both vulnerability and adaptive capacity to climate extremes is essential for effective climate change adaptation planning (Sewando, Mutabazi, & Mdoe, 2016).

Knowledge of climate-induced impacts and vulnerability at the local scale remains limited, as most studies have focussed on the national scale (e.g. Allison et al., 2009; Sissoko, van Keulen, Verhagen, Tekken, & Battaglini, 2011; Vincent, 2007). Furthermore, the issues of vulnerability and adaptation have not been widely studied in the Pacific Islands despite this region being among the most vulnerable to climate change. Past research efforts have largely focussed on communities' vulnerability to climate change as a whole (e.g. Islam et al., 2014b; Sallu, Twyman, & Stringer, 2010; Sewando et al., 2016), as opposed to

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their response to specific climatic events (e.g. Arouri, Youssef, & Nguyen, 2015; Forster, Lake, Watkinson, & Gill, 2014; Marshall et al., 2013).

Fiji is highly sensitive to natural disasters and over the last four decades, half of those experienced by the country were tropical cyclones (Lal, Singh, & Holland, 2009). On 20 February 2016, Fiji was hit by Category 5 Tropical Cyclone Winston that left a trail of destruction along its path over a 24–hour period. The cyclone damaged or destroyed 30,369 homes, 495 schools, 88 medical facilities and 44 people lost their lives (Government of Fiji, 2016). Crops were destroyed on a large scale and the livelihoods of 62% of the population were affected. The total value of damages and losses was estimated at US $943 million and the fisheries sector, comprising 1.8% of Fiji's GDP, sustained damages and losses estimated at over US$19.3 million (Government of Fiji, 2016). A post-cyclone village-level assessment led by the Wildlife Conservation Society (WCS), the Fiji Locally-Managed Marine Area (FLMMA) network and partners, documented losses in boats, engines, fishing and post-harvest gear totalling US$1,402,582 across six provinces (Chaston Radway et al., 2016). Losses in fishing gear and infrastructure impacted key fisheries such as coral reef fish, sea cucumbers, prawns, shrimp and mud crabs; and data were sex disaggregated to look at how the cyclone impacted men versus women. For example, for both women and men, the number of fisheries they were involved in decreased after the cyclone. Coral reefs and open ocean fisheries were among the fisheries hardest hit as access usually required a boat (Chaston Radway et al., 2016). In terms of fishing gear, over 50% of dive gear was lost and/or totally destroyed, and the majority of this type of gear was owned by men. In contrast, the majority of hand nets were owned by women and this gear was less likely to be damaged (Chaston Radway et al., 2016).

The losses and damages suffered as a result of the cyclone affected the food security of the coastal villages as fisheries and aquaculture for local consumption contribute considerably toward household nutritional security, particularly in the developing world. For example, fishing provides between 50% and 90% of animal protein in rural areas in the Pacific Islands (Bell et al., 2009; Ram-Bidesi, 2015). In these countries women rely heavily on nearshore marine resources, especially marine invertebrates, to provide regular and stable food supplies to their families (Bonine, Bjorkstedt, Ewel, & Palik, 2008; Keenan, 1999; Kibria, Haroon, & Nugegoda, 2017). The women also provide a disproportionate contribution to household and village protein requirements, around 80% (Chapman, 1987; Kronen & Vunisea, 2009).

Marine invertebrates, such as mud crabs (*Scylla serrata*), form a large portion of small-scale coastal fisheries where their capture generates considerable revenue (Davis, Newell, & Quinn, 1998; Le Vay, 2001). Mud crabs provide an important source of food (protein) and income for coastal communities throughout its range, including Fiji (Dalzell, Adams, & Polunin, 1996). In Fiji, mud crab harvesting is largely done by indigenous Fijian *(iTaukei)* communities within mangrove forests, adjacent mud and sandflats within their traditional fishing grounds (*qoliqoli*) and, to a small extent, in rivers and opportunistically on coral reefs (Vandervord, Fox, Nand, Nalasi, Veibi, & Mangubhai, 2016). Mud crabs are prized due to their large size, high meat yield and delicate flavour. In late 2015, WCS conducted the first supply and value chain analysis (VCA) of the wild caught mud crab fishery (Mangubhai, Fox, & Nand, 2017). The VCA provided baseline data to assess the impact of Cyclone Winston on mud crab fishers. The VCA study found that the majority of mud crab fishers harvested the crabs by hand and travelled less than an hour to their fishing site(s). The main use of the mud crabs was to sell them for income, rather than household consumption. Almost all fishers had at least one other source of income aside from fisheries, and most considered one of those sources to be their main source of income.

The objectives of this study were to: (1) assess the social and economic impact of Cyclone Winston on the mud crab fishers in Bua Province two to three months after the cyclone and (2) provide recommendations for government and development partners on how to better direct recovery and rehabilitation efforts.

2. Materials and methods

2.1. Study area

The study was undertaken in Bua Province which is located on the western side of Fiji's second largest island, Vanua Levu (Figure 1). The province has nine districts with 54 villages, including 40 coastal villages that were in the path of Cyclone Winston. The area is one of Fiji's least developed regions, with high poverty levels and dependence on natural resources (Kim, Mangubhai, Fox, Gernez, & Jupiter, 2017). The villages are rural with a population of predominantly *iTaukei* that are isolated from markets and urban centres due to poor transportation, infrastructure and rugged terrain. Local *iTaukei* communities hold customary rights to the resources in their forests and fishing grounds, which are managed in practice through traditional systems of governance (Clarke & Jupiter, 2010; Sloan & Chand, 2016).

2.2. Data collection and analysis

2.2.1. Pre-cyclone assessment

A scoping study was carried out from 7–17 September 2015 to identify respondents for a VCA of the mud crab fishery. A map of mangrove forests was used to select 20 coastal villages in Bua Province potentially engaged in mud crab harvesting. Focus group discussions in the villages were used to confirm if anyone in the village caught and/or sold mud crabs, and if so, their names were obtained. Although the focus groups were open to anyone, attendees were predominantly women as they were more likely to be involved in mud crab harvesting. Focus group attendees were also asked to name any other villages where residents harvested mud crabs ('snowball' technique).

The VCA questionnaire was developed by adapting a questionnaire designed by WCS for the sea cucumber fishery (Appendix 1 in Mangubhai et al., 2017). Although the VCA study surveyed all the market players and assessed their investments along the wild caught mud crab supply chain, only the data from the fishers was used to assess the impact of Cyclone

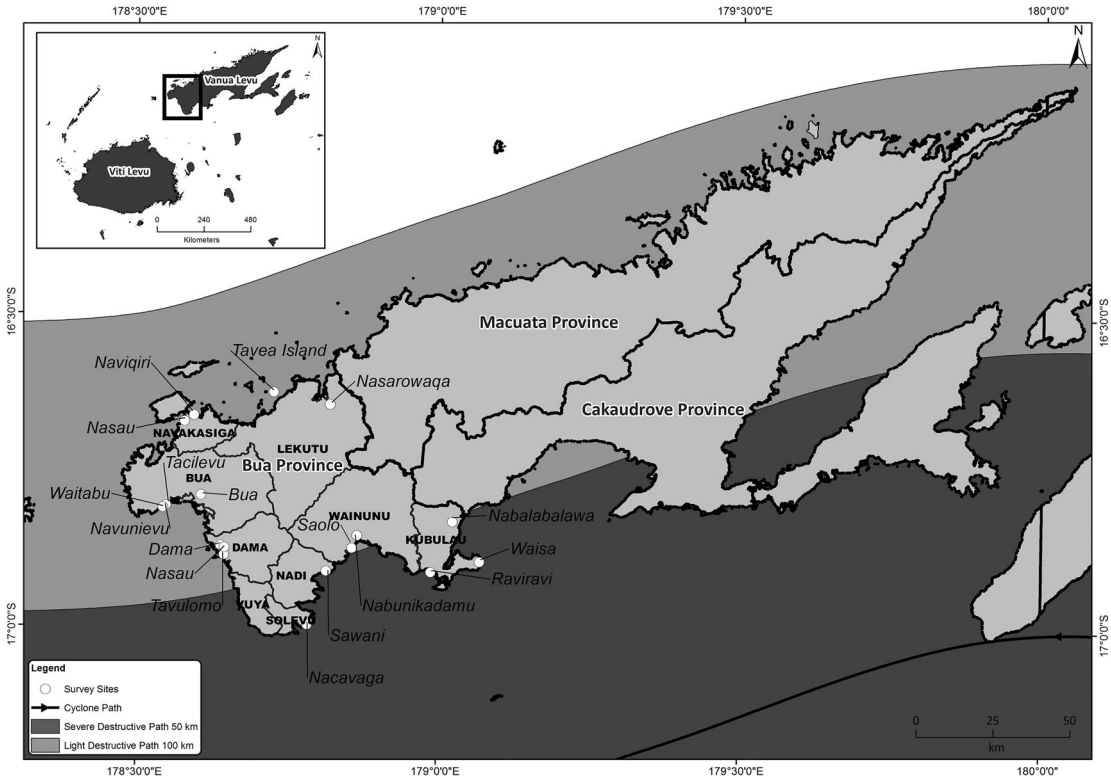

Figure 1. Location of villages in Fiji where mud crab fishers were interviewed in Bua Province, and the path of Cyclone Winston.

Winston. The VCA documented catch, size preferences, prices and markets targeted by fishers and the contribution of the fishery to household income. The study aimed to survey as many mud crab fishers that were available and agreed to be interviewed. A total of 109 mud crab fishers were interviewed pre-cyclone, of which 96 were women and 13 were men.

2.2.2. Post-cyclone assessment

A socioeconomic survey was conducted in Vanua Levu from 13 April to 13 May 2016, two to three months after Cyclone Winston made landfall. We attempted to interview all of the mud crab fishers that had participated in the 2015 VCA. Respondents were assured that all information would be kept confidential and only aggregate information would be used in publications. No fishers interviewed in 2015 refused to participate in the 2016 survey. The fishers interviewed in 2016 therefore comprised of a mixture of fishers interviewed in 2015 (55 of 109), who were present in the village and available for interview and new fishers (13). The final number of fishers interviewed post-cyclone was 68, in 16 communities across 8 of the 9 districts in Bua Province. Of the fishers interviewed, 61 were women and 7 were men. Interviews took an average of 30–40 min to complete and were conducted in people's homes in the *iTaukei* language by trained local female interviewers.

To allow comparison between pre- and post-cyclone responses of fishers, the majority of the questions asked were identical or complementary to the corresponding ones in the VCA study. The questionnaire was composed of three parts. The first part focussed on mud crab harvesting and any post-cyclone changes. The second part contained questions on the economic aspects of the fishery, including whether the crabs were eaten or sold, and if sold, to whom. The final part covered ecosystem and fisheries infrastructure impacts from the cyclone.

2.2.3. Data analysis

Data were analysed using SPSS Version 23 and the regression models carried out in R Version 3.3.3 (lme4 package). Paired sample t-tests were used to compare pre- and post-cyclone responses to the same quantitative questions (time to site and average price). Chi Square tests were used to test for differences in post-cyclone categorical data (e.g. mangrove damage) as well as differences between pre-and post-cyclone categorical data (e.g. collection frequency, use of crabs, other sources of income). When the Chi Square requirement of cells with an expected count of at least five was not met, a Fisher's exact test was used instead. A standardized residual (Std. Residual) of +/− 1.9 was used as the minimum value for significance. Post-cyclone variables were tested for the influence of district but only significant results ($p < 0.05$) are reported.

Finally, a series of five logistic regression models were formed to explore the main predictors of a fisher's decision to whether or not to harvest mud crabs post-cyclone. The first model solely considered the demographic variable previously analysed – district. Model 2 added another demographic variable, perceived damage to mangroves. The third model consisted of the two main economic variables (collection of other seafood and other sources of income) and Model 4 added the comparative importance of fisheries vs. non-fisheries income sources. The final model was the saturated model including all predictor variables.

The null hypothesis for the regression models was that none of the five predictor variables would influence a fisher's decision to continue harvesting post-cyclone. The alternative hypotheses suggested that fishers that fell into the following categories would be less likely to still harvest mud crabs post-cyclone: (1) from districts that were harder hit by cyclones, (2) from areas with greater perceived mangrove damage, (3) that sold other types of seafood, (4) had at least one non-fisheries source of income and, (5) considered that non-fisheries livelihood to be a better source of income.

3. Results

3.1. Changes in harvesting patterns

Two to three months after Cyclone Winston, 52% of the fishers interviewed had stopped collecting mud crabs. The primary reasons given were because of fallen trees and/or debris preventing clear access to mangroves (32%) and bad weather (15%) (Figure 2). Other reasons provided included being busy with village repairs or babysitting, damage to mud crab habitat, and a mangrove *tabu* (a temporary no-take area) in place (7% each). Fifty percent of the fishers had returned to the mangrove forests to harvest mud crabs within the first 30 days after the cyclone made landfall.

Of the 33 fishers who still collected mud crabs, only three reported that their harvesting sites had changed. The travel time to the sites had not significantly changed from pre- to post-cyclone ($X^2(3) = 1.69$, $p = 0.638$). The majority of fishers travelled less than one hour, and none reported travelling more than two hours to the site. The primary methods of crab collection were also unchanged from 2015. Hand collection was the most common (68%) and hand net (27%) was the second most common method of harvesting mud crabs. Only two fishers, both male, used spears.

Forty-two percent of fishers reported that the frequency of their fishing trips (to collect crabs) had changed. All fishers answering 'yes' to the previous question reported that they now collected mud crabs less often. Post-cyclone more fishers ($X^2(1) = 4.50$, $p = 0.034$) collected mud crabs on a weekly basis (69%) than on a monthly basis (31%). Fishers were also more likely ($X^2(1) = 7.95$, $p = 0.005$; $V = 0.30$) to collect mud crabs less than once a week in 2016 (30% vs. 7%; *Std. Residual* = 2.0).

A significantly higher percentage (68% vs. 32%) of fishers also reported that post-cyclone there had been a change in the quantity of mud crabs caught. These fishers were more likely ($X^2(2) = 13.46$, $p = 0.001$) to report they caught higher numbers of mud crabs pre-cyclone (*Std. Residual* = 8.3), than post-cyclone. There was a large variation in the number of crabs caught per trip ranging from 1–30 ($M = 5.60$, $SD = 5.44$, $Mdn = 4.50$), with weights varying from 5–8 kg. The majority (88%) of fishers caught 10 or fewer mud crabs per trip. Around half of the fishers (43%) thought the size of mud crabs collected had changed since the cyclone. These fishers were more likely (63%; $X^2(2) = 6.13$, $p = 0.047$) to report the crabs they now caught were smaller (*Std. Residual* = 4.70).

Fishers were asked to rank the main use of the mud crabs they collected, and their pre- and post-cyclone responses were compared. Figure 3 shows what fishers listed as the most common (rank 1) and the second most common (rank 2) use both pre- and post-cyclone. For both years, the majority of mud crabs (75% pre- and 85% post-cyclone) were sold rather than used for household consumption (25% pre- and 11% post-cyclone). However, when the type of buyer was considered, the most common use of mud crabs significantly differed between years ($X^2(7) = 20.37$, $p = 0.005$). Prior to the cyclone, the most frequent uses of mud crabs were consumption by the household (25%), sale to traders (24%) and sale to local markets

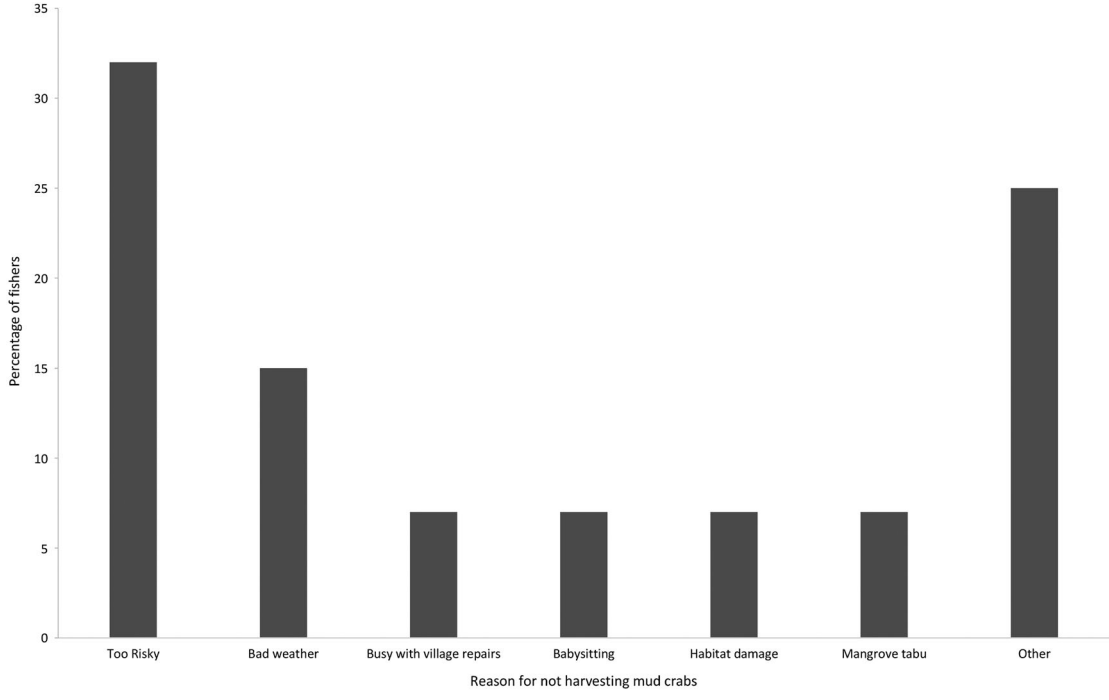

Figure 2. Reasons fishers did not collect mud crabs post-Cyclone Winston. A *tabu* is a temporary no–take area. Other reasons included being sick or too old.

(23%) (Figure 3(a)). After the cyclone, the most frequent use of mud crabs was sale to traders (65%). Both pre- and post-cyclone, the number two use of mud crabs was the same: consumption by households ($X^2(6) = 7.80$, $p = 0.238$) (Figure 3(b)).

3.2. Changes in mud crab sales

Of the fishers still harvesting, only 21% stated that the cyclone had impacted their ability to sell mud crabs. This was largely due to road access being blocked (46%), access to markets being only by boat (23%), or a perceived decrease in mud crab stocks (15%). A significant percentage of these fishers also reported that the cyclone had affected the sale price of mud crabs. The majority (81%) noted the price of mud crabs had increased, without attributing the increase to the cyclone. The remaining (19%) fishers reported that they could now sell their mud crabs at a higher price because of the cyclone.

Post-cyclone, 76% of the fishers still collecting sold the crabs at least once a week and 21% sold on a monthly basis. The price of sold mud crabs averaged US$6.77/kg and ranged from US $3.79–$8.53/kg ($SD = 2.54$), with 50% of the fishers getting US$6.63/kg or less. This was a 36% price increase, and significantly higher ($t(120) = 4.67$, $p < 0.001$, $d = 1.05$) than pre-cyclone prices. Prior to the cyclone, fishers had sold their mud crabs for an average of US$4.96/kg (range US$1.41–$10.35/kg).

3.3. Other sources of income

Fishers were asked if they had opted to harvest other seafood to compensate for changes in mud crab harvesting. Post-cyclone, fishers were more likely not to sell any other types of seafood ($X^2(1) = 14.60$, $p < 0.001$, $V = 0.36$, *Std. Residual* = 1.9). Sixty-four percent of respondents fell into this category, up from 29% pre-cyclone. The effect of district was significant ($X^2(7) = 23.65$, $p < 0.001$, $V = 0.68$), with fishers from Dama District more likely to sell another type of seafood (*Std. Residual* = 2.7). The other two main seafood species sold were sea cucumber (70%) and fish (55%), which was similar to data from 2015.

All respondents were asked if they had any other source of income, unrelated to fishing, and 57% answered 'yes'. Compared with 2015, fishers stated they had fewer alternative sources of income ($X^2(1) = 16.69$, $p < 0.001$, $V = 0.37$). Weaving and/or sewing mats was the most common source of other income, closely followed by sales of kava (*yaqona, Piper methysticum*) and coconut (Figure 4). The main sources of non-fisheries income did not vary significantly from 2015 ($X^2(7) = 5.67$, $p = 0.612$). Post-cyclone, fishers with other livelihoods were more likely to report it provided a better source of income ($X^2(2) = 12.05$, $p = 0.002$, *Std. Residual* = 7.7) than fisheries.

3.4. Damages and losses

Ninety-one percent of the fishers reported that Cyclone Winston had damaged their gear for fishing and/or harvesting crabs. The level of damage varied; 80% of fishing gear (including hand nets) was reported as 'still good', 11% of diving gear was damaged and 13% was 'lost/totally destroyed'. However, two of four crab traps were 'lost/totally destroyed' and one was 'damaged'. In terms of fishing infrastructure, the most damaged items were boats (79%), which included bamboo rafts *(bilibili*), and wooden and fiberglass boats. Damaged boats were mainly owned by the individual mud crab fishers (64%), or others in the village (36%) but frequently used by the fishers. To address the damage, fishers planned to share and use other boats within the village or district. The second most damaged infrastructure item identified was the ice plant in the main town of Nabouwalu (southeast corner of Vanua Levu), which was used by many of the villages pre-cyclone.

The majority of fishers reported their household had suffered from fishing losses. The main losses were less seafood eaten (47%), loss of income (24%), both less seafood eaten and loss of income (9%), and gear damage (9%). To address gear damage, the majority of fishers (71%) planned on buying new gear (without specifying how they would get the money), 14% planned on catching more mud crabs to pay for new gear, 7% planned to sell kava to earn the money and 7% did not specify.

3.5. Ecosystem protection and impacts

The perceived effect of Cyclone Winston on mangrove systems was categorised as mildly, moderately or highly impacted. The highest percentage of respondents (52%) reported their fishing area had been mildly impacted, followed by highly impacted (33%) and then moderately impacted (14%). District location had a large effect on reported mangrove damage ($X^2(14) = 59.08$, $p < 0.001$, $V = 0.70$). Fishers in Lekutu and Bua Districts were more likely to say the mangroves had been 'mildly impacted' (*Std. Residual* = 2.1). In contrast, the districts of Wainumu and Kubulau were less likely (*Std. Residuals* = −2.5 and −1.9, respectively) to have answered 'mildly impacted' and more likely (*Std. Residuals* = 3.0 and 3.1, respectively) to answer 'highly impacted'. Finally, fishers from Navakasiga District were more likely to report the mangroves were 'moderately impacted' (*Std. Residual* = 2.4). Additionally, a majority of the fishers (87%, $X^2(1) = 35.06$, $p < 0.001$) believed the mangrove system provided some form of protection for their village. The most common responses were that the mangroves acted as a wind breaker (28%), protected the village (23%), were a habitat/breeding place for marine species (20%), and prevented erosion along the river banks (15%).

Fishers were also provided with the opportunity to offer suggestions as to how the government could help them recover from the impacts of Cyclone Winston. There were six main requests (Figure 5) given by the fishers. Providing access to new markets for selling the crabs, ideally at a higher price the most frequent request (45%). Standardizing the market price of mud crabs, especially in consideration of the money needed for repairs, was the second-most common (38%) request from the fishers.

3.6. Factors influencing harvesting

The model selection process started with the fully saturated model and explored the effect of deleting predictor variables on the overall model fit. Results showed that none of the models

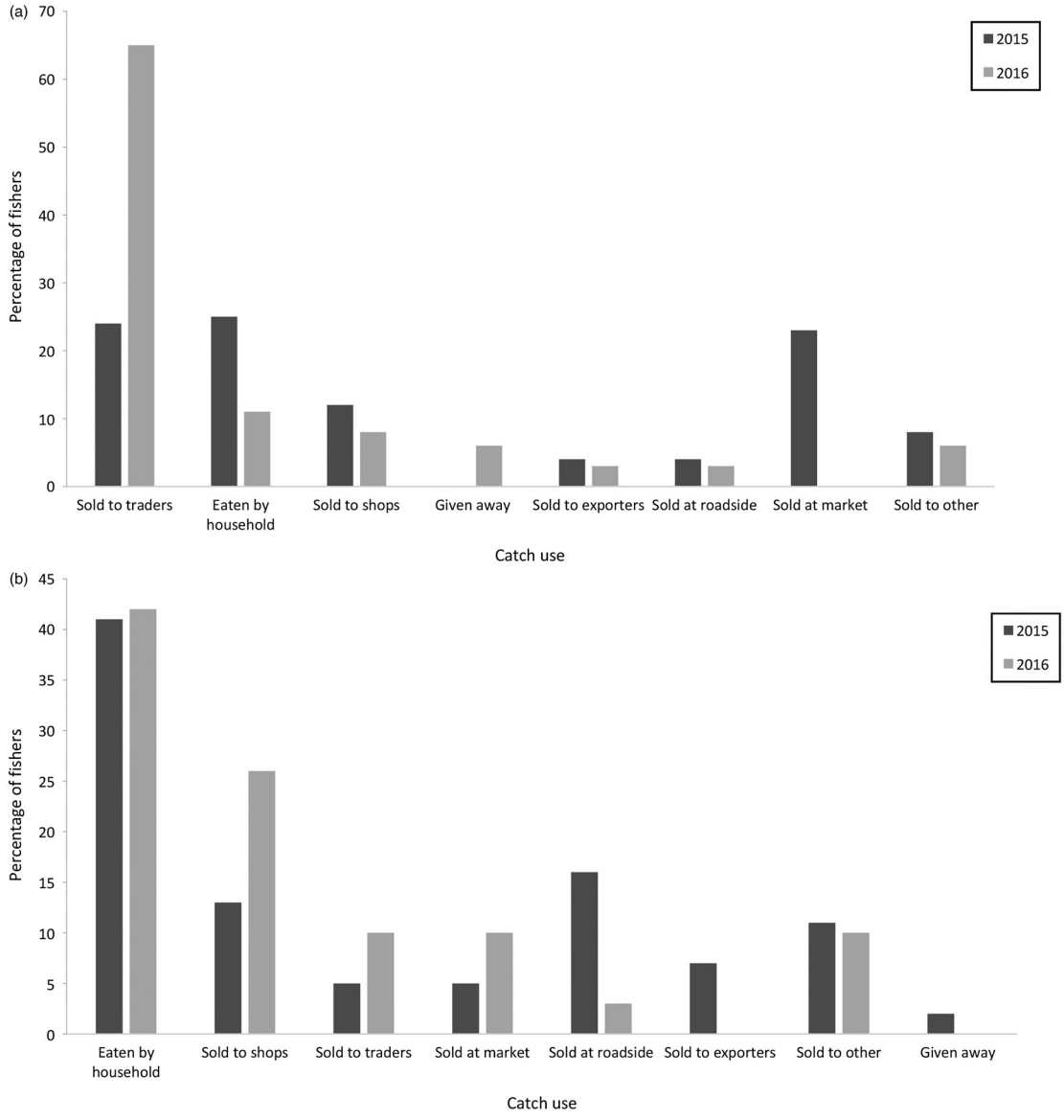

Figure 3. The number one (a) and number two (b) use of mud crabs pre- and post-Cyclone Winston.

were a good fit; with no predictor variables showing a significant effect on crab harvesting. We were therefore unable to reject the null hypothesis for any of the five models.

4. Discussion

Fishing communities, especially coastal ones, face the immediate and growing threat of climate change and associated disasters (FAO, 2017). In 2016, Tropical Cyclone Winston caused wide scale impacts to fisheries–dependent communities along its pathway in Fiji (Chaston Radway et al., 2016). This study enabled a detailed analysis of the effects of Cyclone Winston on the mud crab fishery in Bua Province, including changes in fishing effort, catch volumes and prices. Consistent with other studies (Adger et al., 2003; Shackleton & Cobban, 2016; Smit & Wandel, 2006) the effect on fishers within a province appeared to vary as a function of differentiated vulnerability and adaptive capacity, as well as damage from the cyclone. Inequalities in access to resources, capabilities and opportunities (Afriyie, Ganle, & Santos, 2017; Mersha & Van Laerhoven, 2016; UN Women, 2015) meant the mud crab fishers, which were mainly women, were highly vulnerable to the cyclone and its impacts.

Mud crabs were an important source of income for fishers in Bua Province, with most fishers preferentially selling the majority of their catch both pre-and post-cyclone. Cyclone Winston significantly impacted this source of income for the majority of mud crab fishers in the study. Half the fishers no longer harvested mud crabs two to three months after the cyclone; and the fishers that continued to do so faced multiple challenges. As the results indicated, many fishers were restricted in physically accessing the mangroves and many reallocated their resources and time towards recovering from cyclone damage. The fishers that continued to harvest mud crabs reported both fewer and smaller crabs, as well as harvesting less frequently. The higher price received post-cyclone

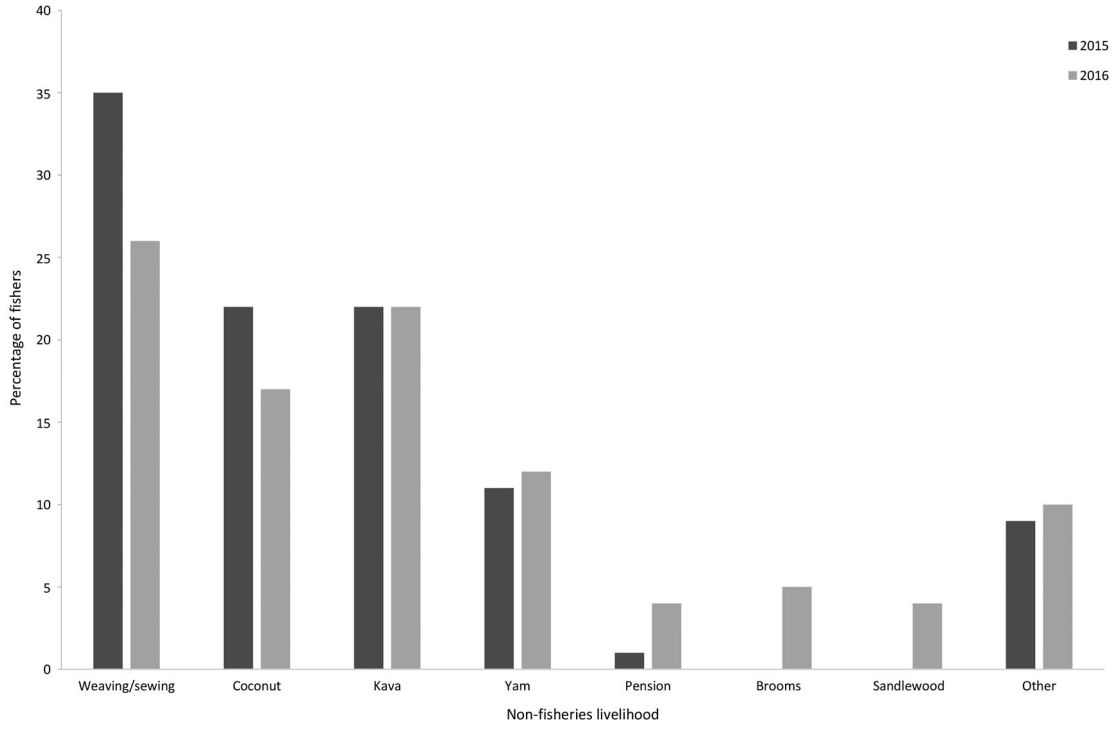

Figure 4. Comparison of pre- and post-cyclone non-fisheries income. Kava (*yaqona*) is a traditional drink in Fiji. 'Brooms' are traditional Fijian brooms (*sasa*) made out of the vein of coconut leaves.

appeared to be insufficient compensation for these decreases (as well as other fisheries-related losses) as many of the fishers still reported a loss of income from fisheries.

In order to earn income fishers would have needed to adapt to changes in the availability of natural resources (such as the mud crabs) and/or focus on alternative livelihoods that were not dependent on natural resources. Limited access to markets post-cyclone has been influential in other countries recovering from cyclones (Eriksson et al., 2017) and appeared to be a key barrier for mud crab fishers in the current study. Although visits by traders increased post-cyclone, the price received would have been lower than the corresponding market price as was the case pre-cyclone (Mangubhai et al., 2017). For many fishers, increasing the amount of seafood harvested is a typical response to fisheries impacts (Eriksson et al., 2017) however, many mud crab fishers were unable to utilize this strategy due to the mangrove damage affecting the mud crab populations. Another potential adaptation strategy was to switch to other fisheries in order to earn income. Post-cyclone many fishers in Bua Province targeted fewer fisheries (1–3 instead of 2–4) and focussed more on freshwater fisheries such as mussels and prawns as this habitat was accessible by foot, and depended less on oceanic fisheries that required boats (Chaston Radway et al., 2016).

The mud crab fishers faced numerous barriers to adaptation, including a lack of livelihood alternatives, lack of access to markets, technologically poor boats and dependency on the fishery. However, none of the five models tested were successful in predicting whether or not a fisher still harvested mud crab post-cyclone. This is most likely because key explanatory variables may not have been included given the rapid nature of the study. Potential variables include continued access to the mangroves (although mangrove damage could be considered a proxy, it does not measure the same variable), other time commitments (both given as reasons for no longer collecting), education (Adelekan & Fregene, 2015), and income (Black, Bennett, Thomas, & Beddington, 2011; Kleiber, Harris, & Vincent, 2015; Paavola, 2008). We hypothesize that inclusion of these factors would have significantly increased the explanatory power of the model and provided greater insight into the vulnerability and adaptive capacity of the fishers. An increased sample size would have also increased the likelihood that one or more of the predictor variables showed a significant effect, as they have proven relevant in other studies (e.g. Brooks, Adger, & Kelly, 2005; Dumenu & Obeng, 2016).

Despite some of the fishing gear being damaged by the cyclone, this was not given as a reason for not collecting mud crabs. Women's fishing methods and technology is generally simpler than men's, who often use multiple types of hooks and lines, traps, nets, spears and boats (Chapman, 1987; Kleiber, Harris, Vincent, & Rochet, 2014). This was true of the female-dominated mud crab fishery, where the most common harvesting method was hand collection and most fishers did not need a boat to access the mangroves. Even the second most commonly used gear, hand nets, were less likely to have been damaged during the cyclone, reducing vulnerability. However, for some households this was offset by a reliance on the sale of other types of seafood for a majority of their income. The damage to boats would have prevented many men from going out fishing, consistent with fewer households selling other types of seafood post-cyclone. Furthermore, the damage to boats combined with the decreased consumption of mud crabs could have negatively impacted household nutritional security, depending on access to other sources of protein.

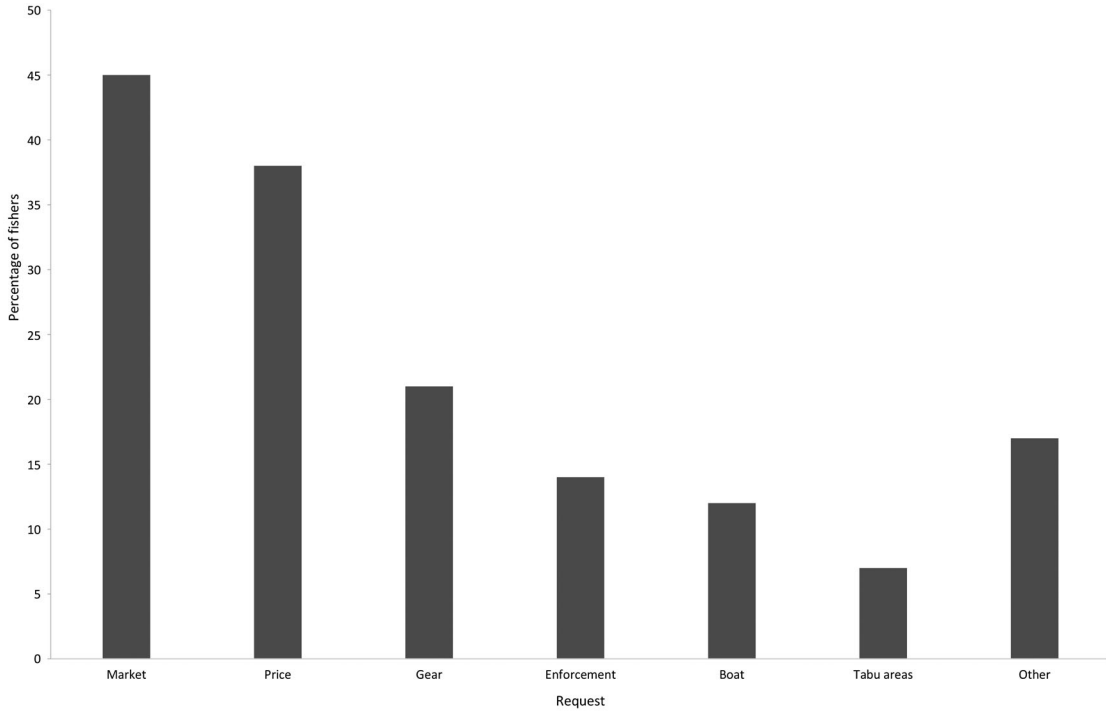

Figure 5. Fishers' requests to the government concerning mud crab fisheries. "Market" included access to new markets and more stable markets. Price-related requests from fishers were both higher and/or standard prices for the mud crabs they sold. Gear requested by the fishers included traps, nets and reef shoes. A *tabu* is a temporary no-take area.

Emergency food supplies were provided to rural communities largely during the first four weeks following the cyclone by the Fiji Government and emergency aid agencies (Chaston Radway et al., 2016). Households that had at least one non-fisheries source of income would have been less vulnerable to the cyclone and have a higher adaptive capacity because of the continued income from the other source(s).

Notably, in addition to the damage sustained to current gear, the cyclone also created a need for new gear. Multiple fishers requested reef shoes (i.e. pull over closed toes shoes with water resistant bottoms) as post-cyclone the mangrove areas were damaged and could not be walked on with bare feet. In a time where income was already reduced, the need for further money to invest in new gear to continue their livelihood was problematic for the fishers and added another barrier to continued crab harvesting. This would have been a greater barrier for the women mud crab fishers, as they are more likely not to have access to credit (the borrowing of money) or, even if available, the knowledge of how to access it (Fletschner, 2009; Mersha & Van Laerhoven, 2016). Although men can more easily obtain credit, they may not choose to share it with their wives (Fletschner, 2009), especially when they also have a need of the money. Availability to credit has been cited as one of the main pillars of female empowerment (Malik & Gautam, 2015) and the lack of this lowers adaptive capacity. In Fiji, *iTaukei* community members' access to credit is largely restricted to village shops to purchase daily needs. Access to credit from financial institutions is more difficult due to the regulatory requirements (e.g. bank accounts, tax ID numbers, proof of regular income, credit history) and lack of assets to offer as collateral (M. Fox, unpublished data). Expanding access to this form of credit would assist the mud crab fishers in both recovering from the cyclone and decreasing their vulnerability to future extreme weather events.

Poor women are often the most affected by changes to natural resources because of their high dependency on the resource and fewer opportunities for income diversification; and climatic changes leave them more vulnerable (Denton, 2002; FAO, 2017; Siagian, Purhadi, Suhartono, & Ritonga, 2014). Post-cyclone, fishers were less likely to have non-fisheries sources of income; despite reporting they needed to earn money and had seen their income from mud crabs decrease. More respondents reported that the alternative livelihood(s) provided a better source of income. However, women in developing countries often have a very limited educational background. The knowledge and skills they have with regards to their fishing-related roles are not easily transferred to other types of occupations (Fay-Sauni, Vuki, Paul, & Rokosawa, 2008). After an extreme weather event, women are not able to transition out of these livelihoods as easily as men, for whom options like migration or alternative livelihoods are more readily available. This can lead to the breakup of families and communities, further increasing women's vulnerability (Daw, Adger, Brown, & Badjeck, 2009).

Extreme weather events further reduce opportunities for women to earn a livelihood (FAO, 2017). For example, in Bua Province coconut was the second most common non-fisheries livelihood before the cyclone (22%); but the cyclone damaged many of the trees and made this alternative less viable. The rural nature of the province also meant the households had a high vulnerability to events such as cyclones. Post-cyclone, road access to many markets was blocked (and even in instances where it was open, travel time often increased) further narrowing the alternative livelihoods available and limiting

their adaptive capacity. Women gain an added sense of security and respect through income generation (Fay-Sauni et al., 2008). This suggests that being unable to collect mud crabs, as well as a lack of alternative livelihoods, had negative repercussions for a woman's sense of independence.

Extreme weather events can also force individuals and/or households to shift their resource use patterns in order to adapt (Balgah & Buchenrieder, 2014). A significant consequence of the cyclone was that the majority of fishers sold their catch to traders, rather than primarily using it for household consumption. This shift in rankings can best be explained by decreased harvesting of mud crabs in cyclone affected areas where mangroves were extensively damaged, prompting traders to actively source mud crabs from other districts. This was confirmed by the fishers who said they would sell more mud crabs to obtain the money to repair and/or replace the damaged gear. The 36% increase in price may have also factored into their decision to preferentially sell the mud crabs rather than consume them. Lack of access to the markets post-cyclone could have been another contributing factor, although only a small percentage of fishers (10%) ranked this important pre-cyclone.

Historically, women's fishing contributions to the household diet are usually a larger and more important component then men's share (FAO, 2005; Hauzer, Dearden, & Murray, 2013; Matthews, 1993), but is often overlooked and undervalued (Chapman, 1987; FAO, 2017; Weeratunge, Snyder, & Sze, 2010). This is explained by two factors: (1) fisheries catch from women normally goes to feeding their family, whereas catches by men go mostly to markets; and (2) contributions from women's fishing activities are usually more regular and frequent than the irregular contributions from men (Kronen & Vunisea, 2009; Matthews, 1993). Post-cyclone, the increased sale of mud crab meant less seafood available for household consumption; with a resulting reduction in the consumption of this protein source for families. In the study area, many men were likely unable to compensate for the reduced mud crab catches and provision for household consumption due to reasons such as damage to boats and other fishing gear, and resources required (time and financial) for village repairs.

The failure of any of the regression models to identify significant predictor variables demonstrates potential difficulties in providing support at the district and/or village levels. The number of potential factors determining the differing impacts even within a district suggests comprehensive data at the village and/or household level would be needed in order to achieve significant models. However, obtaining such data post-cyclone when communities are still recovering is difficult and often not feasible.

As previously noted, the available sample size made it less likely for the data to show significant differences; especially at the district level. Similarly, with only seven male respondents, we were unable to perform any gender-based comparisons. A future study exploring differences between genders in vulnerability and adaptive capacity would provide important information for mitigation and response efforts. Finally, the impacts reported in this study were short-term (2–3 months), but without actual data it is difficult to say what the long-term impacts were on the mud crab fishers. A follow-up study to assess any long-term impacts of the cyclone would be useful in understanding any changes in vulnerability or adaptive capacity.

5. Conclusions

The vulnerability of communities dependent on natural resources is shaped by the interaction of bio-physical and socio-economic factors (e.g. Paavola, 2008; Sallu et al., 2010). Climate change 'acts to push natural resource systems, and those dependent upon them, toward their thresholds of tolerance, testing whether they can absorb the impact and adapt' (Marshall & Stokes, 2014). Developing countries have a high vulnerability to climate change due to social, economic, and environmental conditions that amplify propensity to negative impacts and contribute to a low capacity to cope with and adapt to climate change (Cutter, Boruff, & Shirley, 2003; Nelson et al., 2010). Extreme weather events such as droughts and cyclones have increased the vulnerability among communities who depend on natural resources for their livelihoods. The intensity of cyclones has already increased in the last thirty years (Emanuel, 2005; IPCC, 2013) and is predicted to continue (Knutson et al., 2010; Walsh et al., 2016).

A comprehensive approach for risk reduction involves lowering vulnerabilities, strengthening resilience and building adaptive capacities (FAO, 2017). Understanding vulnerability is therefore an important first step in minimizing the impacts of future extreme weather events on linked socio-ecological systems (Adger, 2006; Howden et al., 2007). Information on how communities are affected and barriers they face is therefore crucial information for drafting effective mitigation and adaptation strategies; especially at the local level (Méheux, Dominey-Howes, & Lloyd, 2007). The following recommendations are made from this study:

(1) Ensure government support to fishing communities is gender sensitive and takes into consideration the losses and damages incurred by women fishers;
(2) Encourage villages and districts to establish regulations or guidelines for the mud crab fishery which promotes the resilience of the fishery to cyclone events;
(3) Ensure districts that have *tabu* areas with damaged mangrove keep them closed to help promote recovery; and
(4) Continue monitor the mud crab fishery to gauge the recovery of the fishery and the impact to subsistence and livelihoods in Bua Province.

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