


# BMJ Open Health and well-being in small island communities: a cross-sectional study in the Solomon Islands

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## ABSTRACT

**Objectives** This study explored the health problems of inhabitants of small South Pacific Islands under the influence of climate change, focusing on three communities in the Solomon Islands.

**Design** Cross-sectional study of the Solomon Islands' populations.

**Setting** A field survey was conducted in Taro Island, a small, urbanised island with a whole-community relocation plan; Manuopo community of Reef Islands, a small remote island on an atoll environment and Sasamungga, an intermediately urbanised community on a larger island. The Sasamungga community was used for comparison.

**Participants** Each community's participants were recruited through local health authorities, and 113, 155 and 116 adults (aged 18+ years) from Taro, Manuopo and Sasamungga, respectively, participated voluntarily.

**Methods** Each participant's body height, weight and body mass index were measured. A drop of blood was sampled for malaria testing; glycated haemoglobin and C reactive protein levels, measured from another drop of blood, were markers for diabetes and inflammation, respectively. The Primary Care Screening Questionnaire for Depression measured depressive mental states.

**Primary and secondary outcome measures** Regarding health status, the dependent variables—communicable diseases, non-communicable diseases and mental state—and independent variables—differences in communities and socioeconomic status—were measured through health check-ups and interviews of individual participants.

**Results** Taro Island inhabitants had a higher risk of obesity (OR 1.13, 95% CI 1.02 to 1.27,  $p=0.0189$ ), and Manuopo inhabitants had a higher risk of depression (1.25, 95% CI 1.08 to 1.44,  $p=0.0026$ ) than Sasamungga inhabitants. Manuopo inhabitants recognised more serious problems of food security, livelihood, place to live and other aspects of daily living than other communities' inhabitants.

**Conclusions** The three small island communities' observation identified different health problems: the urbanised community and remote community had a high risk of non-communicable diseases and mental disorders, respectively. These health problems should be monitored continuously during future climate-related changes.

## INTRODUCTION

Human-induced climate change is now a real threat to human health and well-being.<sup>1–3</sup>

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study directly measured human health and well-being among the inhabitants of the Pacific Islands.
- ⇒ The incidence of communicable and non-communicable diseases, including mental health, was assessed as the current baseline health status to monitor future changes.
- ⇒ The study was conducted in three types of communities: an atoll, an overcrowded, and a comparison community on volcanic islands, for which epidemiological data are rarely available.
- ⇒ The number of participants (N=384) was limited and not all potential confounding factors were controlled in the analyses.
- ⇒ Because of lack of comparable data, further studies are necessary to monitor prevalence of the depressive conditions.

WHO indicated that climate change affects environmental systems that determine health and the socioeconomic and cultural modifiers of risks to health, thereby impacting health as well.<sup>4</sup> Woodward *et al* suggested that there has been a major increase in health problems because of intense heat waves and fires; undernutrition resulting from diminished food production in poor regions; lost work capacity and reduced labour productivity in vulnerable populations; and foodborne, waterborne and vectorborne diseases.<sup>5</sup> In addition, Fritze *et al* suggested that extreme weather events increased post-traumatic stress disorders, and the resulting environmental damage caused loss of work and had other consequences.<sup>6</sup> The 'loss of connection to a place and sense of belonging associated with displacement' (eg, involuntary migration) also led to psychological stress.<sup>6</sup>

Lifestyle changes can be a risk factor for infectious diseases, and changes from a traditional subsistence to a cash economy increase the incidence of non-communicable diseases (NCDs), such as obesity, diabetes

and hypertension. In the South Pacific Islands, infectious diseases and malnutrition are still severe problems. At the same time, diabetic, metabolic and cardiovascular diseases are now highly prevalent. People, therefore, face the double burden of increased risk of communicable diseases and NCDs.<sup>7</sup> In reality, the NCD Risk Factor Collaboration showed that the risks of infectious diseases and malnutrition are high in Pacific Island countries with low-income economies,<sup>8</sup> and NCDs increase during disaster events such as when the inhabitants were evacuated to temporary camps near townships during the 2007 Solomon Islands earthquake and tsunami.<sup>9</sup>

Therefore, the WHO Division of Pacific Technical Support with its partner countries suggested that the small island countries of the Pacific are vulnerable to climate change. In these Pacific Islands, the high-priority, climate-sensitive health risks are suggested to be trauma from extreme weather events, heat-related illnesses, safety and security of waterborne and foodborne, vectorborne diseases, zoonoses, respiratory illnesses, psychosocial ill health, NCDs, population pressures and health system deficiencies.<sup>10</sup>

Taro Island of the Solomon Islands is known to be one of the communities most vulnerable to a rise in sea level<sup>11 12</sup> because it is much smaller than the other independent states in the South Pacific (eg, Tuvalu). However, the actual health status of small island communities, especially in remote islands, has rarely been studied. It is, thus, necessary to reveal and record the real health status of the small island communities that have recently been affected by and are likely to be further influenced by climate change. As Haines *et al* suggested, monitoring and surveillance are needed for this purpose to (1) identify important changes in disease incidence, health risk indicators, and health status; (2) determine whether these changes are likely to be the result of local, regional or global environmental changes; (3) help develop countermeasures and assess their effectiveness and (4) develop hypotheses about the potential health effects of climate change.<sup>2</sup>

Accordingly, this study aimed to explore health problems in small South Pacific Island communities that are affected by climate change through health check-ups and interview surveys in three communities in the Solomon Islands. The research assessed communicable diseases and NCDs, including mental disorders. Special attention was paid to health risks in the two communities that were most vulnerable to sea-level rise compared with a community on a large island. This study also aimed to provide a baseline of health information for these communities, which could be referenced should relocation or other adaptation strategies materialise.

## METHODS

### Study sites

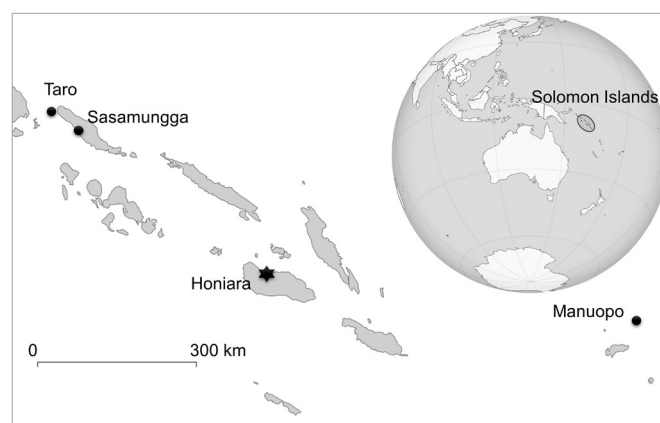
The Solomon Islands (population=approximately 650 000) constitute more than 900 islands. More than 80%

**Table 1** Basic characteristics of the selected villages

	Sasamungga	Taro	Manuopo
Province	Choiseul	Choiseul	Temotu
Effects of sea-level rise	Minimum	Severe	Severe
Health facility	Hospital (no doctor stationed)	Hospital	Clinic
Estimated population*	1000	810	1030
Participating households, n	92	89	131
Participants (adults), n			
Male	37	43	39
Female	76	73	116
Total	113	116	155
Participants' age in years, mean (min-max)	49 (20–79)	42 (18–85)	46 (18–79)
*Estimated population size, as cited in government reports. <sup>13 16</sup>			

of the population of these islands lives in places remote from urban infrastructure and follows a subsistence way of life that relies on traditional agriculture and fishing.<sup>13</sup> This study was conducted in three villages chosen for their representativeness of the main types of communities found on the islands: they are all central communities in their respective regions and have hospitals or clinics (table 1, figure 1).

Taro is the name of both the community and the island. Taro is the provincial capital of Choiseul Province and has about 810 inhabitants. Taro Island has a land area of only 0.44 km<sup>2</sup><sup>14</sup> and is vulnerable to rising sea levels. Therefore, the Choiseul Government has developed a relocation plan to permanently move all Taro Island inhabitants and infrastructure to the main island of



**Figure 1** Map showing the communities selected in this research.

Choiseul, approximately 2 km from Taro.<sup>6</sup> This is the first plan for a community-level relocation in the country, even though many other small islands are also at risk of a rise in sea level.<sup>15</sup> Since there is almost no suitable agricultural land on the island, people purchase food from vendors who travel from Choiseul Island by canoe every day.

Manuopo is a village on Lomlom Island of the Reef Islands in Temotu Province. The Reef Islands are atoll islands that are free from the type of urban infrastructure found on large islands. The Manuopo village community is also at risk of being affected by the rising sea level. Unlike Taro, the people of Manuopo are rarely able to obtain food or other kinds of goods from the main island and need to produce sufficient food, building materials, drinking water and other products on the atoll. Although no official evaluation of the impact of sea-level rise is available for the Reef Islands, soil erosion, land inundation and loss of coastal vegetation have been observed here.<sup>16</sup> Manuopo has the largest population among the Reef Islands, with 1030 inhabitants, and it has a clinic that serves as the local healthcare centre for the islands.<sup>17</sup>

Sasamungga is one of the biggest villages (of about 1000 inhabitants) on the main island of Choiseul.<sup>14</sup> It was chosen as a comparison community because the rising sea level has almost no influence on this village since it is located on a large volcanic island and neither the village nor the coastal vegetation are directly affected by the sea-level rise.

Therefore, these three villages are suitable for cross-sectional research to explore the effect of the rise in sea level and provide baseline data for future changes.

### Participants

Health check-up and interview surveys were conducted in December 2017 and July 2018 in Choiseul Province (Taro and Sasamungga) and Temotu Province (Manuopo), respectively. Participants were recruited from all community members without any selection as follows.

The research team prepared posters that explained the project and invited inhabitants to participate in the survey in advance and sent them to local hospital directors, health authorities and community leaders. The directors, health staff and leaders displayed the posters on public bulletin boards as well as introduced them during community meetings. In the Solomon Islands, bulletin boards and community meetings are a means of communicating public information to all people without partiality or discrimination. It was also specified that a tin of fish (equivalent to about US\$2) would be given as a reward to every participant. In this process, participants were invited to voluntarily visit hospitals or clinics for health check-ups during the survey period. At the reception for the check-ups, the research team explained the study's purpose and method as well as the protection of privacy/personal information. They also explained how data would be used and accessed, and that potential participants would not be penalised if they chose not to participate. Other relevant items were also discussed.

If a person or legal guardian agreed to participate, they signed informed consent forms.

This project accepted all individuals for health check-ups; however, blood pressure measurement, questionnaire survey on mental condition, and interviews on household economic status were conducted exclusively for adults. As a result, 146, 138 and 228 inhabitants from Sasamungga, Taro and Manuopo, respectively, participated in the research. Although no exact census data are available for the study period, the latest population information suggested that these islands had a population of 1000, 810, and 1030, and thus, this study's participants covered 14.6%, 17.0%, and 22.1% of the inhabitants, respectively. Further, this study included only adults (aged 18 years or above). Thus, from among the initial participants, 33, 22 and 73 children aged 17 years or below were excluded from this study for each island, respectively. In total, 113 adults from 92 households, 116 adults from 89 households, and 155 adults from 131 households were included from Sasamungga, Taro, and Manuopo, respectively (table 1).

We aimed to gather a sample of more than 10% of the populations of the communities. It was difficult to recruit a large number of participants, given the field conditions of the Solomon Islands and our policy of voluntary participation. On the other hand, we had estimated that a sample size of 350 was sufficient to achieve statistical power (one minus beta), with 90% under the condition to detect an odds ratio (OR) of 1.5 in the multiple logistic regression analysis with statistical significance (alpha) <5% as a priori sample size estimation, using the G\*Power software (Heinrich-Heine-Universität Düsseldorf). Moreover, as statistical power calculation tends to be low for logistic regression analyses, our sample size was adequately large (99% statistical power) to perform multiple regression analyses with six variables.

### Patient and public involvement

Before conducting this study, we had discussions with officials in Choiseul and Temotu Provinces and incorporated the issues raised into the research plan. We also held discussions with local community leaders and inhabitants. As a result, the premiers of Choiseul and Temotu submitted letters of support for the study and approved the plan for permission from the Solomon Islands National Ethics Committee.

### Health check-up

During the health check-up, each participant's body height was measured to the nearest 1 mm using a field anthropometer (Tsutsumi, Japan), and their weight was recorded to the nearest 0.1 kg using a portable digital scale (Tanita model HD-654, Tanita, Japan), according to a standard protocol. Body mass index (BMI; kg/m<sup>2</sup>) was then calculated. Blood pressure was measured twice using an Omron HBP-1300 device (Omron Corporation, Japan), and the average was used for analyses.



A drop of blood was sampled using the finger-prick method. Glycated haemoglobin (HbA1c) was measured as a marker for diabetes (Afinion Nycocard system, Abbott, USA). C reactive protein (CRP) was also measured as an inflammation marker in the Nycocard system. Another drop of blood was used for the malaria rapid diagnosis test (Entebbe Malaria Rapid Test, Laboratorium Hepatika, Indonesia).

The Primary Care Screening Questionnaire for Depression (PSQ4D) was used to measure depressive mental states.<sup>18</sup> This questionnaire consists of the following four questions, and answering 'yes' to three or more questions is recognised as depression: (1) 'Have you been experiencing sadness or depressed mood during the last 2 weeks or longer?', (2) 'Have you been experiencing loss of interest or loss of pleasure in doing things during the last 2 weeks or longer?', (3) 'Have you been feeling excessively tired or without energy during the last 2 weeks or longer?' and (4) 'Have you been suffering from sleeplessness during the last 2 weeks or longer?'. All four questions are related to four symptoms of depression described in The International Classification of Diseases (ICD)-10 Classification of Mental and Behavioural Disorders: Diagnostic Criteria for Research, and none of the questions is culture-specific. As the official language of the Solomon Islands is English, PSQ4D could be used as is in principle. The healthcare workers noted the answers of the participants.

#### Definition of study parameters

In this study, we defined obesity as BMI  $\geq 30$  kg/m<sup>2</sup>, malnutrition as BMI  $< 18.5$  kg/m<sup>2</sup>, hypertension as systolic blood pressure  $\geq 140$  mm Hg or diastolic blood pressure  $\geq 90$  mm Hg, diabetes as HbA1c level  $\geq 6.5$  %, inflammation as CRP level  $\geq 1$  mg/dL and depressive mental state as  $\geq 3$  items positive for the PSQ4D survey.

#### Interview survey

All participants were interviewed individually to gather information on their gender and date of birth as well as their livelihood and lifestyle (see online supplemental material 1). These interviews were conducted to determine the socioeconomic status of the participants and/or control for confounding factors. This interview survey included the Humanitarian Emergency Settings Perceived Needs Scale (HESPER) to validly assess the perceived needs of people in each community. The HESPER assessed the physical, mental and social needs of the people.<sup>19</sup> Because HESPER has too many items as variables and because it is a questionnaire that represents the community as a whole rather than individuals, we used it to examine differences in communities and not to analyse individuals' health status.

#### Statistical analyses

Tukey's test was used for multiple comparisons of health measures among the three villages.  $\chi^2$  test was used to compare the prevalence of indicators among the three

villages, and Fisher's exact test was adopted for instances of small sample size. In the Solomon Islands and other societies in Oceania, the degree of modernisation is known to be related to health status, and a modernity score has been used to determine how many modern objects an individual has.<sup>20 21</sup> In this study, we examined the ownership of various modern objects but decided to use overall modernity as a variable rather than analysing individual ownership, because people who lead modern lives tend to own more than one thing. Owning several modern goods was summarised into one factor by principal component analysis; the strongest first principal component was used as the variable. This factor explained 38.9% of the total variation. Further, logistic regression analysis was conducted to explore risk factors for communicable diseases, NCDs and mental diseases, and the effects of community differences were analysed after adjusting for age, sex, housing style (as an indicator of living environment), and owning modern goods (socioeconomic status). The variable of housing style was added as an indicator of socioeconomic status because Western-style houses are durable and can be lived in for more than 10 years, while traditional houses are usually changed every few years; thus, living in a Western-style house is considered a status symbol in rural areas.<sup>9 20</sup> Missing data, if any, were excluded from each analysis. All statistical analyses were conducted using the R V.4.0.5 (The R Project for Statistical Computing), and a  $p < 0.05$  was considered statistically significant.

## RESULTS

**Table 2** shows the household-level living environment and socioeconomic status of the participants. Regarding garden crops, fish and cash income, more than 80% of the participants from Sasamungga and Taro answered that they had sufficient amounts of these. However, in Manuopo, about half the participants had enough crops or fish, and only 29.0% had enough cash income. The proportion of Western-style houses was the highest in Taro (68.8%), followed by Sasamungga (63.3%), with the lowest in Manuopo (10.1%). 'Owning modern goods' was the most common in Taro and least common in Manuopo.

**Table 3** shows the health status of the participants. Body weight and BMI were the highest in Taro and the lowest in Manuopo, indicating that the prevalence of being overweight or obese was higher in Taro compared with Manuopo. Hypertension was more prevalent in Sasamungga than the other two villages, while more inhabitants of Manuopo had depressive conditions than in other villages. No cases of malaria and significant differences in communicable diseases (ie, inflammation measured by CRP levels) and malnutrition were observed among the three communities.

Results of the logistic regression analyses for health indicators are shown in **table 4**. Compared with Sasamungga, living in Taro was a significant risk factor for obesity; females also showed a higher risk for obesity across the three villages. After controlling for the effects of age, the inhabitants of Manuopo

**Table 2** Living environment and socioeconomic status of participating households (% in parentheses; n=312)

	Sasamungga (N=92)	Taro (N=89)	Manuopo (N=131)
Housing type			
# Traditional leaf	25 (30.6)	17 (18.8)	112 (85.5)
# Western style	58 (63.3)	60 (68.8)	13 (10.1)
# Traditional-Western mix	6 (6.1)	12 (12.5)	5 (3.6)
# Temporary house	0 (0)	0 (0)	1 (0.7)
# HHs with enough garden crops	90 (98.0)	81 (90.6)	81 (61.6)
# HHs with enough fish	92 (100)	75 (84.4)	73 (55.8)
# HHs with enough cash income	87 (94.9)	77 (87.5)	38 (29.0)
# HHs owning OBM/car	15 (17.4)	32 (38.5)	12 (8.7)
# HHs owning chainsaw	18 (18.4)	19 (22.9)	2 (1.4)
# HHs owning mobile phone	89 (96.9)	85 (95.8)	72 (55.8)
# HHs having radio/stereo	32 (33.7)	25 (30.2)	5 (3.6)
# HHs having video/DVD	25 (27.6)	29 (36.5)	1 (0.7)
# HHs having rainwater tank	73 (77.6)	67 (77.1)	45 (34.1)

DVD, digital video disc; HH, household; OBM, outboard motor.

showed a decreased risk of hypertension. Participants living in Manuopo had the highest risk of depressive conditions.

Table 5 shows the participants' perceived needs; details are available in online supplemental material 2. Of the three communities, Manuopo inhabitants were more likely to perceive serious problems in all items except for lack of 'respect'. Of the 26 items, the majority of the Manuopo participants answered 'yes' to 11 or more items. Compared with Sasamungga and Taro, more than double the Manuopo participants perceived serious problems with 'food' (37.4%), 'place to live in' (16.5%), 'income or livelihood' (77.5%),

'support from others' (50.0%), and others. Alcohol and drug use was recognised as a very common problem in all three communities. In addition, issues with law and justice, violence on women and toilets were recognised as severe problems by 40% or more of the participants in all three communities.

## DISCUSSION

This study was conducted in two communities that are affected by rising sea levels and one comparison community. It revealed that inhabitants of the urbanised island

**Table 3** Adult health status of participants measured by biological markers (n=384)

	Sasamungga (N=113)	Taro (N=116)	Manuopo (N=155)	Village comparison*
Height (male), cm	164.9±0.8	167.3±0.8	165.2±0.9	NS
Height (female), cm	154.7±0.6	154.9±0.7	155.2±0.4	NS
Weight (male), kg	68.4±1.5	77.9±2.2	65.1±1.6	T>S, M
Weight (female), kg	67.9±1.6	71.2±1.6	60.6±1.0	T, S>M
BMI (male), kg/m <sup>2</sup>	25.1±0.5	27.8±0.7	23.8±0.5	T>S, M
BMI (female), kg/m <sup>2</sup>	28.3±0.6	29.7±0.7	25.2±0.4	T, S>M
% Obesity	25.7%	37.1%	10.3%	T, S>M
% Malnutrition	0.9%	0.9%	3.2%	NS
% Hypertension	26.5%	12.1%	13.5%	S>T, M
% Diabetes	1.8%	2.6%	0.65%	NS
% Inflammation	9.7%	4.3%	3.2%	NS
% Malaria positive	0	0	0	Not applicable
% Depressive	32.4%	33.9%	60.6%	M>T, S

\*Tukey's test for multiple comparison (p<0.05).  
BMI, body mass index; M, Manuopo; NS, not significant; S, Sasamungga; T, Taro.

**Table 4** Logistic regression analyses estimates for the risk factors of communicable and non-communicable diseases: OR (95% CI)

Health status	Community (Sasamungga as Reference)		Sex (male=1; female=0)	Age (Years)	Housing type (Western=1; Others=0)	Owning modern goods (PC1)	Intercept	Nagelkerke R <sup>2</sup>
	Taro	Manuopo						
Communicable diseases/malnutrition								
Malnutrition (BMI of <18.5 kg/m <sup>2</sup> )	1.02 (0.98, 1.05) NS	1.01 (0.97, 1.04) NS	1.02 (0.99, 1.05) NS	1.00 (0.999, 1.001) NS	0.99 (0.96, 1.03) NS	1.00 (0.986, 1.008) NS	0.97 (0.91, 1.02) NS	0.025
Inflammation (CRP level of ≥1 mg/dL)	0.96 (0.90, 1.02) NS	0.96 (0.90, 1.01) NS	0.97 (0.92, 1.02) NS	1.00 (0.999, 1.003) NS	0.98 (0.92, 1.04) NS	1.02 (0.999, 1.038) NS	1.04 (0.94, 1.14) NS	0.035
Non-communicable diseases								
Obesity (BMI ≥30 kg/m <sup>2</sup> )	0.92 (0.82, 1.03) NS	1.13 (1.02, 1.27) p=0.0189	0.80 (0.73, 0.88) p<0.0001	1.00 (0.999, 1.005) NS	1.1 (0.99, 1.22) NS	1.02 (0.98, 1.05) NS	1.17 (0.99, 1.34) NS	0.158
Diabetes (HbA1c level of ≥6.5%)	0.99 (0.95, 1.03) NS	1.04 (0.998, 1.081) NS	0.99 (0.96, 1.03) NS	1.00 (0.999, 1.002) NS	0.99 (0.95, 1.03) NS	1.00 (0.99, 1.02) NS	1.00 (0.94, 1.06) NS	0.02
Hypertension (SBP ≥140 mm Hg/DBP ≥90 mm Hg)	0.90 (0.82, 0.99) p=0.0493	0.93 (0.85, 1.02) NS	0.96 (0.89, 1.04) NS	1.01 (1.008, 1.013) p<0.0001	1.04 (0.95, 1.14) NS	0.99 (0.96, 1.02) NS	0.79 (0.68, 0.91) p=0.015	0.189
Mental status								
Depressive (≥3 items positive for the PSQ4D)	1.25 (1.08, 1.44) p=0.0026	1.02 (0.90, 1.16) NS	0.93 (0.84, 1.05) NS	1.00 (0.996, 1.003) NS	1 (0.88, 1.15) NS	0.97 (0.93, 1.01) NS	1.46 (1.19, 1.80) p=0.0004	0.091
BMI, body mass index; CRP, C reactive protein; DBP, diastolic blood pressure; HbA1c, glycosylated haemoglobin; NS, not significant; PSQ4D, Primary Care Screening Questionnaire for Depression; SBP, systolic blood pressure.								

**Table 5** Participants' responses (percentage answering 'yes') to the Humanitarian Emergency Settings Perceived Needs Scale

Do you have a serious problem because of the following items?	Sasamungga, %	Taro, %	Manuopo, %
1.Drinking water	21.2	24.1	38.1
2.Food	10.6	7.6	37.4
3.Place to live in	8.0	4.3	16.5
4.Toilets	43.4	42.2	<b>78.4</b>
5.Keeping clean	11.5	6.0	28.1
6.Clothes, shoes, bedding, or blankets	8.0	5.2	33.8
7.Income or livelihood	19.5	23.3	<b>77.5</b>
8.Physical health	29.2	9.5	43.5
9.Healthcare	3.5	14.6	<b>51.4</b>
10.Distress	38.9	37.1	<b>57.2</b>
11.Safety	17.7	11.2	47.8
12.Education for your children	6.2	13.8	18.8
13.Care for family members	23.0	17.2	32.6
14.Support from others	23.9	23.3	<b>50.0</b>
15.Separation from family members	21.2	9.5	17.4
16.Being displaced from home	6.2	0.9	10.1
17.Information	<b>50.4</b>	12.9	<b>70</b>
18.The way aid is provided	44.2	18.1	<b>75.4</b>
19.Respect	34.5	29.3	24.6
20.Moving between places	3.5	4.3	10.1
21.Too much free time	23.9	25.0	<b>67.4</b>
22.Law and justice in your community	47.8	49.1	<b>75.4</b>
23.Safety or protection from violence for women in your community	<b>51.3</b>	42.2	<b>68.1</b>
24.Alcohol or drug use in your community	<b>92.0</b>	<b>82.8</b>	<b>96.4</b>
25.Mental illness in your community	32.7	38.8	38.4
26.Care for people in your community who are on their own	38.1	31.9	47.1

Values in boldface indicate that more than 50% responded 'yes' (n=384; see online supplemental material 2 for details).

community faced a high risk of obesity, while those of the remote island community faced a high risk of depressive conditions. Further, inhabitants of the urbanised community had better livelihoods and perceived fewer serious problems in their daily lives than those of the remote community. The communities of Taro and Manuopo were selected from among areas of the Solomon Islands where the rise in sea level is particularly severe. This result is valuable as it indicates the health status of inhabitants of islands exposed to sea-level rise.

These findings should be interpreted with caution due to the limitations of our study. First, a causal relationship between the differences in health status found in this study and sea-level rise cannot be inferred from the results of this study alone. These areas are already experiencing vegetation loss and coastal erosion, and additional research will help clarify the causal relationship

when the sea-level rise worsens and adaptive measures such as whole-island resettlement are implemented. In our survey method, participation in the survey was voluntary for the inhabitants, so it is undeniable that there may be some bias among the participants. However, this method is unavoidable in order to respect people's will and right to participate in the survey in a country such as the Solomon Islands where there are no official health statistics. Since the same recruitment method was used in all three communities, the results of the cross-sectional comparison are reasonable.

Careful interpretation of the results of the mental health survey for depression is necessary. The possibility of overestimation cannot be denied, given that even in developed countries, where detailed studies have been conducted, the incidence of depression is approximately 10%, and even among low-income groups, it is less



than 20%.<sup>22</sup> Although no precise studies examined the percentage of the population affected by depression in the Solomon Islands, WHO estimated it to be about 2.9%.<sup>23</sup> For example, in Indonesia, a tropical island country for which statistical data are available, the WHO put the figure at about 3.7%, but a national survey suggested that 23.5% of the adult population is depressed.<sup>24</sup> In light of this, the fact that over 30% of the people in the villages included in this study reported symptoms of depression indicates that scores on a 4-item screening test should not be taken as the prevalence of diagnosed depression in the community.

In addition, our study design did not account for all confounding factors because small island communities potentially face hardships other than the sea-level rise. Hypertension may be influenced by lifestyle factors, and its high prevalence in Sasamungga was not explained in this study. This finding of high prevalence of hypertension in an intermediately urbanised village is similar to the findings reported by other studies.<sup>9</sup> This high incidence is probably the result of a change from a traditional diet to a Western one, with an increased use of salt.<sup>9,25</sup> However, as more urbanised populations may have received medical information to reduce salt intake to avoid hypertension, further studies are necessary.

While this study has limitations, it sheds light on the problems and health risks of small island communities. First, even though the inhabitants of Taro face potentially severe impacts of rising coastal water levels, a relocation plan has already been established for which financial support is being raised.<sup>6</sup> Nevertheless, Taro inhabitants have access to food, medical services, education and other resources, as it is the provincial capital and resources are brought in. Therefore, Taro participants did not show serious health problems due to lack of resources but rather showed greater risk of developing NCDs, similar to other urbanised communities in the Solomon Islands.<sup>8,9,26</sup> This health problem is thought to result from a combination of a diet of purchased foods and low physical activity on the small island.

Second, and in contrast with Taro Island, the findings from Manuopo participants supported those of previous studies that rural people are physically healthier than urban or periurban people in terms of incidence of NCDs.<sup>8,9,27</sup> However, third and importantly, this study found that Manuopo inhabitants showed a high risk of depressive conditions (approximately 60%). Even though there is an assumption that people living in traditional societies are mentally healthy,<sup>28</sup> a wide range of mental health challenges were observed in communities in the aftermath of conflicts and disasters.<sup>29</sup> Therefore, the high prevalence of depressive symptoms in Manuopo is thought to reflect the hardships of life in the remote small island. The HESPER results and the interview on the socioeconomic status suggested that the people of Manuopo, which is remote from the main islands, simply experience a lack of livelihood, food, and other materials as well as information. High concerns regarding

issues related to alcohol and drug use, law and justice, and violence against women were commonly recognised in Guadalcanal Island of the Solomon Islands, which had been affected severely by ethnic conflicts between 1998 and 2003,<sup>29</sup> and the same pattern was observed in the three communities selected in this study. The high incidence of depressive conditions in Manuopo is thought to arise from a variety of stresses in everyday life and survival fears such as those related to a shortage of food and other basic human needs, including fear for the future. Future studies are expected to examine changes that occurred due to such survival fears in Manuopo and in other Solomon Islands communities that also face a high prevalence of mental health challenges.

The results of this study have important implications for small island communities' adaptation to climate change. Concerns have been raised about the increasing prevalence of mental illness under the threat of sea-level rise and adaptation to it (eg, involuntary migration); however, only a few studies have investigated this factor in the South Pacific.<sup>10,30</sup> Interviews with 100 people from Tuvalu suggested that distress could result from either (1) local environmental impacts being caused or exacerbated by climate change or (2) hearing about global climate change and contemplating its future implications.<sup>31</sup> This study conducted a rare direct measurement of mental health that supported the consideration that people living in small islands and vulnerable to threats related to the security of food and livelihood, climate change and others are at a higher risk of depressive conditions. This study also indicates that depressive conditions are widely observed (over 30% of the sample) even in places with adequate employment, transportation and communication infrastructure (eg, Taro). Moreover, migration to urban areas is not a solution because previous studies have shown that remote island people migrating to urban areas far from their homeland also face potential risks of mental disorders.<sup>27</sup> In addition, living in urban areas or evacuation camps is known to be associated with physical illness, as shown in this study's findings for Taro and in a previous study on the health impacts of a disaster.<sup>9</sup>

This observational study, thus, concluded that small island communities displayed different health problems: the risk of increased NCDs is associated with the urbanised community, and that of mental disorders is associated with the remote community. These health problems should be monitored during future socioeconomic and climatic changes. Since the health and well-being of small island populations depend on their social and ecological environments, the implication is that policy-makers should develop climate action plans that are in harmony with the various environmental factors.

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