Analysis on the Damage, Vulnerability and Correlation with Temperature caused by Heat Waves in Jeju Province(Korea), And Heat Wave Impact Based Forecast and Warning Service(HIBFWS)

Kiyunghee Park, Youngbum Kang and Sanghyun Kim

Jeju Regional Office of Meteorology(JROM), Korea Meteorological Administration (e-mail of S. Kim : shkim13@korea.kr)

1. Introduction

- In recent years, human and economic damage has been caused annually due to extreme high temperatures in the summer, and the scale of the damage is increasing.
- In Korea, extreme heat waves are occurring every summer, and the number of people suffering from heat-related illnesses is increasing every year.
- In this study analyzed correlation between excess mortality and daily T max in August when the hottest month in Jeju, during past 10 years(2009-2018).
- Also JROM provides HIBFWS by analyzing the vulnerability and exposure of heat waves in Jeju.

2. Patients by Heat Wave and Heat Wave Days in Jeju

- The most severe heat wave in Jeju was in 2013, with 53 days(T max≧33℃). From 2016, it has occurred for more than 30 days each year.
- The number of people with heat-related illnesses was the highest at 109 in 2016, with the number of patients also increasing along with the increase in the number of days of the heat wave.
- The analysis of 456 patients from 2011 to 2018 showed the largest number of patients at daily T max of 33℃
- In addition, the number of patients with the duration of the temperature was the highest at the beginning of the temperature between 33°C and 35°C, but the number of patients decreased rapidly as the heat wave days longer.
- On the other hand, the incidence of patients is relatively small in the beginning at below 33°C, but the longer the period, the more steadily the patient occurs.
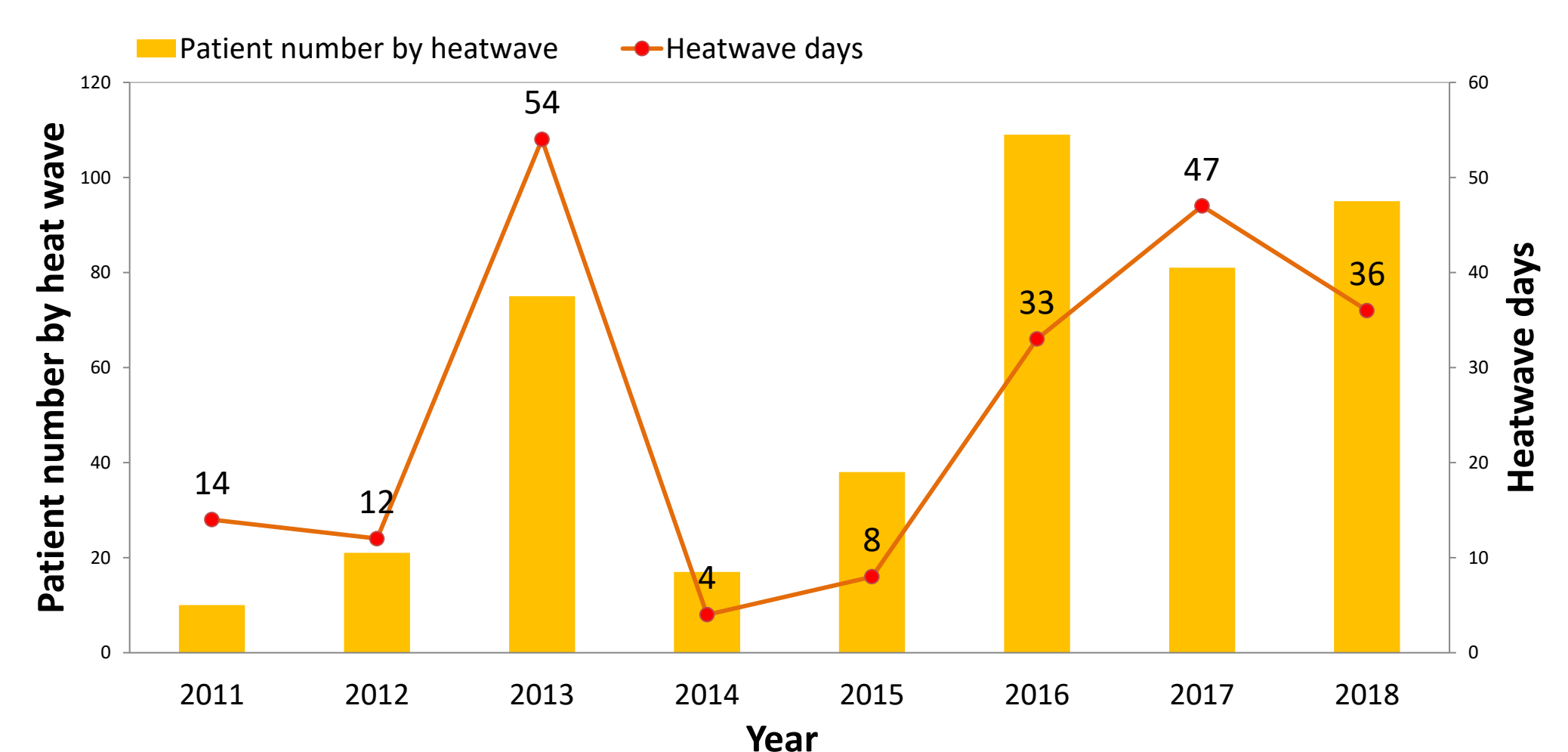

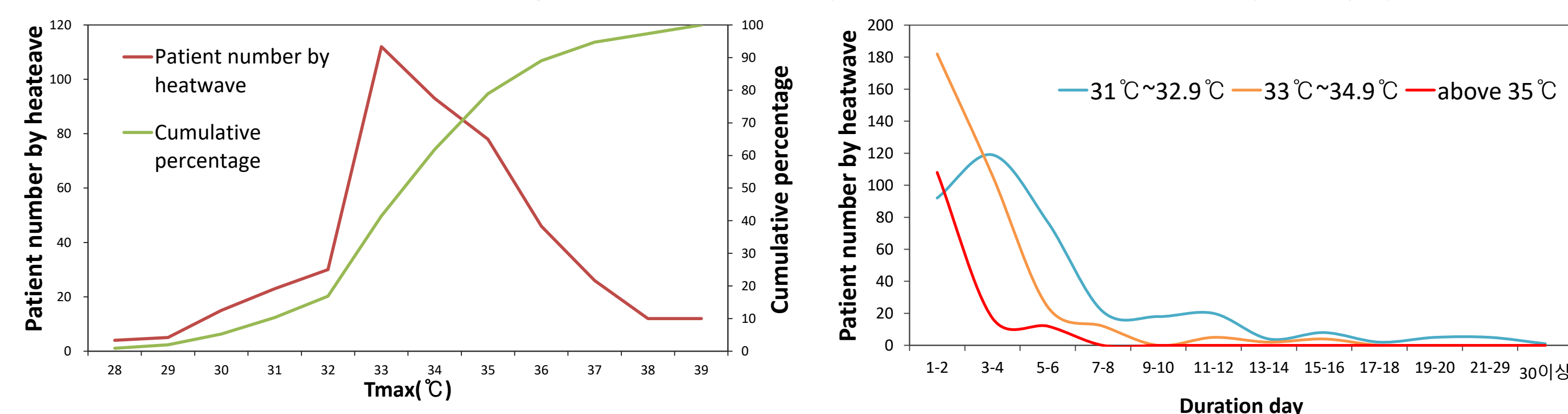Fig.1. Patent number by heat wave and heat wave days in Jeju province

Fig.2. (L) Patient number by T max(℃), (R)Patent number by duration day of each temperature range

3. Excess Mortality Analysis(2008-2017)

① Excess mortality
- The excess mortality is total deaths minus expected deaths. Expected deaths occurs differently depending on the specific year, day, and day of week.(Jung *et al.* 2014).
- The following is the formula for seeking the excess mortality.(Im and Lee, 2016)

$$M_0(y,d) = M_{av} \times W_d(d) \times W_w(y,d) \times W_y(y)$$
$$M_c = M_t - M_0(y,d)$$

$M_0(y,d)$: Expected deaths at y-year and d-day
M_{av} : Average deaths
$W_d(d)$: Daily weight
$W_w(y,d)$: Weekly weight
$W_y(y)$: Annual weight
M_c : Excess mortality
M_t : Total deaths

② Result
- Temperatures used daily T max(℃) , T average(℃) and T anomaly(℃) temperatures, and only showed cases where excess mortalities were more than standard deviation of the average.

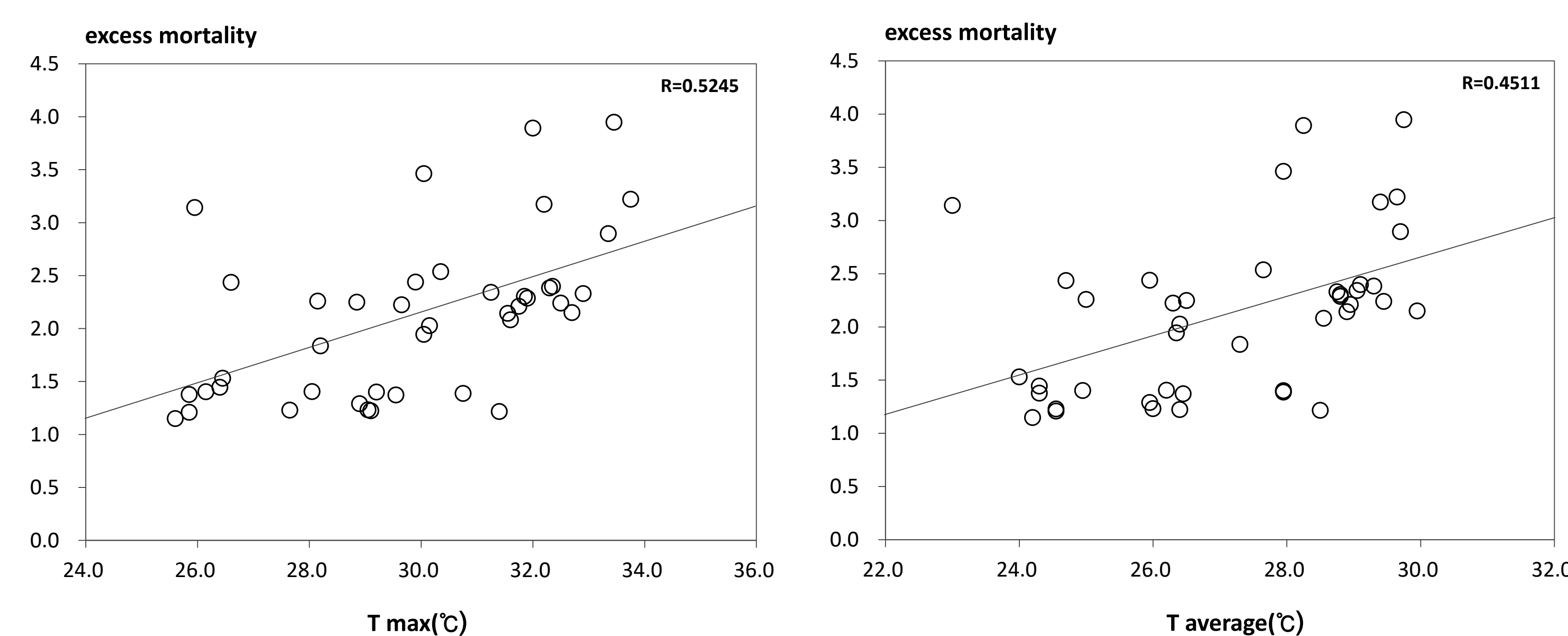Fig.3. (L) Correlation between excess mortality and T max(℃), (R) Correlation between excess mortality and T average(℃)

Excess mortality	T max	T average	T anomaly
Total > 1δ	0.524	0.451	0.112

Table 1. Correlation between Excess mortality and T max, T average, T anomaly

- There was a strong correlation between the excess mortality and the daily T max during the entire period (r=0.524). It can be seen that even at the daily T average(r=0.451). It means that the higher the maximum temperature, the more excess death occurs.
- On the other hand, it was analyzed that the correlation between the T anomaly and the excess mortality was not significant with a correlation coefficient of 0.112.

4. Heat Wave Impact Based Forecast and Warning Service(HIBFWS)

	T max(℃)
Attention	≧31℃ (3 consecutive days)
Caution	≧33℃ (2 consecutive days)
Aret	≧35℃ (2 consecutive days)
Serious	≧38℃

Table 2. Thresholds for HIBFWS

① Service overview
- Providing information customized for each risk level and sector.
- Announce the next day when risk levels above 'Attention' are expected.(once a day)
- The temperature thresholds were calculated by analyzing the causal relationship between temperature and patient occurrence, and the frequency of temperature on the S.Korea.
- Provided through mobile (SMS), homepage, FAX, E-mail, etc.
- Service sectors: Health, Agriculture, Industry, Livestock, Aquaculture, Transportation, Power supply

② Vulnerability, exposure of hazard
- A population of Jeju is 670,508(2018), and more than half(370,000) lives in the urban area of Jeju city (mid-northern part of the island), and about 1/6 of them live in Seogwipo city(mid-southern part of the island).
- Except urban area, the population distribution is around 20,000, but Hankyung is less than 10,000. And the population of Aewol, which is adjacent to Jeju city and attracts a lot of tourists, is about 35,000.
- Agriculture is growing various crops in almost areas, except for the urban area, to suit the climate characteristics of each area. Crops with frequent summer heat damage include carrots in the eastern area and cabbages in the western area.
- Chickens and pigs that are vulnerable to heat are the most bred in Halim in the western area.
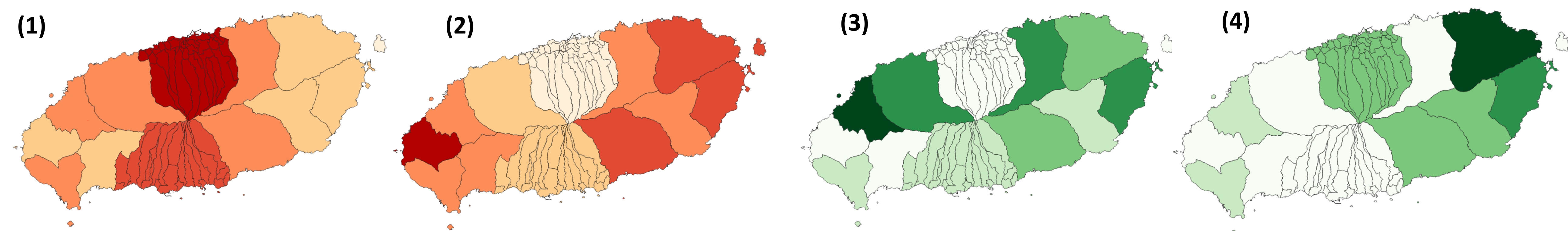

Fig. 4. Heat wave vulnerability map of Jeju .(1) population distribution, (2) population of age over 65 per 10,000, (3) chicken and pig breeding distribution, (4) carrot cultivation distribution

③ Information sheet
- At the top of the information sheet, the risk level is displayed, the risk outlook is provided in text on the left, and on the right is the status of the damage aggregated to the previous day.
- Below the map is a brief overview of the weather for the next two to three days.
- The six boxes at the bottom provide sector-specific risk levels and corresponding responses with the pictogram. There are a seven sectors of HIBFWS, but the 'power supply' sector is basically not exposed and can be expressed in exchange for other sector if damage is expected.
- This information can also be found on the Web page, which provides detailed information on small areas.
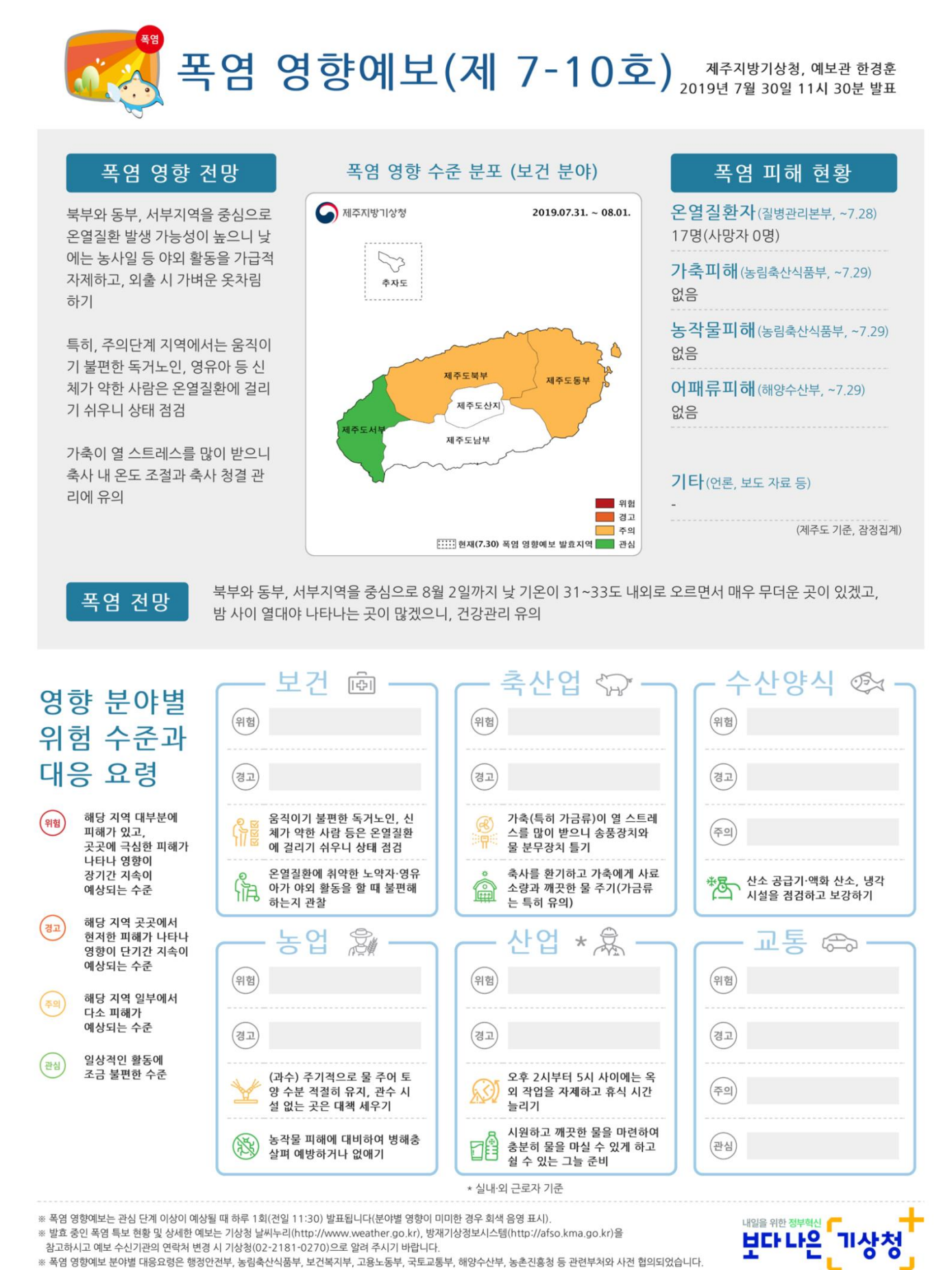- In addition, mobile webpages also provide risk information based on user location using GPS.

Fig. 5. Information sheet of HIBFWS

5. Summary

- The study shows the largest number of patients by heat waves at daily T max of 33℃ and there are many patients in the beginning of the heat wave days.
- The analysis of the correlation between the daily T max and the excess mortality showed a strong correlation, but less correlation with T anomaly.
- HIBFWS provides information on the risks and countermeasures of the heat wave, and will provide new thresholds that add humidity to existing temperature-oriented thresholds in 2020.

References

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Im, S.-J., Lee, S.-H., 2016: A Study of the Relationship between Extreme Temperature and Excess Mortality in Seoul, Korea, *Journal of Climate Research*, **11(2)**, 197-205.