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Analysis

Natural Hazards and Well-Being in a Small-Scale Island Society

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ABSTRACT

The literature investigating the relationship between natural hazards and individuals' subjective well-being has so far focused on industrialized countries. Using the life-satisfaction approach, this paper is the first to study the link between natural hazards, in particular heavy storms and droughts, and subjective well-being for a small-scale island society in the Pacific Ocean. Results indicate that the experience of drought markedly diminished life satisfaction, whereas the experience of storms had only somewhat negative impact. The primary driver of the negative well-being impact appeared to be damage experience for both storms and droughts. Since regular cash-income did not exist for the majority of the population, the marginal effect could not be calculated in monetary terms. To account for differences in wealth across respondents, we developed a wealth index in the form of a simple 'asset score'. Comparing the marginal effect of the hazard variables with our measure of wealth, the positive marginal effect of doubling the number of household assets was significantly smaller than the negative impact of drought experience on subjective well-being.

1. Introduction

It has long been identified that Small Island Developing States (SIDS) are amongst the most vulnerable to climate change and associated climate extremes (e.g. Nurse et al., 2014). Although SIDS, located in the Pacific, Indian and Atlantic Oceans, cannot be classified as a homogeneous group, they share common characteristics including smallness, remoteness, limited natural resources, relative isolation and proneness to natural disasters, resulting in a disproportionately high risk of being adversely affected by climate change and related natural hazards (Betzold, 2015; Briguglio, 1995; Connell, 2013; Pelling and Uitto, 2001). With improving disaster monitoring since the 1950s, a general increasing trend in the annual number of disasters including extreme weather events has been observed in the Pacific Islands region, which has been attributed to global climate change (Barnett and Campbell, 2010; Hay and Mimura, 2010).

Extreme weather events, such as tropical cyclones and coastal storms immediately endanger physical health and livelihoods, whilst extended periods of drought put a long-term strain on island societies, which are threatened by severe water supply shortages and food insecurity (IPCC, 2012). Estimates of the economic and environmental impacts of natural disasters exist (see e.g. Cavallo and Noy, 2011), however, these are not able to account for intangible values such as physical and psychological health impacts including fear, anxiety or mental distress (Freedy et al., 1994). There is growing apprehension that extreme weather events pose a substantial threat towards individual well-being of vulnerable communities worldwide, in the face of climate change (Berry et al., 2018).

Over the past few decades a vast body of literature has emerged in economics interested in subjective well-being (SWB).[1] The rationale for using data on SWB in economic analysis is that they are considered to be an empirical approximation of what Kahneman et al. (1997) have labelled 'experienced utility.' Researchers have since identified and analysed a vast range of personal, demographic, and socio-economic covariates that explain observed SWB (see e.g. Clark et al., 2008; Dolan et al., 2008; Frey and Stutzer, 2002).

In recent years SWB data has increasingly been used for preference elicitation and non-market valuation of environmental amenities and disamenities (see e.g. Welsch and Ferreira, 2014), including a considerable range of environmental problems such as air pollution (Dolan and Laffan, 2016; Levinson, 2012; Luechinger, 2010; Welsch, 2002; Zhang et al., 2017), airport noise (Fujiwara et al., 2017; Van Praag and Baarsma, 2005) and climate parameters (Maddison and Rehdanz, 2011; Rehdanz and Maddison, 2005). All of these studies established that SWB is positively related to environmental quality and negatively related to environmental disamenities.

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[1] For overviews, see, e.g. Van Praag and Ferrer-i-Carbonell (2008); MacKerron (2012).

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Only few studies have been able to quantify the impact of natural hazards on individual well-being and research has primarily focused on industrialized countries or regions. Berlemann's (2016) study on hurricane risk and SWB was the only study to also include the global south. Grouping countries according to their level of development, the results showed that SWB is negatively affected by hurricane risk for the group of less developed countries, whereas a much smaller effect was found for the group of highly developed countries. Other SWB studies on natural hazards exist for Germany (Luechinger and Raschky, 2009; Osberghaus and Kühling, 2016; von Möllendorff and Hirschfeld, 2016), the US (Kimball et al., 2006), Japan (Rehdanz et al., 2015), Bulgaria (Sekulova and van den Bergh, 2016), Australia (Carroll et al., 2009) and the Mediterranean region (Kountouris and Remoundou, 2011).

This paper is the first to analyse the relationship between natural hazards and SWB with a focus on a small island society located in the global south.[2] The unique data set, collected on Bougainville Island, Papua New Guinea, offers novel insights into an indigenous small-scale island society with a subsistence-based economy. With SIDS amongst the first to experience the adverse impacts of climate change, the present paper makes an important contribution towards our understanding of how extreme weather events may impact SWB of indigenous people, living in highly remote areas especially susceptible to climate change-induced risks.

Our results indicate that the experience of storms and droughts as well as associated damages significantly reduced life satisfaction. This relationship was more pronounced for droughts: a higher frequency of drought experience and increasing severity of damages were clearly associated with lower probabilities of stating high levels of life satisfaction. The impact was sizeable and significantly larger than the positive impact of a two-fold increase in household assets (wealth) on life satisfaction. Storms showed similar detrimental outcomes on life satisfaction only for individual's having experienced numerous storms in the five years prior to the interview.

2. Methodology and Data

2.1. Study Area and Cultural Context

The data for our analysis came from a survey conducted in villages situated in the northeastern part of Bougainville Island, an autonomous region of Papua New Guinea, in autumn 2014. Bougainville is located in the Pacific Ocean, Northwest of the Solomon Islands and is exposed to a large number of natural hazards. In combination with low adaptive capacities and economic development opportunities this makes the island state and its many coastal communities particularly vulnerable.

We recruited respondents from small settlements of the Teop society, an Austronesian ethno-linguistic group indigenous to the Tinputz district. Fig. 1 displays a map of the area. The Teop is one of 21 ethno-linguistic groups living on the island and has a population of around 5000 (Lewis et al., 2015), representing approximately 2% of the total population of Bougainville Island (249,358, NSO, 2014). For the current study we sampled approximately 10% of the entire Teop society.

Teop people live in villages that vary in size from 50 to 200 people, which are either located along the coast or inland in the hills. Their subsistence is based on farming and pig husbandry, supplemented by fishing, hunting and foraging (Regan and Griffin, 2015). Some of the surplus from the subsistence sector is sold on markets. Cocoa and copra are the main commercial crops. These crops are harvested several times a year and sold to intermediaries in one of the larger market towns at the coast. At present, there are hardly any possibilities for engagement in wage labor on Bougainville, except for government occupations. Thus, regular cash-income does not exist for the majority of the population. The Teop people are of Christian faith with religious affiliation to both the Catholic Church as well as multiple protestant denominations.

The Teop society is organized around tribes and clans with a bottom-up decision-making process. This form of decision-making process is widely accepted as having provided a degree of stability and sustainability for many such communities, although it often struggles to cope with the modern challenges of rapid population growth, resource depletion, and the manifestations of climate change (Lata and Nunn, 2012; Nunn, 2009).

2.2. Survey Design and Sampling

The questionnaire was structured as follows: First, respondents were asked about their SWB, measured as life satisfaction. It is the answer to the following question: “How satisfied are you with your life in general?”. Answers were recorded on a 10-point numerical scale ranging from 1, representing the greatest dissatisfaction to 10, the highest possible satisfaction. This question format closely followed the approach taken by the World Values Survey and employed the identical numerical response scale (Inglehart et al., 2014). Second, respondents reported their personal experience of natural hazards including the occurrence of heavy storms and droughts.[3] This section also included specific questions about past experienced events, damage suffered, perceived vulnerability and expectations for future events to occur. Finally, respondents were asked to provide information about their socio-economic and demographic background such as age, gender, education and marital status. Monetary income, generally included in SWB studies, was no appropriate measure of well-being, as the Teop people mostly rely on subsistence agriculture in their household garden, fishing and hunting to provide for basic needs. To account for differences in wealth across respondents, we developed a wealth index in the form of a simple ‘asset score’. It was defined as the sum of positive responses over the 11 different household assets included in the questionnaire. The wealth index took values ranging from 0 (low level of wealth) to 11 (high level of wealth).

To ensure that all respondents fully understood the question format, we hired local assistants to translate the questionnaire and to conduct the interviews. Some of these assistants were already experienced with translation tasks (Bible translators). To check for accuracy, we split the group of assistants into two groups: one group translated the questionnaire into the local language whilst the other group translated the survey questions back into English.

Our final sample consisted of 515 respondents – 264 male and 251 female - who voluntarily participated in the interviews across 17 different villages. The majority (67.18%) came from coastal villages, including a small off-shore island ($N = 55$), with the remaining participants living in inland villages ($N = 114$).

Participants were recruited by compiling a random sample from a list of residents in a village. In some cases, these lists were already available, in others we asked local village chiefs to draw them up. We made sure that at least one member from each household participated in the study. Invitations to participate were addressed to respondents one or two days in advance, sometimes on the same day. Participants were asked to come to a central spot in the village (school or church) at

[2] SWB is defined as “people's emotional and cognitive evaluation of their lives” (Diener et al., 2003, p.403). The present study uses life satisfaction as an evaluative measure of SWB. Life satisfaction is defined as “people's explicit and conscious evaluations of their lives, often based on factors that the individual deems relevant” (Diener et al., 2018, p.3). See Dolan and Metcalfe (2012) for a discussion of the different dimensions of SWB.

[3] The survey questions referred to the perceived experience of heavy storms and droughts in the perception of the respondents. The subjective nature of these responses will be discussed in Section 3.2.

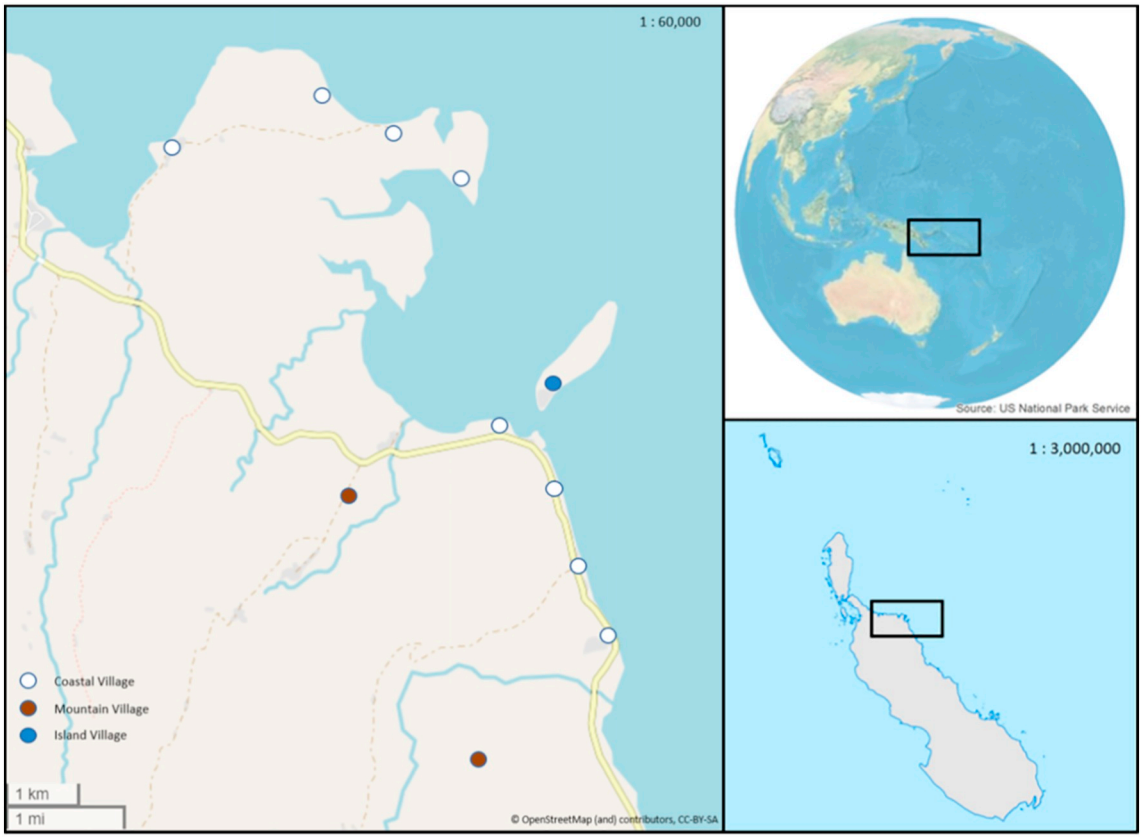

Fig. 1. Map of the study area illustrating villages in the northeastern part of Bougainville (Papua New Guinea).
Top right: Bougainville Island in the Pacific; Bottom right: Teop area in the northeastern part of Bougainville Island; Left: Selection of Teop villages.

a given time. To minimize collusion, we allowed only small groups of people to be present at these sessions.

The respondents were questioned in a face-to-face interview conducted by two local research assistants and supervised by the researchers. The interviews took place in a closed-off area (e.g., classroom) without any other person present. Further, respondents were asked to answer the survey questions on their own behalf. We trained assistants to conduct the interviews during a three-day workshop in the field. Before the final interviews were conducted, the survey was discussed amongst focus groups and then pretested with a small sample of randomly selected respondents. The interviews were carried out in Tok Pisin, the national language.

2.3. Methodology

To assess the relationship between natural hazards and SWB the following general empirical model was employed[4]:

$$SWB_{i,r} = \alpha + \beta_1 \log W_i + \beta_2 X_i + \beta_3 H_i + \beta_4 G_r + u_{i,r}$$

where $SWB_{i,r}$ is general satisfaction with life of individual i in location r, W_i is respondent i's level of wealth, X_i denotes the vector of other socioeconomic and demographic characteristics and G_r is region specific information. H_i represents the hazard variable indicating whether and to what extent an individual had been affected by a hazard. Finally, $u_{i,r}$ stands for the error term.

We used different specifications of H_i. This included (1) the experience of storms and droughts, (2) the perceived number of storms and droughts experienced in the past 5 years and (3) the perceived damage suffered from storms and droughts in the past 5 years. The first set of variables was a dummy variable which took on the value 1 if respondents had experienced at least one storm or drought in their lifetime. The second pair of variables was defined as the number of storms/droughts experienced in the past 5 years in four categories, ranging from "0" to "3 or more". The third set of variables measured the perceived severity of damage suffered from storms/droughts, including the categories no experience of hazards (base category), experience without damage, experience with some damage and experience with serious damage. The vector X_i refers to a standard set of control variables including age, gender, marital status, household head, number of children, education, the logarithm of assets[5] and three variables capturing social relationships. The models were estimated by means of ordered probit maximum likelihood regression with robust standard errors, using Stata14.

3. Results

3.1. Descriptive Statistics

Table 1 reports summary statistics of the main socio-economic and demographic characteristics of the study participants. The mean reported life satisfaction was 7.15 which is comparable to countries such as Spain, Chile and Singapore. Interestingly, the value exceeds the average life satisfaction of 6.83 of 60 countries assessed by wave 6 of the World Values Survey (Inglehart et al., 2014).

Comparing sub-samples, no significant differences between men and women seemed to exist. Men and women in our sample did not differ with respect to age, the number of children, marital status and

[4] We followed the general approach found in the literature. See e.g. Ferrer-i-Carbonell and Frijters (2004).

[5] Logarithm with base 2.

Table 1
Descriptive statistics: Socio-demographic variables.

	All subjects	Men	Women
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)
Life satisfaction	7.15 (2.29)	7.12 (2.27)	7.17 (2.32)
Age (years)	38.65 (13.13)	40.64 (14.19)	36.57 (11.59)
Number of children	3 (2.41)	2.88 (2.37)	3.10 (2.46)
Wealth (index) [a]	4.67 (1.99)	4.64 (1.99)	4.69 (2.00)
Social relationships [b]			
Attending religious services	2.77 (1.40)	2.61 (1.43)	2.94 (1.36)
Visiting market	2.02 (1.63)	1.75 (1.68)	2.29 (1.54)
Playing cards	0.77 (1.29)	1.01 (1.41)	0.51 (1.10)
	percent	percent	percent
Gender		51.26	48.74
No school	9.90	12.88	6.77
Elementary	58.83	54.55	63.55
High school and further education	31.26	32.58	29.88
Married	70.10	69.70	70.52
Head of household	48.35	75.00	20.32
Number of observations	515	264	251

[a] Wealth index representing the asset score of the household; ranging from 0 assets (low wealth) to 11 (high wealth).
[b] Social relationships measured through the frequency of participation in social activities on a 6-point Likert Scale (1 = Never to 6 = Every Day).

wealth. The average age was approximately 38 years and the mean number of children per household was 3. The average level of wealth, measured by the number of assets owned, was 4.67, with 11 being the highest possible level of wealth.[6] About 70% of the respondents were married.

It is interesting to note, however, that substantial educational differences existed between men and women. Only about 7% of women were without any form of formal education, compared to 13% of men. This can be attributed to the matrilineal structure of the Teop society, in which women inherit considerable power over material resources, land and economic as well as spiritual activities. Women enjoy more prestige and respect, whilst bearing greater responsibility for household and family, thus women are more dependent on formal education. Despite the matrilineal structure, the role of the household head was still primarily held by men (75%).[7]

Table 2 gives an overview of the descriptive statistics regarding hazard related questions included in our survey. Around two-thirds of participants had experienced heavy storms and droughts at least once in their life. Heavy storms occurred slightly more frequently than droughts based on the perception of our respondents. About 21% stated to have experienced three or more heavy storms in the past five years, compared to about 18% for three or more droughts. About 52% believed to have not experienced any droughts in the past five years, whilst only 44% had not experienced any storms. Although heavy storms seem to have been experienced more frequently, the severity of damage induced varied considerably between storms and droughts. Based on participant responses, 16% reported to have suffered serious damage from droughts in the past five years, in contrast to only about 10% having suffered serious damage from storms.

Table 2
Descriptive statistics: Hazard variables.

	Heavy storms	Droughts
	Percent	Percent
Experienced at least once in lifetime	68.16	68.93
Number experienced in the past 5 years:		
0	44.08	51.65
1	23.50	20.00
2	11.07	10.49
3 or more	21.36	17.86
Damage suffered in the past 5 years:		
No hazard experienced	44.25	51.95
Experience without damage	29.63	17.58
Experience with some damage	16.18	14.06
Experience with serious damage	9.94	16.41

Note: $N = 515$. Responses based on self-reported experience of storms and droughts.

3.2. Explaining Variability in Hazard Perception

It is important to note that the present study relied entirely on self-reported data. However, research in Papua New Guinea and in the Indonesian province of Papua has shown that oral histories and local perceptions of extreme weather events closely mirror climatological data, whilst reflecting varying local ecological conditions and adaptation strategies (Boissière et al., 2013; Jacka, 2016). In line with previous anthropological research we found varying degrees of local perceptions across regions, between villages of the same region and, in some cases, within the same villages.

In the following section we present the results of a simple analysis assessing the variability in hazard perception across regions, villages and within villages. We used Chi^2 tests to compare the distribution of categorical responses (e.g. drought experience) across different geographical scales (regions, villages).[8] We further used *t*-tests and Pearson's Correlation Coefficient to assess whether socio-economic characteristics were related to hazard perception.

We first compared respondents' perceptions across regions by classifying villages into coastal villages, mountain villages and island villages. This classification allowed us to control for different topographical as well as agro-ecological features of the regions. Coastal villages in the region are in general more wind prone and their farming land is more vulnerable to hazardous events. Taro and sweet potato, the main staple foods in the area under investigation, grow more consistently at higher altitudes and produce more reliable yields than in coastal areas. Based on these agro-ecological differences between regions we hypothesised that experience of natural hazards would be more pronounced in coastal villages compared to mountain villages. Our results suggested that respondents from coastal villages were indeed, on average, more likely to have experienced both heavy storms and droughts, than people from mountain villages. They were also significantly more likely to have recently experienced more drought events (Chi^2 test: $p = 0.000$) and heavy storms (Chi^2 test: $p = 0.000$). Damages in coastal regions were perceived significantly larger than in mountain villages, for droughts (Chi^2 test: $p = 0.038$), but not for heavy storms.

Second, we investigated differences in perceptions across villages within the same region. We assumed that people within the same region, across different villages, would have a similar perception of natural hazards. We found that respondents from mountain villages had similar perceptions of the number of storm events experienced (Chi^2

[6] Assets include household furniture (chairs, benches, tables, mattresses, curtains), gadgets (radio, laptop) and other household equipment (water tank, generator, sewing kit, brush cutter).
[7] 51 women and 198 men indicated that they were the household head at the time of the interview.
[8] The Chi^2 test null-hypothesis states that there is no difference in perceptions between categorical groups (e.g. mountain and coastal villages).

test: $p = 0.600$) and the related damages (Chi^2 test: $p = 0.296$), but differed in their assessment of droughts.[9] For respondents from coastal villages we failed to find a shared understanding on any of the hazard variables (i.e. we rejected the null-hypothesis that hazard perceptions were the same in all coastal villages for all hazard variables).[10] This is plausible due to the strong variability of local ecological and environmental conditions prevailing at different locations at the coast. Coastal villages differ with respect to their exposure to the Pacific Ocean, with some villages being protected by mangrove forests, whilst others, located on the shoreline, are directly exposed to the open sea. Different ecological conditions and local knowledge allow villages to develop individual adaptation and response strategies which may further explain varying perceptions of hazard experience between coastal villages (Boissière et al., 2013).

Third, we investigated whether respondent's socio-economic characteristics influenced the evaluation of events. We would, for example, assume that older respondents were more likely to have experienced at least one hazard (storm/drought) in their lifetime. They should, however, not be more likely to have experienced a larger number of events in the past five years. The results confirm our assumption partly. Older respondents were significantly more likely to have experienced a drought (t-test: $p < 0.001$), but age was not associated with the experience of storms (t-test: $p = 0.140$). As expected, age showed no correlation with the number of events and the magnitude of damage experienced in the past five years.[11]

A simple correlational analysis of individual characteristics with hazard variables allowed us to further distinguish between different groups of individuals with varying hazard perceptions. With respect to occupations, farmers in coastal villages were on average more likely to experience drought and related damages than non-farmers (Pearson's correlation of drought experience and farmer occupation: $r = 0.19$, $p < 0.05$). Individuals more frequently engaged in outdoor community activities, especially in the vulnerable coastal villages, were more likely to perceive extreme events and the damage thereof. More frequent participation in communal fishing of coastal inhabitants was positively related to the perception of having experienced more storms ($r = 0.20$, $p < 0.05$), droughts ($r = 0.12$, $p < 0.05$) and drought damages ($r = 0.27$, $p < 0.05$). Similarly, regular participants of communal gardening reported greater experience of damage from storms ($r = 0.17$, $p < 0.05$). These intuitive results provide some explanation for the variation in perceptions found within some of the same villages. Interestingly, female respondents in all regions perceived lower damage from droughts ($r = -0.17$, $p < 0.05$).

Despite significant variability in the perception of extreme weather events and the lack of objective climatological data, we argue that self-reports provide a valuable proxy for the experience of natural hazards and related damages. Echoing prior research, we argue that local knowledge may in fact be a more detailed and relevant source of information, given the high variability of local ecological and environmental factors as well as adaptation strategies (Boissière et al., 2013). The use of self-reports therefore allowed us to capture a more diverse array of what was perceived as natural hazards to different individuals and groups in differing locations.

3.3. Estimation Results

In order to compare results of our analysis to those of others investigating correlates of SWB we first regressed SWB on the following set of control variables: age, gender, marital status, household head, number of children, education, the logarithm of assets and three variables capturing social relationships.[12] Assets were expressed in logarithmic form to allow for diminishing returns in our measure of wealth and age squared was included to account for non-linear age-effects which have been found in the literature. Potential regional differences were captured by means of a categorical variable distinguishing between coastal, island and mountain villages.

Using an ordered probit model specification with robust standard errors, Table 3 reports the estimation results for the baseline regression (Model 1). Our findings mostly confirmed those of others focusing on developed countries. Specifically, we found a significantly positive association between assets and well-being, which is consistent with past research findings. Individuals who owned more household assets reported, on average, higher levels of SWB. This finding is plausible as household assets reflect the individual's level of wealth in a society in which monetary income is seldom. Like others, we assumed a diminishing marginal effect. Although age (negative) and age squared (positive) had the expected signs they were statistically insignificant. Like others, we further found an inverse relationship between the number of children and life satisfaction. Furthermore, we found that having primary education was positively related to life satisfaction which was weakly significant (at the 10% level). For the dummy variables denoting that individuals were female or the household head, no statistically significant relations with SWB were found. More frequent participation in social and communal activities was positively related with life satisfaction. This corresponds with findings at an international level (Helliwell and Putnam, 2004) as well as evidence from SIDS (Young-Leslie and Moore, 2012; Biswas-Diener, 2018) which have continuously highlighted the importance of social cohesion as a determinant of life satisfaction.

In order to study the association between natural hazards and SWB, we used six additional model specifications including different measures for natural hazards. In Models 2 and 3 we added dummy variables to the base-model which took on the value 1 if a storm (drought) had ever been experienced by the respondent. Models 4 and 5 included measures for the number of storms (droughts) experienced by the respondent in the past five years. Models 6 and 7 included variables combining hazard experience in the past five years with self-reported damage suffered by individuals from storms (droughts).

The results of the additional specifications are presented in Table 4. For ease of interpretation we display only the results of the hazard variables, results for all control variables are included in the Appendix (Table A1). The estimated coefficients were comparable in magnitude and produced similar p-values to those presented in Table 3 above.[13] All storm and drought indicators had the expected negative sign. We found a pervasive negative relationship between drought and SWB in all estimated models, which was statistically significant and robust. However, the impact of storm experience seemed less pervasive, which will be discussed below. Focusing on the impact of droughts, individuals who had experienced at least one drought during their lifetime reported, on average, lower levels of life satisfaction (Model 3). Those individuals having experienced numerous droughts in the past five years were, on average, less satisfied with their lives, than those having experienced only one drought during this period. The parameters of this categorical variable were increasing in magnitude and significance

[9] Number of drought events (Chi^2 test: $p = 0.006$) and damage from droughts (Chi^2 test: $p = 0.000$)

[10] Number of storm events (Chi^2 test: $p = 0.000$), damage from storms (Chi^2 test: $p = 0.002$), number of droughts (Chi^2 test: $p = 0.000$) and damage from droughts (Chi^2 test: $p = 0.000$)

[11] Age and storm experience (Pearson's correlation: $p = 0.21$), storm damage ($p = 0.47$), drought experience ($p = 0.10$) and drought damage ($p = 0.21$).

[12] These measure the frequency of attending religious services, market visits and playing cards with peers.

[13] Age and age squared are jointly significant in Models 2 to 5 and 7. In Models 3 to 7 we find regional differences in SWB. Island inhabitants report statistically significant lower levels of life satisfaction. In Models 6 and 7 we found a statistically significant positive coefficient for married individuals.

Table 3
Baseline regression including relevant control variables.

	Base (1)	
	Coefficient	St. error
Age	−0.01	(0.02)
Age squared	0.00	(0.00)
Female	0.16	(0.12)
Married	0.19	(0.12)
Head of household	0.19	(0.12)
Number of children	−0.04*	(0.02)
Log assets	0.27***	(0.09)
No education (reference)		
Primary education	0.30*	(0.17)
High School/further education	0.15	(0.18)
Religious service attendance	0.09***	(0.03)
Market visits	−0.03	(0.03)
Social card playing	0.11***	(0.04)
Coastal villages (reference)		
Island villages	−0.17	(0.13)
Mountain villages	−0.02	(0.12)
Observations	515	
Log likelihood	−988.5	
F-test (P > F) [a]	0.11	

Note: Dependent variable: General life satisfaction (1−10). Method: Ordered probit using robust standard errors. Female, Married and Head of household are dummy variables that take the value 1 if the respondent is female, married or the household head, respectively.
[a] *F*-test on joint significance of Age and Age squared.
* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

(Model 5). Having suffered some, or serious damage from droughts significantly lowered general life satisfaction. Both damage categories of the 'damage suffered from droughts' variable were statistically significant at the 99% confidence level (Model 7). Interestingly, having experienced a drought without suffering any damage was not statistically different from the base category of no drought experience in the past five years.

The regression results suggest that the experience of droughts was associated with a decrease in life satisfaction amongst the Teop people of Bougainville. However, we found weaker evidence that the experience of heavy storms negatively influenced life satisfaction (Model 2). The coefficients for the number of storms experienced (Model 4) had the expected negative sign, but only those individuals who had experienced three or more heavy storms in the past five years reported significantly lower levels of life satisfaction. Furthermore, respondents who believed to have suffered 'some' or 'serious' damage from storms, were on average, more likely to be dissatisfied with life (Model 6). Similar to drought, storm experience without damage was not statistically different from the base category, which may suggest that well-being impacts of hazard experience were primarily driven by damage experience. Although in our sample the extent of damage caused by extreme events was based on high levels of subjectivity, heavy storms seemed to be less likely to cause serious damage (10% of the sample report serious damages; see Table 2). This finding seems plausible as storms are likely to cause some immediate damage to housing, infrastructure and health which result in welfare losses for the Teop people. However, storms are less likely to entail severe long-term damages as may be encountered over an extended period of drought. This will be further discussed in Section 4.

Table 4
Estimation results including hazard indicators.

Dependent variable: *Life satisfaction*	Storms experienced		Droughts experienced		Number of storms		Number of droughts		Damage from storms		Damage from droughts	
	(2)		(3)		(4)		(5)		(6)		(7)	
Natural hazard experienced:												
Storm(s)	−0.20*	(0.10)										
Drought(s)			−0.28***	(0.11)								
Number of hazards experienced:												
None (reference)												
One					−0.14	(0.11)	−0.21*	(0.12)				
Two					−0.10	(0.16)	−0.37**	(0.16)				
Three or more					−0.31**	(0.13)	−0.63***	(0.14)				
Damage suffered from hazards:												
No event experienced (reference)												
Experience without damage									0.01	(0.11)	−0.07	(0.13)
Experience with some damage									−0.45***	(0.15)	−0.47***	(0.15)
Experience with serious damage									−0.43***	(0.16)	−0.71***	(0.14)
Region	Yes		Yes		Yes		Yes		Yes		Yes	
All other controls	Yes		Yes		Yes		Yes		Yes		Yes	
Log likelihood	−986.5		−984.8		−985.4		−976.6		−974.3		−965.9	
Observations	515		515		515		515		513		512	

Note: Dependent variable: General life satisfaction (1–10). Method: Ordered probit (*oprobit*) using robust standard errors. Storm(s) and Drought(s) are dummy variables that take the value 1 if at least one storm/drought has been experienced during lifetime. 'Number of hazards' denotes the number of droughts or storms experienced in the past 5 years, with zero representing the omitted baseline category. 'Damage suffered from hazards' denotes the damage suffered from droughts or storms in the past 5 years, with no experience representing the omitted baseline category. 'All other controls' and 'Region' refer to the control variables included in the baseline regression (see Table 3).
Robust standard errors in parentheses.
* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

Table 5
Marginal effects.

Percentage point change	*Life satisfaction Categories*		
	1 to 3	4 to 7	8 to 10
Assets (log2)	−3**	−8**	10**
Drought experienced during lifetime	3*	9**	−11**
Storm experienced during lifetime	0.4*	6*	−8*
Number of droughts experienced (past 5 years):			
None	–	–	–
One drought	1	6*	−7*
Two droughts	1*	11*	−13**
Three or more droughts	7**	19***	−24***
Number of storms experienced (past 5 years):			
None	–	–	–
One storm	1	5	−6
Two storms	0	3	−3
Three or more storms	2*	9**	−12*
Damage suffered from droughts (past 5 years):			
No drought experienced	–	–	–
Experience without damage	0	2	−3
Experienced some damage	4*	14**	−19*
Experienced serious damage	7**	20***	−27***
Damage suffered from storms (past 5 years):			
No storm experienced	–	–	–
Experience without damage	0	0	0
Experienced some damage	4*	13***	−18**
Experienced serious damage	4*	12**	−16*

Note: Marginal effects represent the percentage point change in the probability of being observed in one of the 10 life satisfaction categories, ranging from 1 (lowest) to 10 (highest). For ease of interpretation, categories are summed into three larger groups reflecting low (1 to 3), medium (4 to 7) and high (8 to 10) levels of life satisfaction.
Marginal effects of Assets refer to a one unit increase in the log of assets with base 2. This is equivalent to a doubling of household assets within the non-logarithmic scale of the asset index.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

3.4. Marginal Effects

Focusing on the marginal effect of droughts, Table 5 reports the results derived from the ordered probit regressions discussed above. The results again highlight the strong negative relationship between droughts and life satisfaction. Individuals who had experienced at least one drought during their lifetime were 11 percentage points less likely to be observed in the highest three life satisfaction categories. Having only recently experienced droughts (in the past five years) had an even stronger effect on the distribution of life satisfaction responses. The probability of being part of the highest life satisfaction categories decreased by 7, 13 and 24 percentage points for those who had experienced 'one', 'two' or 'three or more' droughts respectively, whilst the percentage of individuals found in the lowest three categories increased (1 and 7 percentage points). The 'damage suffered from droughts' variable showed similar outcomes.

We further compared the marginal effects of our 'drought variables' with our measure of wealth. We found that a two-fold increase in the number of household assets increased the probability of stating a high level of life satisfaction by 10 percentage points, whereas the probability of stating a lower level of life satisfaction decreased. Interestingly, the effect of household assets was comparatively small when compared with the impact of droughts on well-being. With respect to the highest levels of life satisfaction (8–10), the positive increase in probability from doubling the number of household assets (10 percentage points) corresponded to only approximately half of the negative effect associated with experiencing 'some' damage from droughts (−19 percentage points), whilst 'serious' damage exhibited an even larger decrease in probability of stating high levels of life satisfaction (−27 percentage points). This finding once again points towards the relatively severe impact drought experience may have on the lives of the Teop people.

4. Discussion

In keeping with our prior expectations, and the literature, we found an inverse relationship between droughts and life satisfaction (Ahmadiani and Ferreira, 2016; Carroll et al., 2009; Osberghaus and Kühling, 2016). Osberghaus and Kühling (2016), who assessed the effect of self-reported damage experience from heatwaves on life satisfaction in Germany, found a negative effect. The experience of a heatwave related health or financial damage reduced life satisfaction by 0.662 on an 11-point scale. Ahmadiani and Ferreira (2016) found a persistent negative impact of droughts on SWB in a comparison of different extreme weather events across the US. Experiencing a drought in the 12-months prior to the interview reduced life satisfaction by 0.005 on a 4-point Likert scale, whereas each additional drought in the same period of time was associated with a 0.004 decrease.

The results of the present study clearly reflect the high threat that drought poses to the fragile small-scale subsistence economy of the Teop society. Heavy storms seemed to have a comparatively lesser, although significant, impact on life satisfaction, as judged by the size of the estimated coefficients. This is in line with the findings by Möllendorf and Hirschfeld (2016) who found negative well-being effects related to the number of storm and hail events in Germany (−0.027 on an 11-point scale) and approximated damages from regional insurance expenditure claims (< −0.001). Osberghaus and Kühling (2016), however, found no significant effect of self-reported health and financial damages from storms on life satisfaction.

Interestingly, our results suggested that the well-being impact of both storms and droughts were primarily driven by damage experience. This becomes evident in Models 6 and 7 which include categorical variables combining hazard experience and severity of perceived damage (in the past five years). Here we found no statistically significant difference between the base category – no event experienced – and the category representing experience without damage. On the other hand, event experience combined with some or serious damage yielded highly significant negative coefficients.

The analysis of the damage and cost structure associated with droughts and storms may provide a plausible explanation for the differences encountered in our results. Heavy storms (i.e. tropical cyclones and coastal storms) with high wind speeds, heavy rainfall and associated storm surges often cause physical damages to coastal ecosystems, agriculture, infrastructure and health. Storm damages may also entail additional recovery costs ranging from reconstruction and rehabilitation of physical infrastructure, agricultural systems and social structure to mental illness resulting from post-traumatic stress (Méheux et al., 2007). Drought, on the other hand, generally develops over a drawn-out period of increased evapotranspiration in the absence of precipitation. Hence, the occurrence of drought is strongly correlated with psychological impacts and long-run damages (Edwards et al., 2015; OBrien et al., 2014). During extended drought periods, food security and health are put in jeopardy by the lack of freshwater for agricultural production and people. The agricultural systems of the Teop are especially sensitive to drought due to the inexistence of irrigation systems and water reservoirs, causing crop failure and food shortage. Communities are forced to travel long distances for water collection as existing water sources such as most streams, rivers, wells and rain-catchment tanks dry up (Jacka, 2009). Resulting famine, mal-nourishment, increased morbidity and disease put an extreme long-term strain on the island communities and in some cases may require humanitarian aid. In light of the different types of damages incurred by heavy storms and droughts, it seems plausible that the occurrence of drought showed a stronger detrimental impact on SWB than storms. With subsistence

agricultural lying at the heart of the Teop society, prolonged periods of drought threaten the very survival of communities, as crops fail and water sources dry up. Storms most likely have short term negative impacts on SWB; the occurrence of storms is less likely to directly damage crops as landholdings are often located in relatively protected inland forest areas. In general, storms do not seem to have had the same severe impact on an individual's satisfaction with life as a whole. Nonetheless, the well-being impact of storms should not be understated. Our results showed a statistically significant negative relationship between experienced storm damages and life satisfaction. Therefore, adaptation efforts should aim to minimize damages resulting from heavy storms through increased community preparedness, improved forecasting and warning as well as precautionary land use planning (Smith, 2013).

Although an exact quantification in monetary terms is not possible at this point, this analysis provides evidence of the significant welfare losses associated with natural hazards which again underlines the importance of policy initiatives in disaster risk management and climate change adaptation strategies. Future research should aim at a comparison of subjective and objective hazard data and longitudinal studies should explore the temporal decay of well-being effects related to extreme weather events in a developing country context. Ideally, future work would be based on panel data, allowing to control for unobserved individual fixed effects. The lack of panel data poses a major limitation to our analysis and hence we are only able to provide correlational evidence which may be subject to omitted variable bias.

5. Conclusion

This paper shed light on the relationship between the experience of natural hazards and individual SWB. It is the first to study this relationship in the context of an indigenous island society located in a region highly susceptible to climate change impacts and associated climate extremes. It utilised a unique data set collected amongst members of the Teop society of Bougainville Island located in the South Pacific, linking individual life satisfaction data with self-reported hazard experience.

Our results indicate that the experience of storms and droughts as well as associated damages significantly reduced life satisfaction. This relationship was more pronounced for droughts: a higher frequency of drought experience and increasing severity of damages were clearly associated with lower probabilities of stating high levels of life satisfaction. The impact was sizeable and significantly larger than the positive impact of a two-fold increase in household assets (wealth) on well-being. Storms show similar detrimental outcomes on life satisfaction only for individual's that experienced numerous storms in the five years prior to the interview. For both storms and droughts, the main driver of the adverse well-being outcome appeared to be experience of damage. Hazard experience without suffering damage was not statistically different from no experience at all.

The findings once again highlight the negative well-being impacts associated with extreme weather events and point towards the urgent need for adaptation efforts. Specifically, adaptation strategies should be targeted at mitigating damage suffered from extreme events and efforts should be specific to given locations and needs. In the absence of economic measures of well-being (e.g. income) the life satisfaction approach provides a promising alternative proxy for measuring wealth and development. It further captures the intangible values which are important and often neglected drivers of individual well-being. On a larger scale, the approach may be harnessed as a useful tool for disaster risk management. It could be used to identify regions and groups that are especially vulnerable to extreme weather events, facilitating the design of policies and development plans. Future research could explore how adaptation efforts in other SIDS contribute to mitigating the negative impacts of extreme weather events. Future work could attempt to assess multiple dimensions of subjective well-being. It could be explored whether experiential (e.g. happiness) and eudemonic (e.g. self-efficacy) measures of SWB relate differently to the experience of extreme weather events.

Declarations of Interest

None.

Table A1
Full estimation results: Models 1–7.

Dependent variable: Life satisfaction	Baseline regression		Storm experienced		Drought experienced		Number of storms and droughts experienced in past 5 years				Damage suffered from storms and droughts in past 5 years			
	(1)		(2)		(3)		(4)		(5)		(6)		(7)	
Age	−0.01	(0.02)	−0.02	(0.02)	−0.01	(0.02)	−0.02	(0.02)	−0.01	(0.02)	−0.01	(0.02)	−0.00	(0.02)
Age squared	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Female	0.16	(0.12)	0.16	(0.12)	0.17	(0.12)	0.14	(0.12)	0.18	(0.12)	0.12	(0.12)	0.10	(0.12)
Married	0.19	(0.12)	0.19	(0.12)	0.18	(0.12)	0.19	(0.12)	0.19	(0.12)	0.22*	(0.12)	0.20*	(0.12)
Head of household	0.19	(0.12)	0.18	(0.12)	0.19	(0.12)	0.18	(0.12)	0.18	(0.12)	0.16	(0.12)	0.13	(0.12)
Number of children	−0.04*	(0.02)	−0.04*	(0.02)	−0.04*	(0.02)	−0.04*	(0.02)	−0.04**	(0.02)	−0.04*	(0.02)	−0.04*	(0.02)
Log Assets	0.27***	(0.09)	0.27***	(0.09)	0.27***	(0.09)	0.27***	(0.09)	0.23**	(0.09)	0.26***	(0.09)	0.23**	(0.09)
No education (base)														
Primary education	0.30*	(0.17)	0.30*	(0.17)	0.35**	(0.17)	0.30*	(0.17)	0.36**	(0.17)	0.28*	(0.17)	0.38**	(0.17)
High School/Further education	0.15	(0.18)	0.15	(0.18)	0.19	(0.18)	0.14	(0.18)	0.18	(0.18)	0.12	(0.18)	0.20	(0.18)
Religious service attendance	0.09***	(0.03)	0.09**	(0.03)	0.10***	(0.04)	0.09***	(0.03)	0.10***	(0.04)	0.10***	(0.04)	0.12***	(0.04)
Market visits	−0.03	(0.03)	−0.03	(0.03)	−0.04	(0.03)	−0.03	(0.03)	−0.03	(0.03)	−0.04	(0.03)	−0.04	(0.03)
Social card playing	0.11***	(0.04)	0.11***	(0.04)	0.11***	(0.04)	0.11***	(0.04)	0.12***	(0.04)	0.12***	(0.04)	0.14***	(0.04)
Coastal villages (base)														
Island villages	−0.17	(0.13)	−0.20	(0.13)	−0.23*	(0.13)	−0.24*	(0.13)	−0.30**	(0.13)	−0.29**	(0.13)	−0.35***	(0.13)
Mountain villages	−0.02	(0.12)	−0.03	(0.12)	−0.03	(0.12)	−0.09	(0.13)	−0.13	(0.12)	−0.10	(0.12)	−0.12	(0.12)
Storms experienced			−0.20*	(0.10)										
Droughts experienced					−0.28***	(0.11)								
Storms = None (base)														
Storms = 1 in the last 5 years							−0.14	(0.11)						
Storms = 2							−0.10	(0.16)						
Storms = 3							−0.31**	(0.13)						
Droughts = none (base)														
Drought = 1									−0.21*	(0.12)				
Drought = 2									−0.37**	(0.16)				
Drought = 3									−0.63***	(0.14)				
Storms: Not experienced (base)														
Storms: Exp without damage											0.01	(0.11)		
Storms: Exp & some damage											−0.45***	(0.15)		
Storms: Exp & serious damage											−0.43***	(0.16)		
Drought: Not experienced														
Drought: Exp without damage													−0.07	(0.13)
Drought: Exp & some damage													−0.47***	(0.15)
Drought: Exp & serious damage													−0.71***	(0.14)
Constant cut1	−1.22**	(0.52)	−1.37**	(0.53)	−1.28**	(0.53)	−1.40***	(0.54)	−1.39***	(0.52)	−1.33**	(0.55)	−1.20**	(0.53)
Constant cut2	−0.88*	(0.52)	−1.04**	(0.52)	−0.95*	(0.52)	−1.07**	(0.53)	−1.06**	(0.51)	−0.99*	(0.54)	−0.87*	(0.52)
Constant cut3	−0.58	(0.52)	−0.73	(0.52)	−0.65	(0.51)	−0.76	(0.52)	−0.76	(0.51)	−0.70	(0.53)	−0.59	(0.52)
Constant cut4	−0.21	(0.51)	−0.35	(0.52)	−0.27	(0.51)	−0.38	(0.52)	−0.37	(0.51)	−0.30	(0.53)	−0.19	(0.52)
Constant cut5	0.69	(0.51)	0.54	(0.52)	0.63	(0.51)	0.52	(0.52)	0.54	(0.51)	0.62	(0.53)	0.72	(0.52)
Constant cut6	0.95*	(0.51)	0.81	(0.52)	0.90*	(0.51)	0.78	(0.52)	0.82	(0.51)	0.89*	(0.53)	1.00*	(0.52)
Constant cut7	1.19**	(0.51)	1.05**	(0.52)	1.14**	(0.51)	1.02**	(0.52)	1.07**	(0.51)	1.13**	(0.53)	1.26**	(0.52)
Constant cut8	1.62***	(0.52)	1.47***	(0.52)	1.57***	(0.51)	1.45***	(0.52)	1.50***	(0.51)	1.57***	(0.53)	1.70***	(0.52)
Constant cut9	1.88***	(0.52)	1.74***	(0.52)	1.83***	(0.52)	1.72***	(0.52)	1.77***	(0.51)	1.84***	(0.54)	1.97***	(0.53)
F − test (P > F)[a]	0.11		0.09		0.06		0.08		0.04		0.20		0.05	
Observations	515		515		515		515		515		513		512	
Log Likelihood	−988.5		−986.5		−984.8		−985.4		−976.6		−974.3		−965.9	

Note: Dependent Variable: General life satisfaction (1 − 10). Method: ordered probit (*oprobit*). Female, Married and Head of household are dummy variables that take the value 1 if the respondent is female, married or the household head, respectively.
Robust standard errors in parentheses.

[a] *F* − Test on joint significance of Age and Age squared.

*** $p < 0.01$.

** $p < 0.05$.

* $p < 0.1$.

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