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Original article

Bacterial contamination of drinking water and nutritional quality of diet in the areas of the western Solomon Islands devastated by the April 2, 2007 earthquake/tsunami

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Abstract: On 2nd April 2007, at 7:40 local time (20:40 GMT 1 April), a massive earthquake, the epicenter of which was 10 km deep and 45 km south-southeast of Gizo, the provincial capital of the Western Province, struck the Solomon Islands, killing 52 people and displacing approximately 5,000. This study, based on field research in May 2007, reports on the result of the cross-sectional assessment of the bacterial contamination (*E. coli*, *Vibrio* spp. and total bacteria) of drinking water and water sources and the longitudinal comparison of dietary intake and epidemiology in six earthquake- and tsunami-affected villages in the Western Province, Solomon Islands. The test-paper method revealed that 92.0% of drinking-water was unsafe in four camps of evacuated people. Only 3 out of 11 drink-water samples collected from safe water sources were free from contamination throughout the study villages. The reported occurrence of diarrhea, while only 7.6 per mil in 2001 and 4.8 per mil in 2003 in one of the study villages, was 12.7 person-days per mil after the disaster in 2007. Deterioration of dietary intakes was not observed. Although further studies are expected to follow up on the changes in water, diet, and health in mid- and long-term recovery operations, the rapid assessment suggested the need to provide safe water or purifiers and education regarding water and hygiene-related management in order to minimize health risks in devastated villages.
Keywords: tsunami, bacterial contamination, water, dietary intake, diarrhea

INTRODUCTION

On 2nd April 2007, at 7:40 local time (20:40 GMT 1 April), a massive earthquake, the epicenter of which was 10 km deep and 45 km south-southeast of Gizo, the provincial capital of the Western Province, struck the Solomon Islands [1]. This earthquake and the related tsunami and landslides killed 52 people, displaced approximately 5,000, wrecked 3,150 houses, and left behind an affected population of 24,059 from 4,276 households in the Western and Choiseul Provinces [2]. The damage was greatest for the dwellers in Gizo town and the neighboring peri-urban villages in Ghizo Island, followed by fishing-horticulturalists on islands in the two provinces. In the devastated areas, the people took refuge on mountain ridges, since houses and infrastructure, including water supply and storage, hygiene, and subsistence tools (canoes, agriculture tools, etc.), were destroyed.

National, international, and non-governmental efforts were made to deliver relief goods, with priority given to securing safe drinking water (provision of clean water, purifiers, and containers) and ensuring adequate dietary intake (with rice, biscuits, and noodles) [3-6]. While a survey reported that sufficient food was provided within the same month [7], appeals for food relief continued on the local basis. Severe outbreaks of infectious diseases went unreported, but there was an increasing risk of communicable diseases due to the delayed recovery of broken water systems, and degraded hygiene [3, 8]. Several scientific research projects on natural mechanisms [9-11] and emergency aid and recovery efforts [3, 8] have been made; however, few studies have been conducted on the living conditions of the people.

In May 2007, the authors surveyed the devastated villages for the social aspects of the disaster, such as response and recovery processes [12]. During these visits, the bacteriological quality of drinking water and water sources were assessed. In addition, dietary habits and epidemiological conditions were also surveyed in one of the villages where

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one of the authors (TF) had collected comparable data since 2001, in the pre-disaster period.

This study reports on the result of the cross-sectional assessment of the bacterial contamination of drinking water and water resources and the longitudinal comparison of dietary intake and epidemiology in the earthquake- and tsunami-affected villages in the Western Province, Solomon Islands.

STUDY SITES

The Solomon Islands are in the early stages of economic development, and their PPP (purchasing power parity) GNI per capita of 1,520 international dollars in 2002 was lower than the average for the low-income countries in the region [13]. Most of the rural villagers, who accounted for 84% of the total population, depended on fishing and horticulture and irregular cash earnings from activities such as selling marine resources, marketing crops, and engaging in temporary waged labor at the logging camp [14]. On the other hand, due to the progress of urbanization, the dwellers in the urban areas—i.e., the national capital of Honiara, the provincial capital of Gizo in the Western Province and Auki in Malaita Province—relied on income from waged labor, or on employment as public servants, store managers or food purchasers for stores and markets. A water supply (purified water collected from the inner mountains) and toilets were available in parts of some towns, while drinking water was collected from rainwater tanks (galvanized steel or fiberglass), or non-purified water supplied from mountain pools, springs or rivers in other areas. The water collected from a source was usually stored in a kettle or plastic (PET) bottle at home; however, the plastic containers newly provided in relief operations were also used in the devastated areas. Rainwater was also collected in used iron oil drums. Pit-hole toilets in the peri-urban and mangrove and coastal areas in rural villages, respectively, were used as latrines. A health report issued by the Ministry of Health and Medical Services [15] showed that watery and bloody diarrhea occurred at a rate of 51 and 5 cases per 1000 population, respectively, in the Western Province in 2006 — the year before the earthquake (note that there was no report suggesting ethnic differences of water-borne infectious diseases in the province).

The earthquake wrecked houses in Ghizo Island, while the tsunami wreaked havoc on Ghizo, Simbo, and other islands in the Western Province and Choiseul Province, and large landslides occurred in the western parts of Ranongga Island (Figure 1). With a land area of 5,279 km^2, the Western Province had 62,739 people, 94.5% of whom were indigenous Melanesians—the customary land owners—while 3.5% were immigrant Micronesians: landless fishermen settled on governmental land [16]. The Micronesians were migrants from the over-populated Gilbert Islands (Kiribati) who came over in the 1960s [17-19]. Out of 52 deaths, 33, including at least 29 Micronesians, occurred on Ghizo Island, followed by 11 on Simbo Island. The Micronesians settlements were unfortunately located on coasts facing the epicenter. International, governmental, and non-governmental relief operations were also based in Gizo town, although the nearby town of Munda was the center for cargo transportation when the Gizo airfield was closed. A state of

Table 1. Descriptions of the study villages 1.5 months after the April 2 earthquake and tsunami

Village name	Titiana	Niu Manda	Tapurai	Mondo	Dunde	Olive
Island name	Ghizo	Ghizo	Simbo	Ranongga	New Georgia	New Georgia
Modernity [a]	High	High	Low	Low	High	Low
Major effects	Tsunami	Tsunami	Tsunami	Landslides	Earthquake/sea-level rise	Earthquake/sea-level rise
Population [b]	370	280	300	600	1065	365
No. of deaths	10	9	7	2	0	0
Current settlement	Camp on a mountain ridge	Camp on a mountain ridge	Camp in Rupe village: Nearby settlement	Camp on a mountain ridge	Not changed (approximately 10 households lived in the camp on a mountain ridge)	Not changed
Main source of drinking water before disaster	Piped water supply (purified) and rainwater tank	Piped water supply (purified) and rainwater tank	Piped water supply from inner mountain spring	Piped water supply from inner mountain spring	Piped water supply (purified) and rainwater tank	Spring, river and rainwater tank
Source of drinking water after disaster	River stream	River stream	Piped water supply from inner mountain spring	Spring	Piped water supply (purified) and rainwater tank	Spring, river and rainwater tank

[a] Modernity was subjectively assessed according to the authors' observation of housing styles, distance from town, existence of schools, and main economic activities.

[b] Population figures are based on interviews with village representatives in Titiana, Niu Manda, Tapurai, and Mondo, and a census by one of the authors (TF) in Dunde and Olive in 2003.

emergency was declared on the 2nd day of the disaster. On April 5th, a team from the United Nations Disaster Assessment and Coordination (UNDAC) arrived in Honiara, and a regular Stakeholder Meeting began to organize the activities of the NDC (National Disaster Council) of the Solomon Islands, NGOs, local societies, and national and provincial governments. From April 14th, the focus of operations shifted from emergency relief to recovery [3, 8, 12]. The government issued a Recovery Action Plan to solicit donors for mid- to long-term recovery [2]. During the emergency operation, water purifiers were sent to the devastated villages [3], but most of them were gone by May. The authors did not observe the use or storage of purifiers during their field visits.

This study was conducted from May 20th to 28th 2007 in Titiana and Niu Manda villages, both of which were Gilbertese settlements on Ghizo Island, Tapurai in Simbo, Mondo in Ranongga, Dunde, and Olive on New Georgia Island. Among these, Titiana (population: approximately 370), Niu Manda (280), and Tapurai (300) were totally washed away by the tsunami, and all villagers took refuge on higher ground or in a nearby settlement (hereafter referred to as a “camp”) (Table 1; Figure 1). Mondo village (600) was partly destroyed by landslides, and all the villagers established their camp in the inner mountains where horticultural gardens had been located. In Dunde (1,065), which is a coastal peri-urban village nearby Munda townships, approximately 50 villagers from 10 households were still taking shelter on the mountain ridge during the survey period. However, the others had already begun to lead an ordinary life in the original coastal settlements. Olive Village (365), which is a rural coastal village, was affected by

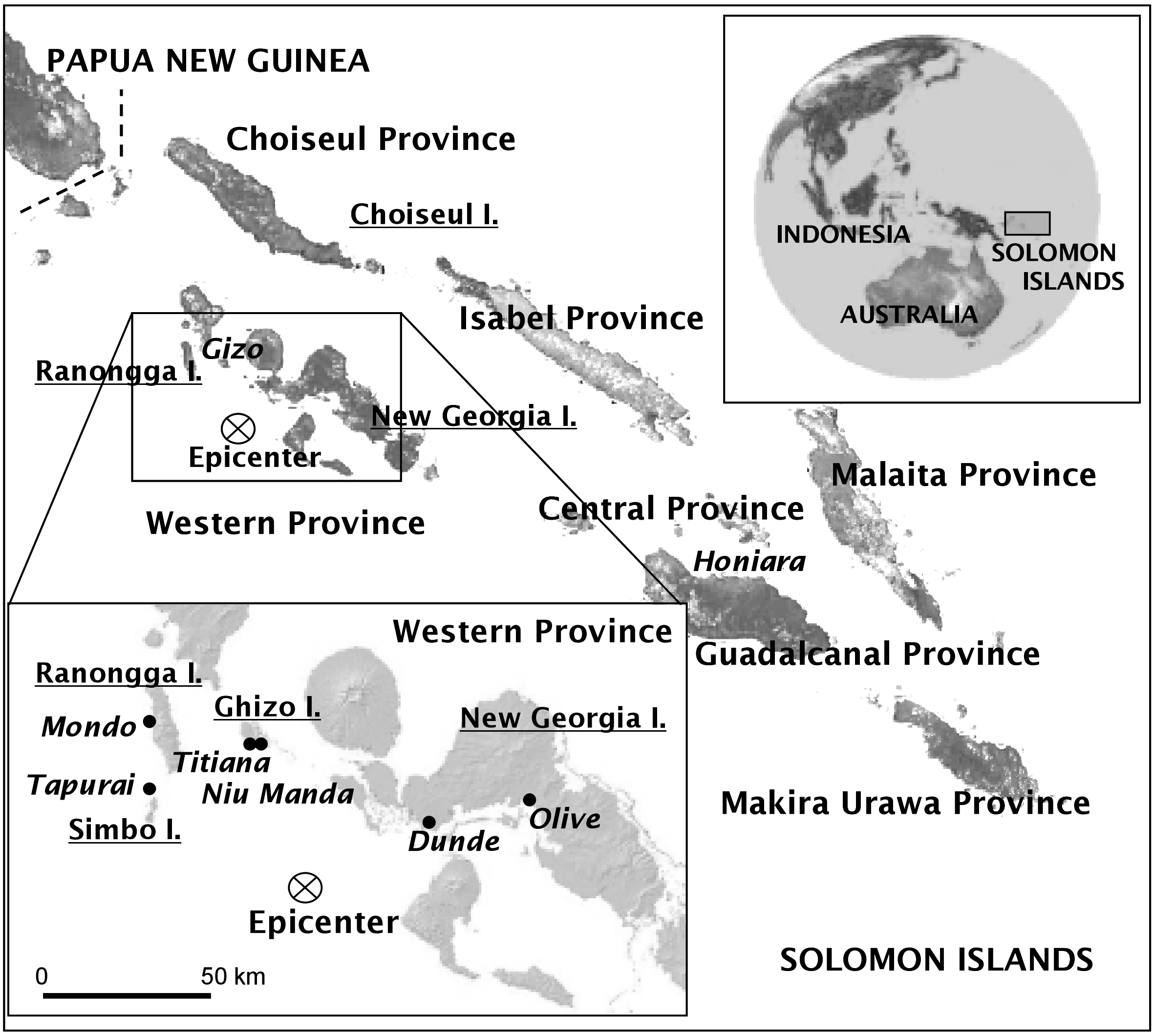

Figure 1. Locations of epicenter (indicated by ⊗) and study villages (indicated by •) in the Western Province, Solomon Islands (The map was compiled from data available at GLCF (Global Land Cover Facility, University of Maryland, USA)).

a strong earthquake and a slow rise in sea level, but none of the villagers changed settlement location without first taking shelter on the mountain. The Olive villagers stayed in the settlement for approximately one week without engaging in subsistence or other activities because, as remote villagers, they did not have information on the situation. They were provided with blankets, rice, biscuits, noodles, and sugar. Since one of the authors (TF) had considerable experience of research in Olive village since 2001, he stayed for five days in Olive collecting data on water, dietary habits, and epidemiology for longitudinal comparison. In addition, he also spent one day in Dunde, but only a limited number of water samples were collected in this period. All of the authors visited the remaining four villages to collect water samples during the two-day period.

METHODS

In each village, all villagers were invited to participate in the research. TF visited the houses of the villagers who were willing to participate. The bacteriological quality of the water was analyzed by the test-paper method in the field [20-23]. Water running from the mouth of plastic water containers (17 in number in total), PET-plastic bottles (17), and kettles (11) in participants' houses and that from the tap of galvanized steel rainwater tanks (9), fiberglass rainwater tanks (4), and outside-public water-supply (4), as well as iron drums (4), springs (3), river (1), and cement rainwater tank (1) was directly absorbed in three types of Suncoli test-paper (Sun Chemicals Ltd., Tokyo, Japan): Bacteria Detection Paper, Coliform Detection Paper X-Type, and Vibrio Detection Paper. These test papers are qualitative filters modified as miniaturized versions of plate count method devices. They are designed to enumerate total colonies at 36 ± 1 ℃ for 24 ± 2 h. The count obtained with the Bacteria Detection Paper is the indicator of bacterial and heterotrophic quality in any form. Colonies of less than 100 per 1 ml water is the criterion for safe drinking water defined in the Japanese standard (Water Supply Law) [24]. Coliform Detection Paper X-Type was modified to enumerate *Escherichia coli* as well as the total of coliform bacteria that indicate human and animal fecal contamination. Since the coliform group contains various forms of bacteria, including non-toxic and non-fecal ones, the absence of *E. coli* is the Japanese and World Health Organization's (WHO's) standard for drinking water [24, 25]. Vibrio Detection Paper was used to detect *Vibrio* spp. such as *V. parahaemolyticus*, *V. alginolyticus*, and *V. fluvialis*. *Vibrio* spp. has not been included in water quality standards, but the test paper for it was also used to indicate unsafe water because this type of bacteria is halophilic and a major cause of food poisoning. It should be noted that these test papers, which were adopted to count the number of colonies in a 1 ml sample instead of using the standard selective-agar medium according to the original protocol [26], were applicable to conditions in the field, where detailed laboratory analyses were unavailable [20, 21, 23]. The accuracy of these detection papers compared with standard methods range between 93.3% and 80.6-92.6% for coliform and bacteria, respectively, according to the information provided by Sun Chemicals Ltd. [27].

In Olive, 19 males and 34 females from 22 households volunteered to participate in the interview survey. Each participant was asked to report whether he or she had experienced diarrhea and/or illnesses related with gastrointestinal conditions, and, if yes, for how many days after the disaster. To avoid potential bias, the participants were advised that their answers would have no influence on official relief operations or the provision of drugs. The summary of the situation was later reported to the health authority (Solomon Islands Malaria Training and Research Institute), which then took action for appropriate medical check-ups and care in August 2007. In 2001 and 2003, every evening for 42 days (in 2001) or 28 days (in 2003), voluntary participants were asked to report all illnesses and related treatments [28, 29]. They were also asked to report the names and amounts of all food items consumed during the last 24-hour period, and their energy (MJ), protein (g), and fat (g) intake were calculated using each participant's daily food consumption record, in tandem with food value tables for the Pacific region [30, 31]. The amount of marine resources protein (reef and pelagic fishes, crustaceans, and mollusks) consumed was calculated, and food items regularly eaten by villagers were measured directly to estimate average food consumed. It should be noted that the 24-hour recall method is a reliable and time-saving method for assessing dietary intake, since the authors had sufficient data from direct measurement in previous years [32, 33].

RESULTS

Table 2 shows the bacteriological quality of drinking water broken down by the type of storage (plastic container, plastic bottle, and kettle) and source (river, water supply, steel rainwater tanks, fiberglass rainwater tanks, and used iron drums). Plastic containers and relief (purified) water were provided by UNICEF and other organizations, although the relief water containers were mostly empty in the study period. In camps for Titiana and Niu Manda villagers, all drinking water was river water that was stored in plastic containers provided by UNICEF. Out of 14 drinking water samples in these two camps, only 2 were classified as safe

Table 2. Bacteriological quality of drinking water in the earthquake- and tsunami-devastated areas, broken down by village, type of storage, and source

Village	Storage	Source	N	No. of samples			
				Safe water	*E. coli* positive	*Vibrio* spp. positive	Total bacteria ≥100 colonies/ml
Titiana							
	Container[a]	River	6	0	6	2	2
Niu Manda							
	Container[a]	River	8	2[b]	6	1	2
Tapurai							
	Plastic bottle	Public water supply	7	0	7	1	3
Mondo							
	Kettle	River	1	0	1	0	1
	Container[a]	Public water supply	3	0	3	0	1
Dunde							
	Plastic bottle	Steel tank	1	0	0	1	0
Olive							
	Plastic bottle	Iron drum	3	0	3	1	2
	Plastic bottle	Cooking pot	1	0	1	0	1
	Plastic bottle	Fiberglass tank	3	1	2	0	1
	Plastic bottle	Steel tank	2	0	2	0	0
	Kettle	Iron drum	1	0	1	0	1
	Kettle	River	1	0	1	0	1
	Kettle	Fiberglass tank	1	0	1	0	0
	Kettle	Steel tank	7	3	4	0	1
Total			45	6	38	6	16

[a] Container provided by UNICEF in relief operation.
[b] One out of 2 samples judged safe was positive for coliform bacteria.

drinking water; all the others were found to be contaminated with *E. coli*. (the indicator for fecal contamination), and one of the "safe" samples was positive for total coliform. *Vibrio* spp. was also detected in 3 samples. The villagers of Tapurai in Simbo Island depended on an inland spring for their water supply. This supply was available in Rupe village where they settled. The Mondo villagers on Ranongga Island depended on river water and on water brought in containers and kettles. All the samples from these two villages were contaminated with *E. coli* and therefore deemed unsafe due to the possibility of human or animal fecal contamination. Therefore, a total of 92.0% of 25 samples collected in camps were found to be unsafe. Sampling in Dunde was limited: only 1 drinking water sample showed a positive reaction for *Vibrio* spp. The water used by the Olive villagers, who were less affected by the disaster than the five other study villages, was also contaminated with *E.coli* and other bacteria, except for 4 samples (21.1%). Three samples were from water stored in kettles and one from water in a plastic bottle.

The authors sampled water from 17 sources in Olive, 6 in Dunde, 2 in Tapurai, and 1 in Mondo. Due to the isolation of water sources from the settlement, none of the sources in the camps of Titiana and Niu Manda was examined. The villagers in these two camps reported that they collect water from the river, because the government water supply was unavailable during the study period. The running water supply system of Tapurai village was contaminated with *E. coli* and other bacteria (Table 3). The river water that Mondo villagers began using as a drinking source was safe. In Dunde, a peri-urban village, water sources, which included steel rainwater tanks, fiberglass rainwater tanks, and the public water supply, were safe—except for non-disinfected water supply and a cement rainwater tank which was first installed during World War II. Several village informants reported that they repaired and cleaned their own rainwater tanks and common water supply sources in cooperation with the water authority after the disaster, since the tanks, as well as the water supply pipes, suffered damage during the earthquake. One water supply source, which had not yet been disinfected, was contaminated with *E. coli* in Dunde. In Olive, 64.7% (11/17) of samples from water sources were unsafe; however, 4 (57.1%) out of 7 steel rainwater tanks were safe while 2 out of 3 samples from fiber-

Table 3. Bacteriological quality of water sources in the earthquake- and tsunami-devastated villages, broken down by type

	Source type	N	Safe	*E. coli*	*Vibrio* spp	Total bacteria >100
Titiana	N.A.					
Niu Manda	N.A.					
Tapurai						
	Public water supply	2	0	2	0	1
Mondo						
	River	1	1	0	0	0
Dunde						
	Steel rainwater tank	2	2	0	0	0
	Public water supply	2	1	1	0	0
	Fiberglass rainwater tank	1	1	0	0	0
	Cement rainwater tank	1	0	1	0	0
Olive						
	Steel rainwater tank	7	4	3	0	0
	Fiberglass rainwater tank	3	1	2	0	1
	Spring	3	0	2	1	0
	Iron drum	4	1	3	2	3
Total		26	12	25	7	9

glass rainwater tanks were contaminated with *E. coli*. Throughout the study villages, 6 (66.7%) out of 9 steel rainwater tank samples were safe, while only 4 (23.5%) out of 17 samples from other sources were safe, suggesting significant differences (Fisher's exact test: p = 0.0461).

Although not tabulated, comparisons between sources and drinking water were performed for 30 storage samples, sources of which were also tested in this study. As a result, 11 drinking water samples were identified as having been collected from a water source judged safe. However, only 3 drinking water samples were judged safe, while 7 were contaminated with *E. coli* and 1 with *Vibrio* spp., suggesting contamination during collection and storage. Total bacteria with more than 100 colonies were also detected from 2 out of 7 *E. coli*-positive samples.

Table 4 shows the occurrence of diarrhea and other gastrointestinal disorders in Olive. It is noted that gastrointestinal disorders included stomach ache (*sigiti tia* in the local Rovianan language), vomiting (*lua*), and other illnesses with local names (*malaria tia*, *tuku ibibu*, *lagu hite*, *popome*, *mateana tia*). Since local terms did not distinguish watery and bloody diarrhea, the two types of diarrhea were included in one [28]. As shown in the table, out of the 2,597 person-days of 53 participants, the occurrence of diarrhea accounted for 12.7 per mil after the disaster in 2007, while it had been only 7.6 per mil in 2001 and 4.8 per mil in 2003. The occurrence of other gastrointestinal disorders (e.g., stomach ache) in 2007 was at the same level as that in 2001 and 2003. Table 5 shows the energy and nutrient intakes of Olive villagers. Males and females respectively consumed an average of 9.78 and 9.91 MJ of energy, 63.6 and 50.4 g of protein, 31.5 to 16.4 g of protein per day coming from marine resources. Since the average body weight of adult males and females aged 30-60 years was 66.5 kg and 59.9 kg, respectively, energy requirements at the moderate activity level (physical activity level = 1.78) [34] and safe levels of protein intake (0.75 g kg body weight) [35] were 12.0 and 9.8 MJ of energy and 49.9 and 44.9 g of pro-

Table 4. Longitudinal comparison of the prevalence of diarrhea and other gastrointestinal disorders, calculated based on interviews, in Olive village in 2001, 2003, and 2007[a]

	2001 June-July	2003 August	2007 May
No. of participants	53	53	53
Average age	38.7±14.6	39.4±15.2	45.0±16.4
Total person-days	2226	1456	2597
Occurrence (ill person days per mil)			
Diarrhea	7.6	4.8	12.7
Other gastrointestinal disorders [b]	13.5	15.1	15.4

[a] See Furusawa [28, 29] for detailed methods in 2001 and 2003.

[b] Gastrointestinal disorders included stomachache (*sigiti tia* in the local Roviana language), vomiting (*lua*), and other illnesses with local names (*malaria tia*, *tuku ibibu*, *lagu hite*, *popome*, *mateana tia*) [28].

Table 5. Energy and macro nutrient intakes of Olive villagers in May 2007[a b]

	Male	Female
No. of participants	19	34
Energy (MJ)	9.78 ± 1.28	9.91 ± 1.02
Energy consumed from local foods (MJ)	5.15 ± 1.11	5.27 ± 1.03
Protein (g)	63.6 ± 13.0	50.4 ± 6.5
Protein consumed from local marine foods (g)	31.5 ± 8.9	16.4 ± 4.4
Fat (g)	30.7 ± 6.9	24.6 ± 4.3

[a] Since the average body weights of adult males and females aged 30-60 years were 66.5 kg and 59.9 kg, respectively, in Olive, energy requirements at the moderate activity level (physical activity level = 1.78) [34] and safe levels of protein intake (0.75 g kg body weight) [35] were 12.0 and 9.8 MJ of energy, and 49.9 and 44.9 g of protein for males and females, respectively.
[b] Aswani and Furusawa [32] showed that in 2001 and 2005, males respectively consumed 8.54 and 11.43 MJ of energy, 62.2 and 61.9 g of protein, and 33.2 and 28.9 g of marine proteins, while females consumed 8.67 and 10.33 MJ, 66.8 and 56.2 g of protein, and 36.1 and 27.9 g of marine protein on an average day.

tein for males and females, respectively. In addition, Aswani and Furusawa [32] showed that, in 2001 and 2005, males consumed 8.54 and 11.43 MJ of energy, 62.2 and 61.9 g of protein, and 33.2 and 28.9 g of marine proteins, while females consumed 8.67 and 10.33 MJ, 66.8 and 56.2 g of protein, and 36.1 and 27.9 g of marine proteins on an average day. Except for the low-level energy intake of males and decreased intake of marine protein by females, local resources were sufficient to supply a substantial proportion of dietary intake.

DISCUSSION

The rapid assessment of the bacteriological quality of drinking water and water sources showed that the villagers in the earthquake- and tsunami-devastated areas relied on water potentially contaminated with fecal components and other bacteria, and had limited access to safe water sources. In addition, even if a water source was free from bacteria, the water was contaminated with bacteria during collection and storage. This is supported by the fact that the prevalence of diarrhea increased after the disaster even in a village that suffered little damage. On the other hand, the villagers did not suffer from severe deterioration in dietary intakes. Therefore, they were experiencing difficulty in securing water resources rather than food.

The high degree of contamination of water sources in Olive suggested that the low quality of water was a chronic rather than an emergent problem in the rural Solomon Islands, despite the fact that the situation became worse after the disaster, probably because human waste in mangroves and coastal areas contaminated villagers' houses and water storage as the sea level rose. To resolve chronic problems, efforts should be made to increase accessibility to safe water sources and/or purification and to improve hygiene. Also, more attention must be paid to the problem of contamination during collection and in storage. The steel rainwater tanks were less contaminated than other sources. The reason for this is unclear, but possible explanations are (1) strong sunlight increased the temperature to a level sufficient to disinfect the inside of a tank during the absence of water, and (2) the steel tank was used for a shorter time than fiberglass tanks, so that the risk of infection was relatively low. The steel tanks were similar in price with or cheaper than fiberglass ones but lasted for a shorter time (5-10 years as opposed to 10-15 years) mainly because salty winds hastened rust erosion in the Solomon Islands coastal villages. Since the safety of rainwater tanks remained controversial, more important is that the villagers should be encouraged to regularly clean the inside of tanks and connecting pipes (personal communication from Mr. Jack Filiomea, Principal Engineer of Rural Water Supply and Sanitation Program, Ministry of Health and Medical Services) and the authority to provide the local villagers with appropriate knowledge on cleaning and necessary purifying materials. The easiest method for purification, boiling, was rarely practiced (i) because of the long time and heavy labor required for collecting the fuel wood necessary for boiling, and (ii) because of the people's preference for cold water. Cooling water after boiling was less frequently practiced because the villagers do not have extra containers and were unwilling to wait for the extended time of boiling and cooling. *Vibrio* spp. occurrence was considered to be related to settlement locations on the coast and the reliance of villagers on marine resources. This may indicate the potential occurrence of cholera (*V. cholera*), although no cholera outbreak has been reported.

Although interpretations of dietary intake were controversial, the total intake was sufficient considering the differences in patterns between males and females. The male energy intake was also low in 2001, and energy and nutrient intakes from local resources were usually half of the total intake [32, 36]. However, it has also been pointed out that the impact of the tsunami may be reflected in micronutrients such as vitamins rather than macronutrients [7]. In addition, the impact was assumed to be more critical for the landless immigrant Gilbertese of Titiana and Niu Manda villages. These villagers, who also resided in the neighboring areas of Gizo town, received support when it came to the provision of food, and had access to purchasable foods in towns. Hence, they did not seem to face food scarcity during the study period [12]. However, an extended period of refuge may affect long-term food production and availability. Therefore, follow-ups and detailed surveys were required to make conclusions regarding the effects on dietary intake.

In previous reports from other areas, people in devastated areas on the islands of Sumatra and Sri Lanka were provided with sufficient amounts of drinking water, purifiers, and other medical care after the 2004 Indian Ocean Earthquake [37, 38]. However, in the case of the Solomon Islands, villagers in very remote areas (e.g., Simbo Island) insisted that the amount of relief goods provided was insufficient [12]. It was also observed that villagers with easy access to towns such as Munda and Gizo were provided with relief goods even if the damage their community suffered was minimal, suggesting inequality in goods distribution. In addition, there is a possibility that the low death toll had reduced the scale of international relief operation and affected the distribution of necessary items.

CONCLUSIONS

This study was important in the sense of reporting the bacterial contamination of drinking water and quality of dietary intakes, which were the most basic needs of the people in the devastated areas. The following conclusions were drawn: (1) 92% and 80% of drinking water in the camps and villages, respectively, were judged unsafe, (2) in total, only 38% of water sources tested were judged safe while (3) 66.7% of water sampled from steel rainwater tanks was safe, (4) diarrhea prevalence increased after the disaster even in a village that suffered little damage, and (5) the villagers had moderately sufficient dietary intakes. However, two weaknesses of this study were that longitudinal data were not available for severely devastated villages, and that water and dietary surveys covered only a limited number of samples and participants. Although these were unavoidable because of the uncontrollable nature of the disasters and the instability of the situation during the relief period, the results were potentially biased. Psychological effects, especially among children, were also reported as major health problems in all villages, although they were not included in this study.

In summary, this study suggests the need for the provision of safe water or purifiers, education regarding water, and hygiene-related management in order to minimize water-borne diseases in devastated villages in the short term. Since the occurrence of earthquakes and tsunamis is on the increase in islands in Southeast Asian and Melanesian subsistence societies, this suggestion is applicable to such societies. Further studies are expected to follow up on the changes in water, diet, health, and other aspects of life during mid- and long-term recovery operations.

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