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Well-being in small island communities faced with a rising sea level: a cross-sectional study in the Solomon Islands

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ABSTRACT

Objectives: This study aimed to explore the health problems experienced by the inhabitants of small South Pacific Islands that are under the influence of climate change in three different types of communities in the Solomon Islands.

Design: A cross-sectional study of the Solomon Islands populations.

Setting: A field survey was conducted in the Taro Island, a small urbanised island with a whole-community relocation plan; Manuopo community of the 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 as the control community.

Participants: Participants in each community were recruited through local health authorities, and 123, 197, and 134 adults from Taro Island, Manuopo, and Sasamungga, respectively, voluntarily participated.

Methods: Each participant's body height, body mass index, and weight were measured. A drop of blood was sampled, and glycated haemoglobin and C-reactive protein levels were measured as a marker for diabetes and inflammation, respectively. The Primary Care Screening Questionnaire for Depression was provided to measure depressive mental states.

Primary and secondary outcome measures: The dependent variables of health status (communicable diseases, non-communicable diseases, mental state) and the independent variables (differences in communities, socioeconomic status) were measured through a health check-up and interview conducted for each participant.

Results: Taro Island inhabitants had a higher risk of obesity, and those of Manuopo a higher risk of depression than the inhabitants of Sasamungga. Manuopo inhabitants recognised more serious problems of food security, livelihood, place to live, and other aspects of their daily living than other communities.

Conclusions: The three small-island communities displayed different health problems: members of the urbanised community had a high risk of non-communicable diseases, and the remote community a high risk of mental disorders. These health problems may worsen depending on future climate changes.

(298 words)

ARTICLE SUMMARY

Strengths and limitations of this study

- This is a unique study that directly measured human health and well-being among the inhabitants of Pacific Islands faced with human-induced climate change, such as high coastal water levels.
- The incidence of communicable and non-communicable diseases, including mental

health, were assessed.

- The study was conducted in three different types of communities: one atoll, one overcrowded, and one control community on volcanic islands.
- Currently, the impact of climate change on these communities is limited, but these results provide important baseline data against which future impact can be measured.

Keywords: Sea-level Rise, Climate Change, Atoll, Non-communicable Diseases, Mental Health

INTRODUCTION

Human-induced climate change is now a real threat to human health and well-being.[1-3] The World Health Organization (WHO) has pointed out that climate change affects environmental systems that determine human health, and socioeconomic and cultural modifiers of the risks to human health, and therefore finally impacts human health.[4] Woodward et al. suggested that the major increase in ill health will occur through 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 food- and water-borne diseases and vector-borne diseases.[5] 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.[2,6]. The 'loss of connection to a place and sense of belonging associated with displacement' (for example, involuntary migration) lead to psychological stresses.

Lifestyle changes caused by climate change or adaptation strategies can be a risk factor for infectious diseases, and changes from a traditional subsistence to cash economy increases the incidence of non-communicable diseases (NCDs), such as obesity, diabetes, hypertension, etc. In the South Pacific Islands, infectious diseases and malnutrition are still severe problems, but diabetic, metabolic, and cardiovascular diseases are now highly prevalent. People, therefore, are under a double burden of increased risk of communicable and non-communicable diseases.[7] In reality, the NCD Risk Factor Collaboration showed that the risk of infectious diseases or malnutrition was high in low economic Pacific Islands countries,[8] while NCDs increased when victims evacuated to temporary camps near townships during the 2007 Solomon Islands earthquake and tsunami.[9]

Therefore, the WHO Division of Pacific Technical Support with its partner countries suggests that the small island countries of the Pacific are vulnerable to climate change. The high-priority climate-sensitive health risks in the Pacific Islands are suggested to be trauma from extreme weather events, heat-related illnesses, safety and security of water and food, vector-borne diseases, zoonoses, respiratory illnesses, psychosocial ill-health, NCDs, population pressures, and health system deficiencies.[10]

Taro Island of the Solomon Islands is known to be one of the communities most vulnerable to a rise in sea level,[11,12] because it is much smaller than other independent states in the South Pacific (for example, Tuvalu). However, the actual health statuses of small island communities have rarely been studied, especially in remote islands. Haines suggested that

monitoring and surveillance are needed to (a) identify important changes in disease incidence, health risk indicators, and health status; (b) determine whether these changes are likely to be the result of local, regional, or global environmental changes; (c) help develop countermeasures and assess their effectiveness, and (d) develop hypotheses about the potential health effects of climate change.[2]

This study aimed to explore health problems in small South Pacific Island communities that are under the influence of climate change through health check-ups and interview surveys in three communities in the Solomon Islands. The research assessed communicable and NCDs, including mental disorders. This study was also conducted to provide a baseline of health information for these communities, which could be referenced should relocation or other adaptation strategies materialise.

METHODS

Study sites and participants

The Solomon Islands consists of more than 900 islands. The majority of the population lives in places remote from urban infrastructure and follows a subsistence way of life that relies on traditional agriculture and fishing. This study was conducted in three villages that were chosen for their representativeness of the main types of communities found on the islands: they were all central communities in their respective regions and had hospitals or clinics (Table 1).

Taro Island is the provincial capital of Choiseul Province and has about 810 inhabitants, with a land area of only 0.44 km^2.[13] This island is vulnerable to higher ocean levels, and the Choiseul Government has developed a relocation plan to move all Taro Island residents and infrastructure to the main island of Choiseul, approximately 2 km from Taro, permanently.[6] This is the first plan of a community-level relocation in the country, even though many other small islands are also at risk of sea-level rise.[14] 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, Temotu Province. The Reef Islands are atoll islands that are free from the type of urban infrastructure found on large islands. Manuopo village is also a community at risk of being affected by a 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 produce on the atoll. Although no official evaluation of the impact of ocean level rise is available, soil erosion, land inundation, and loss of coastal vegetation have been observed in the Reef Islands.[15] Manuopo has the largest population in the Reef Islands, comprising 1030 inhabitants, and has a clinic that serves as the local healthcare centre for the islands.[16]

Sasamungga is one of the biggest villages (comprising about 1000 inhabitants) on the main island of Choiseul[13] and was chosen as the control community as it is a village on which a rising sea level has almost no influence.

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

Patient and public involvement

Health check-up and interview surveys were conducted in December 2017 and July 2018, respectively, in Choiseul Province (Taro Island and Sasamungga) and Temotu Province (Manuopo). Participants were recruited through local hospitals, health authorities, and community leaders. Participants were invited to voluntarily visit hospitals or clinics for health check-ups. At the reception for the check-ups, the research team explained the purpose, methods, and protection of privacy/personal information for this study. They also explained how data would be used and accessed, and that potential participants would not be penalised if they elected 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 on mental condition, and interviews on household economic status were conducted exclusively for adults. Thus, this study included only adults. From the initial 146, 138, and 228 participants from Sasamungga, Taro, and Manuopo, respectively, 12, 15, and 31 children aged 18 years or younger were excluded from this study. 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).

Table 1. Basic characteristics of the study villages

	Sasamungga	Taro	Manuopo
Province	Choiseul	Choiseul	Temotu

Effects of sea-level rise Health facility	Minimum Hospital (no doctor stationed)	Severe Hospital	Severe Clinic
Estimated population [a]	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]

n, number

[a] estimated population size cited in government reports [13,16]

This study was approved by the Solomon Islands Health Research and Ethics Review Board (HRE No. 013/16), Ministry of Health and Medical Services, Solomon Islands and Kyoto University Graduate School and Faculty of Medicine Ethics Committee (G0353), Graduate School of Asian and African Area Studies, Kyoto University.

Health check-up survey

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^2) was then calculated. Blood pressure was measured twice using an Omron HBP-1300 device (Omron Corporation, Japan), and the average 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. The same 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 provided to measure depressive mental states.[17] This questionnaire consists of the following four

questions, and answering 'yes' to three or more questions is recognised as depression: 'Have you been experiencing sadness or depressed mood during the last 2 weeks or longer?', 'Have you been experiencing loss of interest or loss of pleasure in doing things during the last 2 weeks or longer?', 'Have you been feeling excessively tired or without energy during the last 2 weeks or longer?', and 'Have you been suffering from sleeplessness during the last 2 weeks or longer?'. The healthcare workers noted the answers of the participants.

Interview survey

Each participant was interviewed to gather information on their sex and date of birth, as well as their livelihood and lifestyle. These interviews were conducted to determine the socioeconomic status of the participants and/or to control for confounding factors. This interview survey included the 'Humanitarian Emergency Settings Perceived Needs Scale (HESPER)' in order to validly assess the perceived needs of people in each community. The HESPER assessed the physical, mental, and social needs of the people.[18]

Statistical analyses

Tukey's test was used for multiple comparisons of health measures among the three villages. The chi-square test was used to compare the prevalence of indicators among the three villages; Fisher's exact test was adopted for instances of small sample size. Owning several modern goods was summarised into one factor by principal component analysis; the strong first principal component was used as the variable. This factor explained 38.9% of the total variation. Logistic regression analysis was conducted to explore risk factors for communicable, non-communicable, 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). Missing data, if any, were excluded from each analysis. All statistical analyses were conducted using the R version 4.0.5 (The R Project for Statistical Computing), and $P < 0.05$ was considered statistically significant.

RESULTS

Definitions of study parameters

Obesity was defined as a BMI ≥30 kg/m^2; malnutrition, a BMI of <18.5 kg/m^2; hypertension, a systolic blood pressure of ≥140 mmHg over a diastolic blood pressure of ≥90 mmHg; diabetes, an HbA1c level of ≥6.5; inflammation, a CRP level of ≥1 mg/dL, and depressive

mental state as ≥3 items positive for the PSQ4D survey.

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 enough. However, in Manuopo, about half the participants had enough crops or fish, and only 29.0% had enough cash income. The proportion of the Western-style house was the highest in Taro (68.8%), followed by Sasamungga (63.3%), and lowest in Manuopo (10.1%). 'Owning modern goods' was most common in Taro and least common in Manuopo.

Table 2. Living environment and socioeconomic status of participating households (n = 312)

	Sasamungga	Taro	Manuopo
Housing type			
a. % Traditional leaf	30.6	18.8	85.5
b. % Western-style	63.3	68.8	10.1
c. % Traditional-Western mix	6.12	12.5	3.6
d. % Temporary house	0	0	0.7
% HHs with enough garden crops	98.0	90.6	61.6
% HHs with enough fish	100	84.4	55.8
% HHs with enough cash income	94.9	87.5	29.0
% HHs owning OBM/car	17.4	38.5	8.7
% HHs owning chainsaw	18.4	22.9	1.4
% HHs owning mobile phone	96.9	95.8	55.8
% HHs having radio/stereo	33.7	30.2	3.6
% HHs having video/DVD	27.6	36.5	0.7
% HHs having rainwater tank	77.6	77.1	34.1

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

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 obesity was higher in Taro compared to Manuopo. Hypertension was more prevalent in Sasamungga than the other two villages, while more inhabitants of Manuopo had a depressive condition than the other villages. No case of malaria and significant difference in communicable diseases (i.e. inflammation measured by the CRP levels) or malnutrition was

observed among the three communities.

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

	Sasamungga	Taro	Manuopo	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^2	25.1 ± 0.5	27.8 ± 0.7	23.8 ± 0.5	T > S, M
BMI (Female), kg/m^2	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

BMI, body mass index; NS, not significant; M, Manuopo; S, Sasamungga; T, Taro

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

Table 4. Logistic regression analyses estimates of risk factors for communicable and non-communicable diseases: odds ratio [95% confidence interval]

Variables	Communicable diseases/Malnutrition		Non-communicable diseases			Mental states
	Malnutrition	Inflammation	Obesity	Diabetes	Hypertension	Depressive
Location						
Manuopo[a]	1.02 [0.98, 1.05] NS	0.96 [0.90, 1.02] NS	0.92 [0.82, 1.03] NS	0.99 [0.95, 1.03] NS	0.90 [0.82, 0.99] P = 0.0493	1.25 [1.08, 1.44] P = 0.0026
Taro[b]	1.01 [0.97, 1.04] NS	0.96 [0.90, 1.01] NS	1.13 [1.02, 1.27] P = 0.0189	1.04 [0.998, 1.081] NS	0.93 [0.85, 1.02] NS	1.02 [0.90, 1.16] NS
Sex[c]	1.02 [0.99, 1.05] NS	0.97 [0.92, 1.02] NS	0.80 [0.73, 0.88] P <0.0001	0.99 [0.96, 1.03] NS	0.96 [0.89, 1.04] NS	0.93 [0.84, 1.05] NS
Age (years)	1.00 [0.999, 1.001] NS	1.00 [0.999, 1.003] NS	1.00 [0.999, 1.005] NS	1.00 [0.999, 1.002] NS	1.01 [1.008,1.013] P <0.0001	1.00 [0.996, 1.003] NS
Housing type[d]	0.99 [0.96, 1.03] NS	0.98 [0.92, 1.04] NS	1.10 [0.99, 1.22] NS	0.99 [0.95, 1.03] NS	1.04 [0.95, 1.14] NS	1.00 [0.88, 1.15] NS
Owning modern goods (PC1)	1.00 [0.986, 1.008] NS	1.02 [0.999, 1.038] NS	1.02 [0.98, 1.05] Ns	1.00 [0.99, 1.02] NS	0.99 [0.96, 1.02] NS	0.97 [0.93, 1.01] NS
Intercept	0.97 [0.91, 1.02] NS	1.04 [0.94, 1.14] NS	1.17 [0.99, 1.34] NS	1.00 [0.94, 1.06] NS	0.79 [0.68, 0.91] P = 0.015	1.46 [1.19, 1.80] P = 0.0004
Nagelkerke R^2	0.025	0.035	0.158	0.020	0.189	0.091

NS, not significant; PC, principal component

[a]Manuopo = 1, Others = 0; [b]Taro = 1, Others = 0; [c]Male = 1, Female = 0; [d]Western = 1, Others = 0

Table 5 shows participants perceived needs. 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 items or more. When compared with Sasamungga or 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.

Table 5. Participants' responses (percentage answering 'Yes') to Humanitarian Emergency Settings Perceived Needs Scale (HESPER)

Values in bold indicate that more than 50% responded 'Yes' (n = 384).

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%	**78.4%**
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%	**77.5%**
8. Physical health	29.2%	9.5%	43.5%
9. Health care	3.5%	14.6%	**51.4%**
10. Distress	38.9%	37.1%	**57.2%**
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%	**50.0%**
15. Separation from family members	21.2%	9.5%	17.4%
16. Being displaced from home	6.2%	0.9%	10.1%
17. Information	**50.4%**	12.9%	**70%**
18. The way aid is provided	44.2%	18.1%	**75.4%**
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%	**67.4%**
22. Law and justice in your community	47.8%	49.1%	**75.4%**

23. Safety or protection from violence for women in your community	**51.3%**	42.2%	**68.1%**
24. Alcohol or drug use in your community	**92.0%**	**82.8%**	**96.4%**
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%

DISCUSSION

This study was conducted in two communities influenced by rising oceans levels and one control community. It revealed that members of the urbanised island community had a high risk of obesity, while those of the remote island community had a high risk of depressive conditions. Inhabitants of the urbanised community had better livelihoods and perceived fewer serious problems in their daily lives than those of the remote communities.

These findings should be interpreted with caution due to the limitations of our study. We targeted two communities which are influenced by sea level rise, but the real impacts thus far have been limited to land inundation and a few metres of coastal erosion and vegetation loss in both communities. These impacts have possibly resulted in a small loss of food production and the quality of life, but the extent of this loss is limited. This study did not evaluate the extent to which rising ocean levels directly affected health. Rather, these findings should be interpreted as an assessment of the health status of inhabitants of small remote islands at risk of high sea levels. Careful interpretation of the results of the mental health survey for depression is necessary. The PSQ4D was originally designed to detect depression[17] and yielded an incidence of depression of about 30%–60% amongst the participants of our study. Our results seem to have overestimated the prevalence of depression amongst the study population, and should be viewed as the results of screening for risks of mental disorders rather than medical diagnoses of major depression.

In addition, our study design did not clear all confounding factors. Hypertension may be influenced by lifestyle factors, and its high prevalence in Sasamungga was not explained in this study. Our finding of a high prevalence of hypertension in an intermediately urbanised village is similar to the findings reported in other studies.[9] The high incidence is probably a result of a change from a traditional diet to a Western one, with an increased use of salt. However, more urbanised populations may have received medical information to reduce salt intake to avoid hypertension.

While this study had limitations, it sheds light on the problems and health risks of small island communities. First, even though the inhabitants of Taro are faced with potentially severe impacts of rising coastal water levels, a relocation plan has already been established for which financial support is being raised.[6] However, 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 a lack of resources, but rather showed a greater risk for developing NCDs, similar to other urbanised communities in the Solomon Islands[9,19] (see also NCD Risk Factor Collaboration 2019). 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 to Taro Island, the findings from the Manuopo participants supported previous studies that rural people are physically healthier than urban or peri-urban people in terms of incidence of NCDs (see also NCD Risk Factor Collaboration 2019).[9,20] However, third and importantly, this study first found that Manuopo residents showed a high risk of depressive conditions. This finding is contrary to our assumption that people living in traditional societies are mentally healthy.[21] The results of our HESPER survey suggested that 'respect'—a tradition of the Solomon Islands—exists in Manuopo. However, the HESPER results and our interview on the socioeconomic status suggested that the people of Manuopo, remote from the main islands, simply experienced a lack of livelihood, food, and other materials and information. (Until recently, the island was only accessible by an unscheduled ship; the airfield was opened a year after our survey, but the flight schedule was not stable until today). The high incidence of depressive conditions in this community is thought to arise from survival fears such as food shortages and other basic human needs.

The results of this study have important implications for the adaptation of small island communities to climate change. Concerns have been raised about mental illness increasing under the threat of sea level rise and adaption to it (for example, involuntary migration), but only a few studies have investigated this factor in the South Pacific.[10,22] Interviews with 100 Tuvalu people suggested that distress could result from either 1) local environmental impacts caused or exacerbated by climate change or 2) hearing about global climate change and contemplating its future implications.[23] The present study, a rare direct measurement of mental health, also supported the people who are living in the small islands and vulnerable to the security of food and livelihood, to climate change, and others were at higher risk of mental disorders. This present study also implied that incidence of mental disorders might be limited in such places as equipped with employment, transport, and communication (that

is, Taro). However, migration to urban areas is not a solution, because previous studies have shown that migration of remote island people to urban areas far from their homeland is also a potential risk for mental disorders.[20] In addition, living in urban areas or evacuation camps is known to be associated with physical illnesses, as shown in this present study's findings for Taro and a previous study on the health impacts of a disaster.[9]

This study thus concluded that small island communities displayed different health problems: a risk of increased NCDs in the urbanised community and mental disorder in the remote community. These health problems will worsen with the negative impact of climate change. Since the health and well-being of small island populations depend on the social and ecological environments, the implications for policymakers is to develop climate action plans that are in harmony with the various environmental factors.

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Author Contributions

TF conceived the project. TF, TI, TT, and FP designed the study. TF, FP, SG, TI, TT, and AS collected the data. TF performed the statistical analyses and wrote the manuscript draft. FP, SG, TI, TT, and AS read and added significant changes to the manuscript and produced this paper.

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Competing Interests

None declared.

Patients consent for publication

Not required.

Ethic approval

This study was approved by the Solomon Islands Health Research and Ethics Review Board (HRE No. 013/16), Ministry of Health and Medical Services, Solomon Islands and the Kyoto University Graduate School and Faculty of Medicine Ethics Committee (G0353), Graduate School of Asian and African Area Studies, Kyoto University.

Provenance and peer review

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Data availability statement

Data except for personal information are available on reasonable request.

Open access

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,9
		(b) Indicate number of participants with missing data for each variable of interest	7,9
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11

		(*b*) Report category boundaries when continuous variables were categorized	8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-13
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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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+) from Taro Island, Manuopo, and Sasamungga, respectively participated voluntarily.

Methods: Each participant's body height, body mass index, and weight 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 (odds ratio = 1.13 [1.02, 1.27], P = 0.0189), and Manuopo inhabitants had a higher risk of depression (1.25 [1.08, 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 changes.

ARTICLE SUMMARY

Strengths and limitations of this study

- This study directly measured human health and well-being among the inhabitants of the Pacific Islands facing human-induced climate change, such as increased coastal water levels.

- 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.

Keywords: Sea-level Rise, Climate Change, Atoll, Non-communicable Diseases, Mental Health

INTRODUCTION

Human-induced climate change is now a real threat to human health and well-being.[1-3] The World Health Organization (WHO) indicated that climate change affects environmental systems that determine human health and the socioeconomic and cultural modifiers of risks to human health, thereby impacting human health as well.[4] 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 food-, water-, and vector-borne diseases.[5] 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.[6] The 'loss of connection to a place and sense of belonging associated with displacement' (e.g. involuntary migration) also led to psychological stress.[6]

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.[7] 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,[8] 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.[9]

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 water and food, vector-borne diseases, zoonoses, respiratory illnesses, psychosocial ill-health, NCDs, population pressures, and health system deficiencies.[10]

Taro Island of the Solomon Islands is known to be one of the communities most vulnerable to a rise in sea level[11,12] because it is much smaller than the other independent states in the South Pacific (e.g. 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 (a) identify important changes in disease incidence, health risk indicators, and health status; (b) determine whether these changes are likely to be the result of local, regional, or global environmental changes; (c) help develop countermeasures and assess their effectiveness, and (d) develop hypotheses about the potential health effects of climate change.[2]

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% 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.[13] 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).

[Figure 1 here]

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^2 [14] 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 Choiseul, approximately 2 km from Taro.[6] 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.[15] 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.[16] Manuopo has the largest population among the Reef Islands, with 1,030 inhabitants, and it has a clinic that serves as the local healthcare centre for the islands.[17]

Sasamungga is one of the biggest villages (of about 1,000 inhabitants) on the main island of Choiseul.[14] 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 Island 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 posted 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 2 US dollars) 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 1,000, 810, and 1,030, 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 more). Thus, from among the initial participants, 33, 22, and 73 children aged 17 years or younger 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).

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 [a]	1,000	810	1,030
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]

n, number

[a] estimated population size, as cited in government reports.[13, 16]

Ethical approval

This study was approved by the Solomon Islands Health Research and Ethics Review Board (HRE No. 013/16), Ministry of Health and Medical Services, Solomon Islands, as well as the Kyoto University Graduate School and Faculty of Medicine Ethics Committee (G0353), Graduate School of Asian and African Area Studies, Kyoto University.

Patient and public involvement

Before conducting this study, we exchanged views 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^2) 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 provided to measure depressive mental states.[18] This questionnaire consists of the following four questions, and answering 'yes' to three or more questions is recognised as depression: (a) 'Have you been experiencing sadness or depressed mood during the last 2 weeks or longer?', (b) 'Have you been experiencing loss of interest or loss of pleasure in doing things during the last 2 weeks or longer?', (c) 'Have you been feeling excessively tired or without energy during the last 2 weeks or longer?', and (d) 'Have you been suffering from sleeplessness during the last 2 weeks or longer?'. 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 ≥ 30 kg/m^2; malnutrition as BMI < 18.5 kg/m^2; hypertension as systolic blood pressure ≥ 140 mmHg over diastolic blood pressure ≥ 90 mmHg; diabetes as HbA1c level ≥ 6.5; inflammation as CRP level ≥ 1 mg/dL, and depressive mental state as ≥ 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 Supplementary 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.[19] 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. The chi-square 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.[20, 21] 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 in rural areas.[9,20] Missing data, if any, were excluded from each analysis. All statistical analyses were conducted using the R version 4.0.5 (The R Project for Statistical Computing), and $P < 0.05$ 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 enough. 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 2. Living environment and socioeconomic status of participating households (% in parentheses; n = 312)

	Sasamungga (N = 92)	Taro (N = 89)	Manuopo (N = 131)
Housing type			
a. % Traditional leaf	25 (30.6)	17 (18.8)	112 (85.5)
b. % Western style	58 (63.3)	60 (68.8)	13 (10.1)
c. % Traditional-Western mix	6 (6.12)	12 (12.5)	5 (3.6)
d. % 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

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 (i.e. inflammation measured by CRP levels) and malnutrition were observed among the three communities.

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

	Sasamungga (N = 113)	Taro (N = 116)	Manuopo (N = 155)	Village Comparison [a]
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^2	25.1 ± 0.5	27.8 ± 0.7	23.8 ± 0.5	T > S, M
BMI (female), kg/m^2	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

BMI, body mass index; NS, not significant; M, Manuopo; S, Sasamungga; T, Taro

[a] Tukey's test for multiple comparison ($P < 0.05$)

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

Table 4. Logistic regression analyses estimates for the risk factors of communicable and non-communicable diseases: odds ratio (95% confidence interval)

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^2
	Taro	Manuopo						
Communicable diseases/malnutrition								
Malnutrition	1.02	1.01	1.02	1.00	0.99	1.00	0.97	
(BMI of < 18.5 kg/m^2)	[0.98, 1.05]	[0.97, 1.04]	[0.99, 1.05]	[0.999, 1.001]	[0.96, 1.03]	[0.986, 1.008]	[0.91, 1.02]	0.025
	NS	NS	NS	NS	NS	NS	NS	
Inflammation	0.96	0.96	0.97	1.00	0.98	1.02	1.04	
(CRP level of ≥1 mg/dL)	[0.90, 1.02]	[0.90, 1.01]	[0.92, 1.02]	[0.999, 1.003]	[0.92, 1.04]	[0.999, 1.038]	[0.94, 1.14]	0.035
	NS	NS	NS	NS	NS	NS	NS	
Non-communicable diseases								
Obesity	0.92	1.13	0.80	1.00	1.1	1.02	1.17	
(BMI ≥ 30 kg/m^2)	[0.82, 1.03]	[1.02, 1.27]	[0.73, 0.88]	[0.999, 1.005]	[0.99, 1.22]	[0.98, 1.05]	[0.99, 1.34]	0.158
	NS	P = 0.0189	P <0.0001	NS	NS	Ns	NS	
Diabetes	0.99	1.04	0.99	1.00	0.99	1.00	1.00	
(HbA1c level of ≥ 6.5%)	[0.95, 1.03]	[0.998, 1.081]	[0.96, 1.03]	[0.999, 1.002]	[0.95, 1.03]	[0.99, 1.02]	[0.94, 1.06]	0.02
	NS	NS	NS	NS	NS	NS	NS	
Hypertension	0.90	0.93	0.96	1.01	1.04	0.99	0.79	
(SBP ≥ 140 mmHg/	[0.82, 0.99]	[0.85, 1.02]	[0.89, 1.04]	[1.008,1.013]	[0.95, 1.14]	[0.96, 1.02]	[0.68, 0.91]	0.189
DBP ≥ 90 mmHg	P = 0.0493	NS	NS	P <0.0001	NS	NS	P = 0.015	
Mental status								
Depressive	1.25	1.02	0.93	1.00	1	0.97	1.46	
(≥ 3 items positive for	[1.08, 1.44]	[0.90, 1.16]	[0.84, 1.05]	[0.996, 1.003]	[0.88, 1.15]	[0.93, 1.01]	[1.19, 1.80]	0.091
the PSQ4D)	P = 0.0026	NS	NS	NS	NS	NS	P = 0.0004	

BMI, body mass index; NS, not significant; CRP, C-reactive protein; HbA1c, glycated haemoglobin; SBP, systolic blood pressure; DBP, diastolic blood pressure; PSQ4D, Primary Care Screening Questionnaire for Depression

Table 5 shows the participants' perceived needs; details are available in Supplementary 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.

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%	**78.4%**
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%	**77.5%**
8. Physical health	29.2%	9.5%	43.5%
9. Health care	3.5%	14.6%	**51.4%**
10. Distress	38.9%	37.1%	**57.2%**
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%	**50.0%**
15. Separation from family members	21.2%	9.5%	17.4%
16. Being displaced from home	6.2%	0.9%	10.1%
17. Information	**50.4%**	12.9%	**70%**
18. The way aid is provided	44.2%	18.1%	**75.4%**
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%	**67.4%**

22. Law and justice in your community	47.8%	49.1%	**75.4%**
23. Safety or protection from violence for women in your community	**51.3%**	42.2%	**68.1%**
24. Alcohol or drug use in your community	**92.0%**	**82.8%**	**96.4%**
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 Supplementary Material 2 for details).

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 community faced a high risk of obesity, while those of remote island communities 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 communities. 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, the causal relationship between the differences in health status found in this study and sea-level rise needs to be carefully considered. 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. All four items of the PSQ4D were related to four symptoms related to depression from *The ICD-10 Classification of Mental and Behavioural Disorders: Diagnostic Criteria for Research* and none of them was culture-specific.[18] Moreover, they yielded an incidence of depression

of about 30–60% amongst the study participants. 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%.[22] 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.[23] In light of this, the fact that about 30% of the people in villages such as Taro and Sasamunga reported symptoms of depression is indicative of the current situation wherein depression is more prevalent than the WHO's estimation. The high rate (about 60%) in Manuopo village can be attributed to a variety of stresses, as seen in the HESPER results. Nevertheless, the possibility of overestimation cannot be denied, given that even in developed countries, where detailed studies have been conducted, the incidence of depression is around 10%, and even among low-income groups, it is less than 20%.[24] Our results should, thus, be viewed as screening for risks of mental disorders rather than medical diagnoses of major depression.

In addition, our study design did not clear 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.[9] This high incidence is probably the result of a change from a traditional diet to a Western one, with an increased use of salt.[9, 25] 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.[6] 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.[8, 9, 26] 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 peri-urban people in terms of incidence of NCDs.[8, 9, 27] However, third and importantly, this study

found that Manuopo inhabitants showed a high risk of depressive conditions. Even though there is an assumption that people living in traditional societies are mentally healthy,[28] a wide range of mental health challenges were observed in communities in the aftermath of conflicts and disasters.[29] 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 of 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,[21] 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 survival fears such as those related to a shortage of food and other basic human needs. 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 (e.g. involuntary migration); however, only a few studies have investigated this factor in the South Pacific.[10,30] Interviews with 100 people from Tuvalu suggested that distress could result from either (a) local environmental impacts being caused or exacerbated by climate change or (b) hearing about global climate change and contemplating its future implications.[31] The present 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 mental disorders. This study also implied that incidence of mental disorders might be limited in places such as those equipped with employment, transportation, and communication infrastructure (e.g. Taro). However, 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.[27] 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.[9]

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 policymakers should develop climate action plans that are in harmony with the various environmental factors.

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Author contributions

TF conceived the project. TF, TI, TT, and FP designed the study. TF, FP, SG, TI, TT, and AS collected the data. TF performed the statistical analyses and wrote the manuscript draft. FP, SG, TI, TT, and AS read and made significant changes to the manuscript and produced this paper.

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Competing interests

None declared.

Patient consent for publication

Not required.

Ethical approval

This study was approved by the Solomon Islands Health Research and Ethics Review Board (HRE No. 013/16), Ministry of Health and Medical Services, Solomon Islands, as well as the Kyoto University Graduate School and Faculty of Medicine Ethics Committee (G0353), Graduate School of Asian and African Area Studies, Kyoto University.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

Data except for personal information are available on reasonable request.

Open access

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FIGURE LEGEND

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

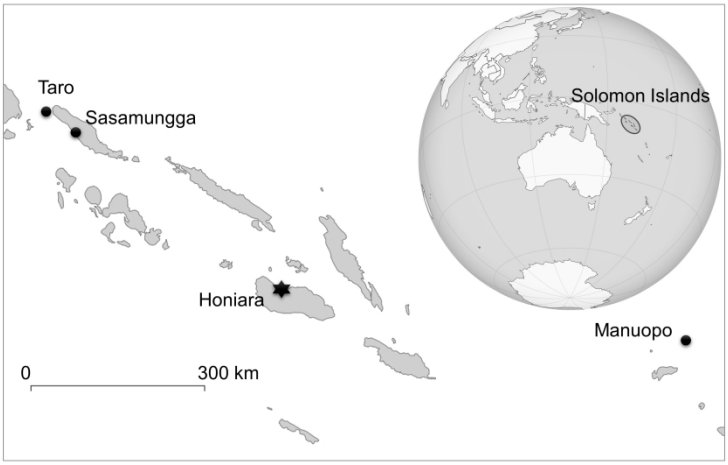

Figure 1. Map showing the communities selected in this research.

338x190mm (300 x 300 DPI)

Registration and Data Sheet

1. ID		2. Village			
3. Name	(Given name)	(Family name)	(Other)		
4. Name of Household Head					
5. Date of Birth	(Year)	(Month)	(Day)	6. Age	
7. Place of Birth	(Province)	(Town/village)	8. Did you immigrate into the present village? ☐ Yes → When did you start to live here? ☐ No (Year)		
9. Father's place of Birth	(Province)	(Town/village)			
10. Mother's place of Birth	(Province)	(Town/village)	10. Mother Language		
11. Gender	☐ Female→ ☐ Male	(If female) Are you pregnant?	☐ Yes (months)/ ☐ No		
		Are you giving *susu*?	☐ Yes / ☐ No		

If other member(s) from your household already replied the following items 12-18, please write the ID of that member(s) and skip to item 19.	ID of your household member, who already answered the following questions: if any.

12.	Do you/your household members make a garden (are you a farmer)?	☐Yes	☐No
	Do you have enough food to eat from your garden?	☐Yes	☐No
13.	Do you/your household members do fishing (including any methods)?	☐Yes	☐No
	Do you have enough food to eat from fishing?	☐Yes	☐No
14.	Are you/your household members employed by company/government/others?	☐Yes	☐No
15.	Do you/your household members run a business (e.g., store manager)?	☐Yes	☐No
16.	Do you have enough money to meet your needs?	☐Yes	☐No

17. What is your housing type? Choose ONE from the following list: (Answer)

(A) Traditional leaf house, (B) Western style house, (C) Traditional-Western-mix house
(D) Temporary house (e.g., tent), (E) Others (specify)

18. Please check ☑ all items that you or your household members own:

☐ Outboard motors/car/truck, ☐ Chainsaw, ☐ Mobile phone, ☐ Radio/Stereo, ☐ Video/DVD, ☐ Rainwater tank

19. Body temperature	°C	20. Do you feel ill now?	☐ Yes (how) / ☐ No
21. Did you take any medicine (including local herbal) over the last week?	☐ Yes → ☐ No	What? ( ) When? ( )	
22. Have you ever diagnosed as diabetes by a doctor?		☐ Yes (when) / ☐ No	
Do you take a drug/local herbal medicine for diabetes?		☐ Yes (what when) / ☐ No	
23. Have you ever diagnosed as hypertension by a doctor?		☐ Yes (when) / ☐ No	
Do you take a drug/local herbal medicine for hypertension?		☐ Yes (what when) / ☐ No	

Blood Pressure	SBP1	(mmHg)	SBP2	(mmHg)	SBP3	(mmHg)
	DBP1	(mmHg)	DBP2	(mmHg)	DBP3	(mmHg)

Height	(cm)	Weight	(kg)	Arm Circumference	(cm)
Triceps skinfold	(mm)	Subscapular skinfold	(mm)		

Malaria ICT	☐ Pf+ ☐ Pv+	☐ Nil	HbA1C	(%)	CRP	(mg/dL)

Do you want to know the results of Health Check-Ups? ☐Yes / ☐No

Supplementary Material 2. Cross-tabulation of the Humanitarian Emergency Settings Perceived Needs Scale (HESPER)

Question	Answer	Sasamungga	Taro	Manuopo	Pairwise comparisons: Holms method (P <0.05)
1. Drinking water	No	89	86	82	M > T, S
	Yes	24	28	52	
	Don't Know		1		
	Not Answered		1	21	
2. Food	No	101	106	81	M > T, S
	Yes	12	9	52	
	Don't Know			1	
	Not Answered		1	21	
3. Place to live in	No	104	110	110	M > T
	Yes	9	4	23	
	Don't Know		1	1	
	Not Answered		1	21	
4. Toilets	No	64	66	27	M > T, S
	Yes	49	49	105	
	Don't Know			2	
	Not Answered		1	21	
5. Keeping clean	No	100	108	95	M > T, S
	Yes	13	7	39	
	Not Answered		1	21	
6. Clothes, shoes, bedding, or blankets	No	104	106	88	M > T, S
	Yes	9	6	46	
	Don't Know		3		
	Not Answered		1	21	
7. Income or livelihood	No	91	88	27	M > T, S
	Yes	22	27	104	
	Don't Know			2	
	Not Answered		1	22	
8. Physical health	No	79	99	73	M > S > T
	Yes	33	11	60	
	Don't Know	1	5		
	Not Answered		1	22	
9. Health care	No	108	98	64	M > T > S
	Yes	4	17	68	
	Don't Know	1		1	

	Not Answered		1	22	
10. Distress	No	65	70	52	M > T, S
	Yes	44	43	79	
	Don't Know	4	2	2	
	Not Answered		1	22	
11. Safety	No	92	102	67	M > T, S
	Yes	20	13	66	
	Don't Know	1			
	Not Answered		1	22	
12. Education for your children	No	76	82	99	n.s.
	Yes	7	16	26	
	Don't Know	30	17	8	
	Not Answered		1	22	
13. Care for family members	No	80	86	88	M > T
	Yes	26	20	43	
	Don't Know	7	9	2	
	Not Answered		1	22	
14. Support from others	No	83	83	65	M > S, T
	Yes	27	27	68	
	Don't Know	3	5		
	Not Answered		1	22	
15. Separation from family members	No	56	68	79	n.s.
	Yes	24	11	24	
	Don't Know	33	36	30	
	Not Answered		1	22	
16. Being displaced from home	No	60	42	72	n.s.
	Yes	7	1	14	
	Don't Know	46	72	47	
	Not Answered		1	22	
17. Information	No	44	17	21	M > S, T
	Yes	57	15	88	
	Don't Know	12	83	16	
	Not Answered		1	30	
18. The way aid is provided	No	41	19	30	M > S, T
	Yes	50	21	101	
	Don't Know	22	75	2	
	Not Answered		1	22	
19. Respect	No	70	62	100	n.s.
	Yes	39	34	33	

19. Respect	Don't Know	4	19		
	Not Answered		1	22	
20. Moving between places	No	100	46	109	n.s.
	Yes	4	5	14	
	Don't Know	9	64	10	
	Not Answered		1	22	
21. Too much free time	No	80	77	44	M > S, T
	Yes	27	29	88	
	Don't Know	6	9	1	
	Not Answered		1	22	
22. Law and justice in your community	No	43	41	31	M > S, T
	Yes	54	57	100	
	Don't Know	16	17	2	
	Not Answered		1	22	
23. Safety or protection from violence for women in your community	No	43	59	43	M > T
	Yes	58	48	90	
	Don't Know	12	8		
	Not Answered		1	22	
24. Alcohol or drug use in your community	No	8	17	5	M > T
	Yes	104	95	128	
	Don't Know	1	3		
	Not Answered		1	22	
25. Mental illness in your community	No	69	63	77	n.s.
	Yes	37	45	53	
	Don't Know	7	7	3	
	Not Answered		1	22	
26. Care for people in your community who are on their own	No	60	60	68	n.s.
	Yes	43	37	63	
	Don't Know	10	18	2	
	Not Answered		1	22	

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,9
		(b) Indicate number of participants with missing data for each variable of interest	7,9
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11

		(*b*) Report category boundaries when continuous variables were categorized	8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-13
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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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, body mass index, and weight 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 (odds ratio = 1.13 [1.02, 1.27], P = 0.0189), and Manuopo inhabitants had a higher risk of depression (1.25 [1.08, 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.

ARTICLE SUMMARY

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.

Keywords: Sea-level Rise, Climate Change, Atoll, Non-communicable Diseases, Mental Health

INTRODUCTION

Human-induced climate change is now a real threat to human health and well-being.[1-3] The World Health Organization (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.[4] 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 food-, water-, and vector-borne diseases.[5] 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.[6] The 'loss of connection to a place and sense of belonging associated with displacement' (e.g. involuntary migration) also led to psychological stress.[6]

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.[7] 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,[8] 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.[9]

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 water and food, vector-borne diseases, zoonoses, respiratory illnesses, psychosocial ill-health, NCDs, population pressures, and health system deficiencies.[10]

Taro Island of the Solomon Islands is known to be one of the communities most vulnerable to a rise in sea level[11, 12] because it is much smaller than the other independent states in the South Pacific (e.g. 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 (a) identify important changes in disease incidence, health risk indicators, and health status; (b) determine whether these changes are likely to be the result of local, regional, or global environmental changes; (c) help develop countermeasures and assess their effectiveness, and (d) develop hypotheses about the potential health effects of climate change.[2]

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% 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.[13] 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).

[Figure 1 here]

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^2 [14] 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 Choiseul, approximately 2 km from Taro.[6] 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.[15] 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.[16] Manuopo has the largest population among the Reef Islands, with 1,030 inhabitants, and it has a clinic that serves as the local healthcare centre for the islands.[17]

Sasamungga is one of the biggest villages (of about 1,000 inhabitants) on the main island of Choiseul.[14] 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 2 US dollars) 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 1,000, 810, and 1,030, 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 (1 minus beta), with 90% under the condition to detect an odds ratio 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.

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 [a]	1,000	810	1,030
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]

n, number

[a] estimated population size, as cited in government reports.[13, 16]

Ethical approval

This study was approved by the Solomon Islands Health Research and Ethics Review Board (HRE No. 013/16), Ministry of Health and Medical Services, Solomon Islands, as well as the Kyoto University Graduate School and Faculty of Medicine Ethics Committee (G0353), Graduate School of Asian and African Area Studies, Kyoto University.

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^2) 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.[18] This questionnaire consists of the following four questions, and answering 'yes' to three or more questions is recognised as depression: (a) 'Have you been experiencing sadness or depressed mood during the last 2 weeks or longer?', (b) 'Have you been experiencing loss of interest or loss of pleasure in doing things during the last 2 weeks or longer?', (c) 'Have you been feeling excessively tired or without energy during the last 2 weeks or longer?', and (d) '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 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 ≥ 30 kg/m^2, malnutrition as BMI < 18.5 kg/m^2, hypertension as systolic blood pressure ≥ 140 mmHg over diastolic blood pressure ≥ 90 mmHg, diabetes as HbA1c level ≥ 6.5, inflammation as CRP level ≥ 1 mg/dL, and depressive mental state as ≥ 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 Supplementary 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.[19] 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-square 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.[20, 21] 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.[9,20] Missing data, if any, were excluded from each analysis. All statistical analyses were conducted using the R version 4.0.5 (The R Project for Statistical Computing), and $P < 0.05$ 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 2. Living environment and socioeconomic status of participating households (% in parentheses; n = 312)

	Sasamungga (N = 92)	Taro (N = 89)	Manuopo (N = 131)
Housing type			
a. % Traditional leaf	25 (30.6)	17 (18.8)	112 (85.5)
b. % Western style	58 (63.3)	60 (68.8)	13 (10.1)
c. % Traditional-Western mix	6 (6.12)	12 (12.5)	5 (3.6)
d. % 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

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 (i.e. inflammation measured by CRP levels) and malnutrition were observed among the three communities.

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

	Sasamungga (N = 113)	Taro (N = 116)	Manuopo (N = 155)	Village Comparison [a]
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^2	25.1 ± 0.5	27.8 ± 0.7	23.8 ± 0.5	T > S, M
BMI (female), kg/m^2	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

BMI, body mass index; NS, not significant; M, Manuopo; S, Sasamungga; T, Taro

[a] Tukey's test for multiple comparison ($P < 0.05$)

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

Table 4. Logistic regression analyses estimates for the risk factors of communicable and non-communicable diseases: odds ratio (95% confidence interval)

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^2
	Taro	Manuopo						
Communicable diseases/malnutrition								
Malnutrition	1.02	1.01	1.02	1.00	0.99	1.00	0.97	
(BMI of < 18.5 kg/m^2)	[0.98, 1.05]	[0.97, 1.04]	[0.99, 1.05]	[0.999, 1.001]	[0.96, 1.03]	[0.986, 1.008]	[0.91, 1.02]	0.025
	NS	NS	NS	NS	NS	NS	NS	
Inflammation	0.96	0.96	0.97	1.00	0.98	1.02	1.04	
(CRP level of ≥1 mg/dL)	[0.90, 1.02]	[0.90, 1.01]	[0.92, 1.02]	[0.999, 1.003]	[0.92, 1.04]	[0.999, 1.038]	[0.94, 1.14]	0.035
	NS	NS	NS	NS	NS	NS	NS	
Non-communicable diseases								
Obesity	0.92	1.13	0.80	1.00	1.1	1.02	1.17	
(BMI ≥ 30 kg/m^2)	[0.82, 1.03]	[1.02, 1.27]	[0.73, 0.88]	[0.999, 1.005]	[0.99, 1.22]	[0.98, 1.05]	[0.99, 1.34]	0.158
	NS	P = 0.0189	P <0.0001	NS	NS	Ns	NS	
Diabetes	0.99	1.04	0.99	1.00	0.99	1.00	1.00	
(HbA1c level of ≥ 6.5%)	[0.95, 1.03]	[0.998, 1.081]	[0.96, 1.03]	[0.999, 1.002]	[0.95, 1.03]	[0.99, 1.02]	[0.94, 1.06]	0.02
	NS	NS	NS	NS	NS	NS	NS	
Hypertension	0.90	0.93	0.96	1.01	1.04	0.99	0.79	
(SBP ≥ 140 mmHg/	[0.82, 0.99]	[0.85, 1.02]	[0.89, 1.04]	[1.008,1.013]	[0.95, 1.14]	[0.96, 1.02]	[0.68, 0.91]	0.189
DBP ≥ 90 mmHg	P = 0.0493	NS	NS	P <0.0001	NS	NS	P = 0.015	
Mental status								
Depressive	1.25	1.02	0.93	1.00	1	0.97	1.46	
(≥ 3 items positive for	[1.08, 1.44]	[0.90, 1.16]	[0.84, 1.05]	[0.996, 1.003]	[0.88, 1.15]	[0.93, 1.01]	[1.19, 1.80]	0.091
the PSQ4D)	P = 0.0026	NS	NS	NS	NS	NS	P = 0.0004	

BMI, body mass index; NS, not significant; CRP, C-reactive protein; HbA1c, glycated haemoglobin; SBP, systolic blood pressure; DBP, diastolic blood pressure; PSQ4D, Primary Care Screening Questionnaire for Depression

Table 5 shows the participants' perceived needs; details are available in Supplementary 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.

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%	**78.4%**
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%	**77.5%**
8. Physical health	29.2%	9.5%	43.5%
9. Health care	3.5%	14.6%	**51.4%**
10. Distress	38.9%	37.1%	**57.2%**
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%	**50.0%**
15. Separation from family members	21.2%	9.5%	17.4%
16. Being displaced from home	6.2%	0.9%	10.1%
17. Information	**50.4%**	12.9%	**70%**
18. The way aid is provided	44.2%	18.1%	**75.4%**
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%	**67.4%**

22. Law and justice in your community	47.8%	49.1%	**75.4%**
23. Safety or protection from violence for women in your community	**51.3%**	42.2%	**68.1%**
24. Alcohol or drug use in your community	**92.0%**	**82.8%**	**96.4%**
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 Supplementary Material 2 for details).

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 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%.[22] 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%.[23] 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.[24] 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.[9] This high incidence is probably the result of a change from a traditional diet to a Western one, with an increased use of salt.[9, 25] 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.[6] 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.[8, 9, 26] 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 peri-urban people in terms of incidence of NCDs.[8, 9, 27] 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,[28] a wide range of mental health challenges were observed in communities in the aftermath of conflicts and disasters.[29] 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,[29] 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 (e.g. involuntary migration); however, only a few studies have investigated this factor in the South Pacific.[10,30] Interviews with 100 people from Tuvalu suggested that distress could result from either (a) local environmental impacts being caused or exacerbated by climate change or (b) hearing about global climate change and contemplating its future implications.[31] The present 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 (e.g. 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.[27] 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.[9]

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 policymakers should develop climate action plans that

are in harmony with the various environmental factors.

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Author contributions

TF conceived the project. TF, TI, TT, and FP designed the study. TF, FP, SG, TI, TT, and AS collected the data. TF performed the statistical analyses and wrote the manuscript draft. FP, SG, TI, TT, and AS read and made significant changes to the manuscript and finalised this paper.

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Competing interests

None declared.

Patient consent for publication

Not required.

Ethical approval

This study was approved by the Solomon Islands Health Research and Ethics Review Board (HRE No. 013/16), Ministry of Health and Medical Services, Solomon Islands, as well as the Kyoto University Graduate School and Faculty of Medicine Ethics Committee (G0353), Graduate School of Asian and African Area Studies, Kyoto University.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data availability statement

Data except for personal information are available on reasonable request.

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FIGURE LEGEND

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

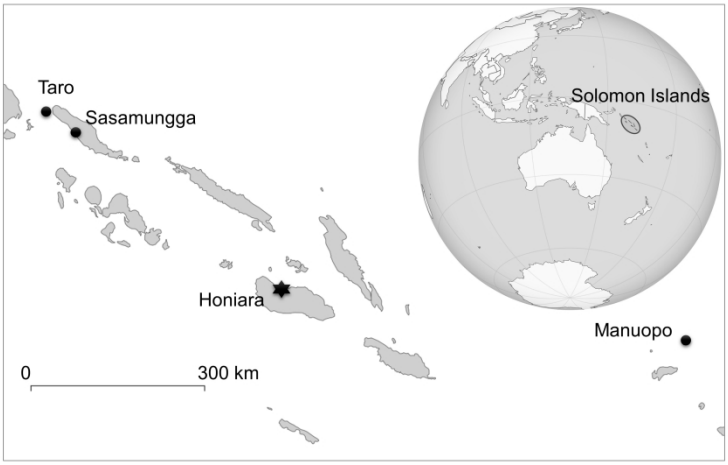

Figure 1. Map showing the communities selected in this research.

338x190mm (300 x 300 DPI)

Registration and Data Sheet

1. ID		2. Village			
3. Name	(Given name)	(Family name)	(Other)		
4. Name of Household Head					
5. Date of Birth	(Year)	(Month)	(Day)	6. Age	
7. Place of Birth	(Province)	(Town/village)	8. Did you immigrate into the present village? ☐ Yes → When did you start to live here? ☐ No (Year)		
9. Father's place of Birth	(Province)	(Town/village)			
10. Mother's place of Birth	(Province)	(Town/village)	10. Mother Language		
11. Gender	☐ Female→ ☐ Male	(If female) Are you pregnant?	☐ Yes (months)/ ☐ No		
		Are you giving *susu*?	☐ Yes / ☐ No		

If other member(s) from your household already replied the following items 12-18, please write the ID of that member(s) and skip to item 19.		ID of your household member, who already answered the following questions: if any.	
12.	Do you/your household members make a garden (are you a farmer)?	☐Yes	☐No
	Do you have enough food to eat from your garden?	☐Yes	☐No
13.	Do you/your household members do fishing (including any methods)?	☐Yes	☐No
	Do you have enough food to eat from fishing?	☐Yes	☐No
14. Are you/your household members employed by company/government/others?		☐Yes	☐No
15. Do you/your household members run a business (e.g., store manager)?		☐Yes	☐No
16. Do you have enough money to meet your needs?		☐Yes	☐No
17. What is your housing type? Choose ONE from the following list:		(Answer)	
(A) Traditional leaf house, (B) Western style house, (C) Traditional-Western-mix house (D) Temporary house (e.g., tent), (E) Others (specify)			
18. Please check ☑ all items that you or your household members own: ☐ Outboard motors/car/truck, ☐ Chainsaw, ☐ Mobile phone, ☐ Radio/Stereo, ☐ Video/DVD, ☐ Rainwater tank			

19. Body temperature	°C	20. Do you feel ill now?	☐ Yes (how) / ☐ No
21. Did you take any medicine (including local herbal) over the last week?	☐ Yes → ☐ No	What? ( ) When? ( )	
22. Have you ever diagnosed as diabetes by a doctor?		☐ Yes (when) / ☐ No	
Do you take a drug/local herbal medicine for diabetes?		☐ Yes (what when) / ☐ No	
23. Have you ever diagnosed as hypertension by a doctor?		☐ Yes (when) / ☐ No	
Do you take a drug/local herbal medicine for hypertension?		☐ Yes (what when) / ☐ No	

Blood Pressure	SBP1	(mmHg)	SBP2	(mmHg)	SBP3	(mmHg)	
	DBP1	(mmHg)	DBP2	(mmHg)	DBP3	(mmHg)	

Height	(cm)	Weight	(kg)	Arm Circumference	(cm)
Triceps skinfold	(mm)	Subscapular skinfold	(mm)		

Malaria ICT	☐ Pf+	☐ Pv+	☐ Nil	HbA1C	(%)	CRP	(mg/dL)

Do you want to know the results of Health Check-Ups? ☐Yes / ☐No

Supplementary Material 2. Cross-tabulation of the Humanitarian Emergency Settings Perceived Needs Scale (HESPER)

Question	Answer	Sasamungga	Taro	Manuopo	Pairwise comparisons: Holms method (P <0.05)
1. Drinking water	No	89	86	82	M > T, S
	Yes	24	28	52	
	Don't Know		1		
	Not Answered		1	21	
2. Food	No	101	106	81	M > T, S
	Yes	12	9	52	
	Don't Know			1	
	Not Answered		1	21	
3. Place to live in	No	104	110	110	M > T
	Yes	9	4	23	
	Don't Know		1	1	
	Not Answered		1	21	
4. Toilets	No	64	66	27	M > T, S
	Yes	49	49	105	
	Don't Know			2	
	Not Answered		1	21	
5. Keeping clean	No	100	108	95	M > T, S
	Yes	13	7	39	
	Not Answered		1	21	
6. Clothes, shoes, bedding, or blankets	No	104	106	88	M > T, S
	Yes	9	6	46	
	Don't Know		3		
	Not Answered		1	21	
7. Income or livelihood	No	91	88	27	M > T, S
	Yes	22	27	104	
	Don't Know			2	
	Not Answered		1	22	
8. Physical health	No	79	99	73	M > S > T
	Yes	33	11	60	
	Don't Know	1	5		
	Not Answered		1	22	
9. Health care	No	108	98	64	M > T > S
	Yes	4	17	68	
	Don't Know	1		1	

	Not Answered		1	22	
10. Distress	No	65	70	52	M > T, S
	Yes	44	43	79	
	Don't Know	4	2	2	
	Not Answered		1	22	
11. Safety	No	92	102	67	M > T, S
	Yes	20	13	66	
	Don't Know	1			
	Not Answered		1	22	
12. Education for your children	No	76	82	99	n.s.
	Yes	7	16	26	
	Don't Know	30	17	8	
	Not Answered		1	22	
13. Care for family members	No	80	86	88	M > T
	Yes	26	20	43	
	Don't Know	7	9	2	
	Not Answered		1	22	
14. Support from others	No	83	83	65	M > S, T
	Yes	27	27	68	
	Don't Know	3	5		
	Not Answered		1	22	
15. Separation from family members	No	56	68	79	n.s.
	Yes	24	11	24	
	Don't Know	33	36	30	
	Not Answered		1	22	
16. Being displaced from home	No	60	42	72	n.s.
	Yes	7	1	14	
	Don't Know	46	72	47	
	Not Answered		1	22	
17. Information	No	44	17	21	M > S, T
	Yes	57	15	88	
	Don't Know	12	83	16	
	Not Answered		1	30	
18. The way aid is provided	No	41	19	30	M > S, T
	Yes	50	21	101	
	Don't Know	22	75	2	
	Not Answered		1	22	
19. Respect	No	70	62	100	n.s.
	Yes	39	34	33	

19. Respect	Don't Know	4	19		
	Not Answered		1	22	
20. Moving between places	No	100	46	109	n.s.
	Yes	4	5	14	
	Don't Know	9	64	10	
	Not Answered		1	22	
21. Too much free time	No	80	77	44	M > S, T
	Yes	27	29	88	
	Don't Know	6	9	1	
	Not Answered		1	22	
22. Law and justice in your community	No	43	41	31	M > S, T
	Yes	54	57	100	
	Don't Know	16	17	2	
	Not Answered		1	22	
23. Safety or protection from violence for women in your community	No	43	59	43	M > T
	Yes	58	48	90	
	Don't Know	12	8		
	Not Answered		1	22	
24. Alcohol or drug use in your community	No	8	17	5	M > T
	Yes	104	95	128	
	Don't Know	1	3		
	Not Answered		1	22	
25. Mental illness in your community	No	69	63	77	n.s.
	Yes	37	45	53	
	Don't Know	7	7	3	
	Not Answered		1	22	
26. Care for people in your community who are on their own	No	60	60	68	n.s.
	Yes	43	37	63	
	Don't Know	10	18	2	
	Not Answered		1	22	

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-8
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	7
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,9
		(b) Indicate number of participants with missing data for each variable of interest	7,9
Outcome data	15*	Report numbers of outcome events or summary measures	9-10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-11

		(*b*) Report category boundaries when continuous variables were categorized	8
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-13
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.