I Introduction

The Federated States of Micronesia (FSM) is composed of approximately 600 small islands lying just above the equator in the Western Pacific, and consists of four states (Yap, Chuuk, Pohnpei, and Kosrae; Fig. 1). Chuuk State, the most populated (48,654 persons as of the 2010 census) state of the FSM (Government of the Federated States of Micronesia, 2014), is composed of approximately 100 islands, 43 of which are inhabited. Chuuk State is characterized by a wet, warm, and humid climate, with temperatures of 24–31°C, relative humidity of 78–87%, and average annual rainfall of approximately 3,800 mm (Chuuk Branch Statistics Office, 2002). Chuuk Atoll, the center of the State, contains six large volcanic islands and many smaller ones. Weno Island is the capital and commercial center of Chuuk State, containing most of the state government offices and an airport on the northwest coast.

Prior to the 1950s, the people of the FSM ate a traditional diet based on staple starchy crops and marine resources. Murai (1954) surveyed the diet of one household on Udot Island, Chuuk Atoll, for 8 days during June to October 1951, and reported that the household consumed breadfruit and local marine resources eight times in 8 days but rice and canned fish only once during the same period. After the United States Department of...
Agriculture commenced a supplementary feeding program in the 1960s, the traditional diet began to be replaced by a modern diet rich in rice, flour, sugar, and other imported or processed foods (Englberger et al., 2003). This phenomenon accelerated after a Compact of Free Association was signed between the FSM and the United States in 1986 (Hezel, 2004). Since then, the FSM has faced serious public health problems, including obesity, diabetes mellitus (Nomura et al., 2005), and vitamin A deficiency (Lloyd-Puryear et al., 1991), in Chuuk State.

Under these circumstances, several food consumption surveys were conducted to reveal the dietary patterns of the FSM people in the 2000s. For example, a 7-day Food Frequency Questionnaire (7-day FFQ) was conducted on Pohnpei Island from January to March 2004 (Corsi et al., 2008); on Pohnpei Island in 2005 and 2007 (Kaufer, 2008); on Pohnpei, Mokil, and Pingelap islands in September 2008 (Kawai et al., 2010); and on Yap, Falalop, and Fais islands in November 2008 (Kawai et al., 2011). These studies targeted the very short term; however, Murai (1954) pointed out the importance of studying dietary patterns over a full year.

Yamamoto et al. (2015a) conducted a 12-month food consumption survey from September 2012 to August 2013 on Piis-Paneu Island, Chuuk State, which revealed that the dietary patterns on Piis-Paneu Island seemed to be basically traditional, with the addition of modern food, rather than lying between traditional and modern. Moreover, an 18-month survey from August 2012 to January 2014 was carried out on Pingelap Island, Pohnpei State, by Yamamoto et al. (2015b) who found that the dietary patterns on Pingelap Island were rather traditional due to limited access to Pohnpei Island, where various and many imported foods are sold. These studies are groundbreaking as food consumption surveys in terms of targeting ≥ 1 year; however, annual fluctuations in food consumption have not been monitored. Therefore, in the present study, data on household food consumption at every meal for 5 years were gathered to understand annual fluctuations in food consumption on Piis-Paneu Island, Chuuk Atoll, Chuuk State, the FSM.

II Study Site and Data Collection

Piis-Paneu Island, located on the ring reef of Chuuk Atoll (Fig. 1), is < 1 km² in area. The whole island lies just above sea level, and houses are scattered throughout the island with three patches of puna (Cyrtosperma merkusii) at the center of the island. About 45 households reside on the island, which has a population of approximately 320. The average income surveyed in 2013 was approximately USD 8,000 per year (Yamamoto
et al., 2015a). The people cultivate breadfruit, banana, root and tuber crops, coconut, and several kinds of fruits and vegetables; they also raise pigs, dogs, and poultry on the island. Marine resources are available from the sea around the island as well as from eight surrounding uninhabited islands without permission (Fig. 1). Although Piis-Paneu Island is the most distantly inhabited island from Weno Island on Chuuk Atoll, it takes 1 hour to travel from Piis-Paneu Island to Weno Island in a small boat with an outboard motor. Therefore, people living on Piis-Paneu Island frequently visit Weno Island to shop, sell marine resources, and go to school or work.

One household was selected to survey dietary patterns based on the average family size and income. Questionnaires were distributed to explore the foods consumed at every meal, as follows: starchy staples (rice, breadfruit, banana, and *puna*), marine resources (fresh fish, dried fish, canned fish, and others), meat (fresh and canned), and others (instant noodles and vegetables). The frequency of consumption of each item per month was
calculated as follows: Frequency (%) = \( \frac{\text{total number of meals at which an item was consumed}}{\text{total number of meals in 1 month}} \times 100 \). Data on food consumption were collected from September 2013 to December 2017. Data for January–August 2013 were referred from Yamamoto et al. (2015a).

During the survey period, a huge typhoon (Category 5 intensity on the Saffir-Simpson Hurricane Scale) hit Piis-Paneu Island at the end of March 2015. Some people took refuge from the strong winds and high waves in a school building. Huge high waves hit the southern part of the island twice; several houses were completely destroyed, whereas others were partially destroyed. Many breadfruit trees were toppled and barely standing. The banana and citrus trees were also damaged, but the coconut trees were not. After the typhoon, the United States Agency for International Development, the International Organization for Migration (IOM), Japan, and other countries and regions expressed support for Chuuk State. The IOM started a rationing program on Piis-Paneu Island in May 2015, and 3,000 pounds of rice, 90 gallons of vegetable oil, and 1,000 cans of corn per month were sent to the island. The program terminated in February 2016. Thus, the difference in food consumption between before and after the typhoon as well as the rationing program are the focus of this study.

### III Results and Discussion

#### 1. Starchy staples

The annual average frequencies of consuming particular foods in one household on Piis-Paneu Island during 2013–2017 are shown in Table 1. The frequency of consuming imported rice did not fluctuate greatly annually, ranging from 61.3% to 100% per month before the typhoon (Fig. 2). After the typhoon, rice was equally distributed to all villagers by foreign aid from May 2015 to February 2016. Therefore, the household consumed rice almost every day at every meal during that time. After the rationing program was terminated, rice consumption returned to a level close to that before the typhoon hit.

The frequency of breadfruit consumption ranged from 16.1 to 77.4% per month before the typhoon, partly due to the seasonality of breadfruit, but became significantly lower after the typhoon (Table 1 and Fig. 2). The frequency of breadfruit consumption in 2015 and 2016 seemed to be slightly higher in September and December 2015 and June to September 2016 compared to the other months after the typhoon, but the frequency was still much lower than the normal level. The frequency of breadfruit consumption in 2017 reached the normal level from June to August and in December, but the annual 2017
average was still half the average in 2013 and 2014. These results reveal that the typhoon had a large negative impact on the production of breadfruit on Piis-Paneu Island, and the frequency of breadfruit consumption did not return to a normal level even 3 years after the typhoon.

The frequency of banana consumption in 2015 became significantly lower after the typhoon, although less damage occurred to banana plants compared to breadfruit trees (Fig. 2). The household did not have to eat bananas because they had sufficient rice supplied by foreign aid. In 2016, the frequency of eating bananas returned to normal partly because of the faster recovery of banana production compared to breadfruit. The frequency of banana consumption increased in 2017. The frequencies of *puna* consumption in 2015, 2016, and 2017 increased slightly compared to those in 2013 and 2014 probably due to the lack of breadfruit and bananas after the typhoon (Fig. 2).

Fig. 2. Frequencies (%) of consuming starchy staples (rice, breadfruit, banana, and *puna* (*Cyrtosperma merkusii*)) in one household on Piis-Paneu Island during 2013–2017 (data from January 2013 to August 2013 were taken from Yamamoto *et al.* [2015a]).
Sudo (1983) reported that the ratio of breadfruit use to that of total starchy crops is extremely high on Chuuk Atoll. However, Yamamoto et al. (2015a) discovered that bananas and puna may be consumed more often when breadfruit is less available during the off-season on Piis-Paneu Island. A similar result was reported by Yamamoto et al. (2015b) that the consumption of bananas and C. merkusii tends to increase when breadfruit consumption is low on Pingelap Island. Therefore, after the rationing program was terminated, the people of Piis-Paneu Island tended to eat more bananas and puna because of an insufficient supply of breadfruit.

Corsi et al. (2008) reported starch consumption (days/week) on Pohnpei Island in 2004 (7-day FFQ, 1 count/day): imported rice 6.5 ± 1.4, breadfruit 2.8 ± 2.2, banana 2.9 ± 2.3, and giant swamp taro (C. merkusii) 0.5 ± 1.0. Kaufer (2008) reported similar results (days/week) on Pohnpei Island in 2005 and 2007 (7-day FFQ, 1 count/day): imported rice 6.8 and 4.1, breadfruit 4.0 and 3.8, banana (white-fleshed) 2.9 and 2.9, and taro and giant swamp taro 0.2 and 0.9, respectively. Although it is difficult to compare these results to the present results, as they did not survey every meal, the consumption of rice was similar on Pohnpei Island and Piis-Paneu Island. In contrast, the consumption of breadfruit, bananas, and puna (giant swamp taro), or local starchy staples was much greater on Piis-Paneu Island than on Pohnpei Island.

2. Marine resources

The frequency of consuming marine resources did not fluctuate greatly annually; the 5-year average was highest for fresh fish (78.9%), followed by dried fish (36.6%), canned fish (19.6%), and other marine resources (8.8%). The frequencies of fresh and dried fish consumption ranged from 47.3% to 100% and 7.5% to 75.3% per month, respectively, during the survey (Fig. 3), suggesting that the monthly variation in consumption of these foods was much greater than the annual variation. Canned fish tended to be consumed when the household did not have fresh fish and/or dried fish. Moreover, the consumption of canned fish depended on the household income (Yamamoto et al., 2015a). Other marine resources such as sea turtle, octopus, and squid were consumed occasionally.

According to Corsi et al. (2008), the frequencies of consuming local fish and seafood and imported fish and seafood (probably mainly canned fish) on Pohnpei Island in 2004 were 4.8 ± 2.3 and 2.4 ± 1.9 days/week, respectively. Kaufer (2008) also reported the consumption of marine resources on Pohnpei Island in 2005 and 2007: local fish 3.9 and 4.2 days/week and imported fish 2.4 and 2.7 days/week, respectively. The frequency of consuming local marine resources (fresh fish, dried fish, and other marine resources) ranged
from 111.3% to 135.6% per year in the household on Piis-Paneu Island during 2013–2017, indicating that the consumption of local marine resources is much greater on Piis-Paneu Island than on Pohnpei Island. In contrast, the consumption of canned fish (19.6%, 5-year average) on Piis-Paneu Island was lower than that on Pohnpei Island.

3. Meat and other

The frequency of fresh meat consumption was much lower than marine resources on Piis-Paneu Island (Table 1). The household consumed imported fresh meat (mainly chicken) only if income allowed. Local animals such as pigs, dogs, and poultry were seldom consumed. The frequency of consuming fresh meat in December of each year during the survey period was consistently high (Fig. 4), as the household prepared fancy meals for the
Christmas season. Canned meat was rarely consumed by the household on the island during this survey. Local meat and imported meat were consumed $1.3 \pm 1.6$ and $1.9 \pm 2.1$ days/week, respectively, on Pohnpei Island in 2004 (Corsi et al., 2008), 1.5 and 1.7 days/week in 2005, and 1.1 and 2.6 days/week in 2007 (Kaufer, 2008). The consumption of total

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**Table 1. Annual average consumption frequencies of particular foods in one household on Piis-Paneu Island during 2013−2017**

|                          | 2013 | 2014 | 2015 | 2016 | 2017 | Five-year average |
|--------------------------|------|------|------|------|------|-------------------|
|                          | n=1092 | n=1095 | n=1092 | n=1062 | n=1077 |                 |
| **Starchy staples**      |       |       |       |       |       |                   |
| Rice, imported           | 92.3  | 91.8  | 92.5  | 98.5  | 97.6  | 94.5             |
| Breadfruit, local        | 43.7  | 43.2  | 20.7  | 8.2   | 21.5  | 27.5             |
| Banana, local            | 29.3  | 20.3  | 7.9   | 23.7  | 51.5  | 26.5             |
| *puna (Cyrtosperma merkusii)*, local | 11.8  | 11.9  | 13.7  | 12.2  | 13.7  | 12.7             |
| **Marine resources**     |       |       |       |       |       |                   |
| Fresh fish, local        | 69.1  | 76.6  | 87.0  | 74.7  | 87.2  | 78.9             |
| Dried fish, local        | 37.8  | 50.7  | 29.2  | 26.0  | 39.2  | 36.6             |
| Canned fish, imported    | 27.6  | 13.4  | 22.3  | 18.6  | 16.2  | 19.6             |
| Others, local            | 9.2   | 8.3   | 10.9  | 10.6  | 5.0   | 8.8              |
| **Meat**                 |       |       |       |       |       |                   |
| Fresh total              | 27.1  | 19.1  | 9.3   | 13.4  | 10.9  | 16.0             |
| Local                    | 2.4   | 1.8   | 0.2   | 0.5   | 0.7   | 1.1              |
| Imported                 | 24.7  | 17.4  | 9.2   | 12.9  | 10.2  | 14.9             |
| Canned, imported         | 0.5   | 0.0   | 0.0   | 0.1   | 0.3   | 0.2              |
| **Others**               |       |       |       |       |       |                   |
| Instant noodle, imported | 48.5  | 33.6  | 37.2  | 28.5  | 20.3  | 33.6             |
| Vegetable total          | 0.7   | 1.1   | 3.7   | 3.4   | 0.2   | 1.8              |
| Local                    | 0.7   | 1.1   | 3.7   | 3.4   | 0.2   | 1.8              |
| Imported                 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0              |

*1: Frequency (%) = (total number of meals at which an item was consumed/total number of meals in 1 month) × 100.

*2: Data from Jan. 2013 to Aug. 2013 were referred from Yamamoto et al. (2015a).

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**Fig. 4. Frequencies (%) of consuming of fresh meat and instant noodles in one household on Piis-Paneu Island during 2013−2017**

(data from January 2013 to August 2013 were taken from Yamamoto et al. [2015a]).
meat, including fresh and canned (16.2%, 5-year average), on Piis-Paneu Island was less than half that on Pohnpei Island.

Instant noodles are popular in Micronesia, and the annual frequency of consuming instant noodles ranged from 20.3% to 48.5% (33.6%, 5-year average) on Piis-Paneu Island (Table 1). The household on Piis-Paneu Island consumed more instant noodles compared to the two households on Pingelap Island (22.5% and 9.9%, respectively, 18-month average; Yamamoto et al. 2015b). The consumption of flour products on Pohnpei, which cannot be directly compared with the results of this study, was 3.5 ± 2.6 days/week in 2004 (Corsi et al., 2008), 4.1 days/week in 2005, and 5.0 days/week in 2007 (Kaufer, 2008). These results indicate that the consumption of flour products was lower on Piis-Paneu Island than on Pohnpei Island. Local vegetables such as chaia (Cnidoscolus chayamansa), pene (Thespesia populnea), pumpkin fruit, and tonga (Benincasa hispida) were consumed occasionally, but the frequency of consuming vegetables was low. However, there is a possibility that the household did not mention vegetables on the questionnaire because of the small amount of vegetables consumed, including buds and leaves of sweet potato and imported garlic and onions. Thus, the real consumption levels of vegetables were higher than indicated.

VI Conclusions

This study revealed that a huge typhoon had a large negative impact on crop production, particularly breadfruit, on a small island in Micronesia, and the frequency of breadfruit consumption did not return to normal for almost 3 years after the typhoon. If foreign aid had not implemented the rationing program, the people of Piis-Paneu Island would have run short of food due to the insufficiency of breadfruit and bananas. So-called famine foods such as Alocasia macrorrhizos and Tacca leontopetaloides are available on Piis-Paneu Island, but some younger people do not know how to prepare those foods. It is clearly necessary to manage these food plants consciously and to pass traditional knowledge of famine foods to the next generation as a precaution for food shortages caused by typhoons or other natural disasters.

The dietary patterns on Piis-Paneu Island are rather traditional compared to those on Pohnpei Island, the center of Pohnpei State and the home of the FSM capital city Kolonia; the consumption of local starchy staples and local marine resources is much greater; and the consumption of canned fish, imported meat, and flour products is lower. These results are consistent with the “center-periphery” hypothesis for Micronesia
proposed by Kawai et al. (2010, 2011), which states that the closer an island is to an urban
center, the more globalized that island becomes; islands further from the center remain
more traditional. This 5-year study agrees with Yamamoto et al. (2015a), suggesting that
the dietary patterns of the people on Piis-Paneu Island are basically traditional with added
modern foods even after a typhoon hit the island during the survey. It is suspected that
public health problems are related to dietary intake and/or the combination of meals
rather than traditional or modern food. Quantitative food consumption data should be col-
lected over the long-term to analyze public health problems in the FSM.

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Long-Term Food Consumption Survey on Piis-Paneu Island, Chuuk State, the Federated States of Micronesia

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keywords: banana, breadfruit, ethnobotany, puna (Cyrtosperma merkusii), typhoon

Piis-Paneu Island, located on the ring reef of Chuuk Atoll, Chuuk State, the Federated States of Micronesia (FSM), is the most distantly inhabited island in Chuuk Atoll from Weno Island, the capital and commercial center of Chuuk State. A 5-year food consumption survey was conducted on Piis-Paneu Island to reveal annual fluctuations in food consumption and to understand the effects of a typhoon on dietary patterns on a small island. The huge typhoon had a devastating impact on the production of some crops, especially breadfruit, on the island, and the frequency of breadfruit consumption did not return to a normal level even 3 years after the typhoon. It is necessary to manage famine food, such as Alocasia macrorrhizos and Tacca leontopetaloides, or naturalized plants on each island, and to pass traditional knowledge of these plants to the next generation as a precaution for food shortages caused by typhoons or other natural disasters. The dietary patterns on Piis-Paneu Island are traditional compared to those on Pohnpeian Island, the center of Pohnpei State and home of the FSM capital city Kolonia; the consumption of local starchy staples and local marine resources is much greater, while the consumption of canned fish, imported meat, and flour products is lower. This 5-year study confirms that the dietary patterns on Piis-Paneu Island remain traditional with the addition of modern food, even though a typhoon hit the island during the survey.