Did visitors for sightseeing actually spread COVID-19 outbreak dominated the omicron variant strain in Japan ? A case study at resort island

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ICMJE Statement

Contributors JK was responsible for the coordination of the study and analyzed the data. YI set the data. All authors contributed to the writing of the final manuscript.

Abstract

Background: Long distance travel for sightseeing was believed to spread outbreak and had been banned until 2022. However, it had never been examined in detail.

Object: Object of this study was to confirm effect of long distance travel to infectivity in a resort island including the period when the mutated strain dominated.

Method: We used unique data about daily number of Yakushima airport users and visitors in a major hotel in Yakushima so as to evaluate how long distance travelers affect infectivity. Study period was since January 1, 2022 to August 10m 2022 when omicron variant strain dominated.

Results: Long distance travels, airport users and hotel visitors, were not significant at all.

Discussion and Conclusion: Estimation results about number of long distance travelers might not affect infectivity.

Introduction

Obviously, policy conducted by government should be evaluated ex post facto as well as ex ante evaluation. However, in Japan, official these evaluations were rare because the government was believed to never make mistakes as public stance. In particular, counter measure against the COVID-19 outbreak have never been evaluation ex post. Because it was pandemic and thus less knowledge and experience about COVID-19, ex ante evaluation should be too difficult and imprecise. However, ex post evaluation also rare. For example, long distance travel for sightseeing was believed to spread outbreak and had been banned until 2022. A study [1] advocated this public stance, though it included many mistakes and was considered to be declined as evidence.

It insisted that travel-associated COVID-19 incidence during July 22–26, when GTTC had started, was much higher than during either earlier period of June 22 to July 21 or July 15–19 . That study also compares the period of August 8–31. Patient data of two types were used: onset date and the date of testing positive.

We have identified some odd points in the report of that study. The first is that the proportion of people with a travel history during the GTTC period was almost comparable to those of people during the two prior periods. Especially, when the earlier period was defined as July 15–19, the proportions of people with a travel history among patients with an available onset date were smaller for the GTTC period than during the prior period. However, the authors found statistically significant higher incidence in the GTTC started period. Their finding might merely reflect the fact that the total number of patents in the GTTC period was higher than during the prior period. In other words, they did not control the underlying outbreak situation and therefore found incorrect association. Comparison of incidence rate among teo periods would be valid if the underlying outbreak situation other than the examining point was the same in the two considered periods. Therefore, comparison of incidence rate among teo periods might be inappropriate for this issue. At least, controlling the potential differences in the outbreak situation is expected to be necessary. The underlying outbreak situation, unrelated to GTTC, was reflected in the number of patients without a travel history or any sightseeing. To control the underlying outbreak situation, analysis of the share of patients with a travel history or sightseeing might be one procedure. However, that share did not increase markedly during the GTTC starting period. This fact indicates that the authors' result and conclusion are misleading.

A second point is that the authors of that report referred to the period of August 8–31, when GTTC was continuing. The proportion of patients with a travel history or tourism was much smaller than in the GTTC period or the prior period. Although the authors did not compare incidence in the period with that of either the prior period or the GTTC period, the rate of incidence during the period in August was probably lower than in other periods. In fact, some patients using GTTC perhaps might have been included in the period, as described above. Their inclusion might be inconsistent with the authors' conclusion.

A third point is that, we observed the peak of newly infected persons as July 23 in the whole of Japan: the GTTC starting date. Therefore, we infer that GTTC might have reduced infectiousness. We also consider climate conditions. At around the end of July, the rainy season in Japan ceased; summer began, with high temperatures. At least, GTTC was insufficient to raise the number of patients and cancel out benefits from the improved climate conditions. Taken together, these points suggest that GTTC might not be the main factor determining the course of the outbreak.

Moreover, GTTC must also increase the number of patients without travel history if GTTC has strong impact to the outbreak, For example, a patient travel using GTTC on July 22 and 23 and then onset on July 24. This patient had travel history with GTTC but not included a group of patients with travel history whose onset date was included in the GTTC started period, July 27-31. However, it is well known that presymptomatic patients have infectiousness as symptomatic period [2]. This patient might infect staffs of hotel or persons with visiting areas. They obviously did not have travel history. Their onset date were in July 27 and 28 and thus they were included a group of patients without travel history in the GTTC started period July 27-31. Therefore, GTTC certainly increased the number of patients without travel history, but did not increase patients with travel history in this case. Therefore, when we consider the effect of GTTC, we have to check the number of patients irrespectively travel history.

Finally, we have to note that this study could be done in mid of March or the end of March, 2021, if we had prepared those valuable data. Then, we had found the same results as this study. In fact, this study was performed in 2022, though the similar research without valuable data in this study was posted in January 4, 2021, and obtained the same results for GTTC[3]. In general, ex ante policy evaluation is necessary, but it was very difficult to estimate its effect precisely. However, ex post evaluation as soon as possible can be done if the preparation for it had planned before policy activation. If so, policy banning long distance travel without ant rationale legitimate could be prevented in 2021 and after.

Conversely, other study [4] found reverse evidence that effective reproduction number was significantly lower in the period when long distance travel was promoted. Moreover, another study [5] airport users at a local airport reduced infectivity. These findings might be strong evidence cast doubt to legitimate and rationality of banning policy for long distance travel. However, these studies focused on large area, the former was the whole of Japan and latter was a prefecture, and original strain. In general, study area was larger, it should be more difficult to identify who travel for long distance to sightseeing and thus analysis might be more indirect. Moreover, it was well known that the mutated strain have higher infectivity than the original strain [6,7], and thus there was some probability that long distance travel might affect infectivity of the mutated strain differently comparison with the original strain. Therefore we have to analyze it in much smaller area ad including the period when the mutated strain dominated.

Therefore, object of this study was to confirm effect of long distance travel to infectivity in a resort island including the period when the mutated strain dominated. In particular, we focused Yakushima island, Kagoshima prefecture sown in Figure 1. It is a world Natural Heritage and thus famous tourist spot. It has about 13 thousands residents. A collaboration among epidemiologist and leading company in Yakushima operating airport and hotel can deepen analysis for the object if this study. Especially, we can use the daily number of users of Yakushima airport and visitors in the major hotel in Yakushima. In official published data was monthly or annual data. Thus, we cannot analyze association among long distance travelers and infectivity using the published data to date.

As a countermeasure against the COVID-19 outbreak in Japan, school closure and voluntary event cancellation were required from February 27 to the end of March. Large commercial events also cancelled. After that, an emergency state was declared on April 7 until 25 May, requiring voluntary restriction to going out and business for consumers were shut down. During this period, the first peak was achieved on April 3. It then reemerged until July 29, as shown in Figure 1. However, the so-called “Go To Travel Campaign” (GTTC) started on July 22 50% subsidized travel and issuing coupons for shopping at tourist destinations which aims to enforce sightseeing business even though it may expand the outbreak. GTTC continued to the end of December, by which time the third wave had emerged. The third wave was larger than either of the prior two waves in December. Therefore, GTTC was inferred as the main reason underlying the third wave [8].

However, although results were mixed, some research suggests that COVID-19 might be associated with climate conditions, at least in China [9-11]. Conversely, some researched no association among climate condition and surging date of COVID-19 outbreak from cross sectional international comparison in Europe countries [12]. If the association was true for Japan, then GTTC might not be the main reason for the third wave in winter.

Moreover, mobility was inferred as the main cause of the outbreak dynamics, at least in the first wave in Japan [13] as well as in the world [14]. On the other hand, a study [15] showed that non-pharmaceutical interventions including lockdown had a large effect on reducing transmission at least in 11 European countries until April. However, the other study [16] of 131 countries found the introduction and relaxation of lock down or movement restrictions had limited effects on infectiousness, except for public events ban, though their data was limited until the end of July, 2021. Other study [17] showed that strict movement restrictions in Argentina from March were effective in reducing mobility but not in the outbreak. These mixing result might suggest that those counter-measures might not affect mobility significantly.

However, how the number of visitors for sightseeing or with travel long distance themselves affect outbreak situation in rural had not been analyzed. The reason of it certainly that those information might be less available for epidemiological analysis. Of course, some of annual or monthly, if they were lucky, data concerning about travelling or sightseeing might be available in general. However, these data should be too aggregated and thus too small number of data to do statistical analysis for relatively short period for less than one year. Fortunately, we can collaborate among epidemiologist, statistician and company managing resort hotels and buses to airport in rural. Thus, daily data of bus users from airport and visitors at these hotels. Therefore, we can test directly the hypothesis that visitors for sightseeing and/or travelling long distance spread outbreak in rural. This hypothesis was rationale for ban to long distance travel while 1st and 2nd emergency state or ceasing GTTC, though it have not been analyzed and confirmed so far.

Methods

The unique data about daily number of Yakushima airport users and visitors in a major hotel in Yakushima were provided Iwasaki Industrial Corporation at Kagoshima prefecture, Japan. However, these information were not complete. Some long distance travelers might take jetfoil or ferry to Yakushima than airline connecting Kagoshima, Osaka and Tokyo. Moreover, some visitors stayed other hotel in Yakushima than the corporate hotel. The repressiveness of these information were discussed in later.

We defined infectivity as effective reproduction number, R(t) in Yakushima. The numbers of newly confirmed patients in each day reported by Yakushima public health center [18]. Estimation procedure for effective reproduction number was the same as previous study [19]: letting $f(t)$ be the empirical distribution of incubation period and $g(t)$ be the empirical distribution of the period from onset to be reported in public. Both assumptions were used for an earlier study [11]. Then, $\Sigma_{s=1} g(s)\ x\ (t+s)$ should be estimated from the number of patients whose onset date was t , where $x(t)$ represents the number of newly confirmed symptomatic patients on date t. Also, $x(t)$ was assumed to be the constant proportion of the total of newly confirmed symptomatic patients including asymptomatic cases, which were reported to the public. Consequently, $\Sigma_{k=1}\Sigma_{s=1} f(k)g(s)x\ (t+s+k)$ should be the estimated number of patients infected on date t. Let $h(t)$ be the distribution of infectivity power defined in the earlier study [11]. Then $\Sigma_{k=1}\Sigma_{s=1} h(k)g(s)x\ (t+s+k)$ represents the sum of infectivity on date t. Therefore, $R(t)= \Sigma_{k=1}\Sigma_{s=1} f(k)g(s)\ x\ (t+s+k)\ /\Sigma_{k=1}\Sigma_{s=1} h(k)g(s)\ \ x(t+s+k)$. The proportion of asymptomatic cases does not affect $R(t)$ if it is constant.

The study period was defined as from the beginning of 2022 until April 10, 2022. Before this period, COIVD-19 patients were confirmed sporadically, and thus R(t) cannot be estimated. It was too volatile until January 2022 because patients in Yakushima were very few. After emerging omicron variant strain in 2022, it fluctuated more stable because patients grown up. Therefore, we examined the data since February 2022 as well as in 2022. Moreover, R(t) was calculated from the number of patients among Yakushima resident. Because they were supposed to be infected outside Yakushima.

We use some variables as explanatory variables. At first, volume of long distance traveler to Yakushima was measure through number of Yakushima airport users or number of visitors in a corporate hotel. Because these two variables were supposed to be correlated to each other, we use one of them in a regression.

Average temperature and relative humidity data at Kagoshima prefecture were used as climate condition. Temperatures were measured in degrees Celsius. We obtained data from the Japan Meteorological Agency (https://www.data.jma.go.jp/gmd/risk/obsdl/index.php).

Additionally, we identified several remarkable countermeasures in Japan: four state-of-emergency declarations, a travel campaign, and school closure and voluntary event cancellation (SCVEC). The latter, SCVEC, extended from February 27 through March in 2020: this countermeasure required school closure and cancellation of voluntary events, and even cancellation of private meetings. The first state of emergency was declared on April 7, 2020. It ceased at the end of May. It required school closures, shutting down of some businesses, and voluntary restriction against going out. To subsidize travel and shopping at tourist destinations, GTTC started on July 22, 2020. It was halted at the end of December, 2020.

The second state of emergency was declared on January 7, 2021 for the 11 mostaffected prefectures. This countermeasure required restaurant closure at 8:00 p.m., with voluntary restrictions against going out, but it did not require school closure. It continued until March 21, 2021.

To clarify associations among R(*t*) and GTTC or the valuable data in addition to climate, mobility, and countermeasures except for GTTC, we used ordinary least squares regression to regress the daily R(*t*) on daily dummy variables for GTTC, and daily data of airport limousine bus users and visitors at the resort hotels, as well as dummy variables for daily climate, mobility, and dummy variables for countermeasures. We used Google provided mobility data showing staying at six types of place, such as restaurant, shopping mall or amusement; grocery store or pharmacy; park; transition; workplace; and home .(https://www.google.com/covid19/mobility/) . It measures mobility relatively comparison with base day. It defined 100 if number of persons staying at a type of place was the same as base day.

We expected the sign of the explanatory variables as follows: airport limousine bus users and visitors at the resort hotels or GTTC increased infectively if the banning policy of long distance travel was rational. Counter measure as the emergency status or SCVEC were supposed to decline the infectively. We adopted 5% as the significance level.

Results

Figure 2 shows the newly confirmed cases of COVID-19 including asymptomatic cases until August 10, 2021 in Yakushima. The initial case was detected in August, 2020, however, it was sporadic until 2022. Since January, 2022, the cases were continuously reported and showed the larges peak in August when omicron BA.5. variant strain was dominated.

In this figure, there were cases confirmed at Yakushima among visitors to Yakushima, however, they had not caused outbreak among Yakushima residents until 2021. In 2022, confirmed cases in Yakushima residents and visitors were parallel, however, visitors may not lead outbreak among residents. These findings might suggest to negate legitimate and rationality of banning policy for long distance travel.

Figure 3 depicts estimated R(t) and its 95% confidential interval since August 19, 2021 to August 10, 2022. In 20221, it was too large and volatile, because there were very few cases were reported at that time. It was not defined several period because of no patients. In 2022, especially since February, because the cases were reported almost every day, R(t) was changed to be smaller number around one and less volatile.

Figure 4 illustrated the number of the Yakushima airport users and hotel visitors in a corporate hotel. In April and May, 2020, while 1st emergency status declared, two variables declined heavily. After that, these had recovered in GTTC activated period until December 27, 2020. After that, these fluctuated between almost the same range in GTTC.

Table 1 presents the estimation results with airport users in 2022, and estimation results limited to be since February 2022. Table 2 similarly showed the estimation results with hotel visitors. Common results in tables was that variables for long distance travels, airport users and hotel visitors, were not significant at all. Therefore, we cannot find out some evidence that long distance travelers promote infectivity in Yakushima.

Temperatures, going to restaurant and proportion of delta variant strain raise infectivity. Conversely, coverage of fourth vaccination and proportion of BA.2 lineage, omicron variant strain decreased infectivity. The results of vaccine coverage was as expected. In the study period, vaccine coverage of the second and third dozes reached almost the ceiling, though the fourth vaccination increased rapidly. The results of restaurant might support to "stay at home" policy. Concerning about variant strains, delta had higher infectivity and BA.2 lineage had lower than BA.1 or BA.5 lineage, omicron variant strain.

Discussion

Estimation results about number of long distance travelers might not affect infectivity. Though nonsignificant does not mean strong evidence, we cannot find out the evidence that long distance travels promote infectivity. It might not support legitimate ad rationality to banning policy for long distance travels.

On the other hand, we focus only in 2022 when omicron variant strain dominated. Fortunately, confirmed patients in Yakushima were very rare before 2022 and thus R(t) cannot be defined stably. Therefore, we cannot extrapolate the obtained result to strains which emerged and disappeared before omicron variant strain emerged. However, previous study [4,5] also suggested that long distance travelers reduced infectivity of the original strain until February, 2021. Therefore, our obtained results were not inconsistent with those previous study. On the other hand, our obtained results is casting a doubt to the misleading study[1] , additionally.

The most weak point in this study may be representativeness of using unique data, daily Yakushima airport users and visitors in the corporate hotel. Unfortunately, there were no comparable data in daily, however, monthly comparable data were available. One is monthly number of users to Yakushima by means of transport, airline, jet foil and ferry[20]. Concerning about airline and jet foil users, number of Yakushima resident or visitors were also reported. Unfortunately, we cannot identified residents or not in ferry users. Thus, even though it covered all visitors to Yakushima including Yakushima residents, however, we cannot exclude residents from all of three transportation users completely.

Figure 5 showed that all airline users, airline users who were not Yakushima residents, all jetfoil users, jetfoil users who were not residents and ferry users. Almost all of airline users were not residents, however, about half of jetfoil users were residents. Correlation coefficients among all airline users and total three transportation users during the period since January, 2019 to December, 2021, was 0.8858 and its *p*-value was 0.000. Correlation coefficient among airport users including Yakushima residents and sum of visitors using airline or jetfoil excluding Yakushima residents during the period since January, 2019 to September, 2022,was 0.9236 and its *p*-value was 0.000. Therefore, we can conclude that all airline users represents all three transportation users or nonresident visitors.

Another data so as to confirm responsibility of used unique data was monthly data of visitors in another two major hotel in Yakushima shown in Figure 6. Correlation coefficients among them since January 2020 to October 2022 was 0.7365 and its *p*-

value was 0.000. Therefore, a corporate hotel providing daily data has responsibility of other major hotel and thus all hotel visitors in Yakushima.

The present study has some limitations. First, this study focus only at Yakushima , Kagoshima prefecture, and thus it is not sure whether the same result held at other places or in the whole of Japan.

Second, we focus only on omicron variant strain. It was not clear that the similar result held under the original train or alpha or delta mutated strains.

Third, regression analysis such as this study does not mean causality. Namely, though we interpreted that travelers might affect infectively, infectively night affeect travel to Yakushima. We have to keep in mind it to interpret the results.

Conclusion

We demonstrated that increasing in long distance traveler may not always raise infectivity. Therefore, legitimate of the policy banning long distance travel including cease of GTTC was not fair and rational.

The present study is based on the authors' opinions: it does not reflect any stance or policy of their affiliations.

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Ethical considerations

All information about patients used for this study was collected under the Law of Infection Control, Japan and published by Yakushima town office[18] . Iwasaki industrial company provided business recorded data about airport and jetfoil users and hotel visitors. Information about two other hotels were provided voluntary. Data about airport or jetfoil users users and hotel visitors did not have any personal and/or private information. Therefore, there is therefore no ethical issue related to this study.

Competing Interest

No author has any conflict of interest, financial or otherwise, to declare in relation to this study.

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Table 1: Estimation results of association among R(t) and Yakushima airport users until August 10, 2022.

	Since January 1,2022		Since February 1,2022	
Explanatory variables	Estimated Coefficient	*p*-value	Estimated Coefficient	*p*-value
Yakushima airport users	0.001073	0.669	0.0003368	0.767
Temperature	0.22869	0.012	0.2399063	0
Humidity	-0.01612	0.479	-0.0145575	0.183
Place: Restaurant, shopping mall or amusement	0.244369	0	0.0771566	0.007
Place: Grocery store or pharmacy	-0.14344	0.024	-0.0270804	0.402
Place: Park	-0.01392	0.516	-0.0051742	0.636
Place: Transition	0.052272	0.23	-0.0043877	0.841
Place: Workplace	0.236312	0	0.0487662	0.095
Place: Home	0.536682	0.004	0.1103732	0.257
Vaccine coverage of the second dose with lag (%)	1.289499	0.27	-1.658935	0.085
Vaccine coverage of the third dose with lag (%)	-0.27021	0	0.0803521	0.254
Vaccine coverage of the fourth dose with lag (%)	-0.59047	0	-0.6017944	0

Share of delta variant strain (%)	0.239518	0	4.761326	0.032
Share of omicron BA.1 variant strain (%)	-0.12703	0.002	-0.0104136	0.66
Share of omicron BA.2 variant strain (%)	-0.06968	0.002	-0.0542541	0
Share of omicron BA.5 variant strain (%)	-0.02972	0.036	-0.0281507	0
constant	-88.8365	0.355	136.7195	0.077
Adjusted R^2	0.6571		0.5383	

Note: Yellow marker indicates significant except for constant terms. Number of observation was 222 for the left columns and 191 for the right columns. The period when R cannot be calculated were excluded to estimate.

Table 2: Estimation results of association among R(t) and Yakushima airport users in 2022

	Since January 1,2022		Since February 1,2022	
Explanatory variables	Estimated Coefficient	*p*-value	Estimated Coefficient	*p-value*
Hotel visitors	-0.00587	0.372	-0.0003343	0.915
Temperature	0.25272	0.006	0.2390225	0
Humidity	-0.0227	0.325	-0.0148941	0.175
Place: Restaurant, shopping mall or amusement	0.143675	0.005	0.0757929	0.009
Place: Grocery store or pharmacy	-0.08308	0.2	-0.0255396	0.432
Place: Park	-0.03263	0.128	-0.0050964	0.642
Place: Transition	0.123653	0.006	-0.00136	0.953
Place: Workplace	0.179087	0.001	0.0494974	0.089
Place: Home	0.43181	0.016	0.1165953	0.228
Vaccine coverage of the second dose with lag (%)	1.224069	0.276	-1.689176	0.078
Vaccine coverage of the third dose with lag (%)	-0.2574	0	0.0809263	0.25
Vaccine coverage of the fourth dose with lag (%)	-0.55461	0	-0.5983648	0
Share of delta variant strain (%)	0.196821	0.001	4.71741	0.033

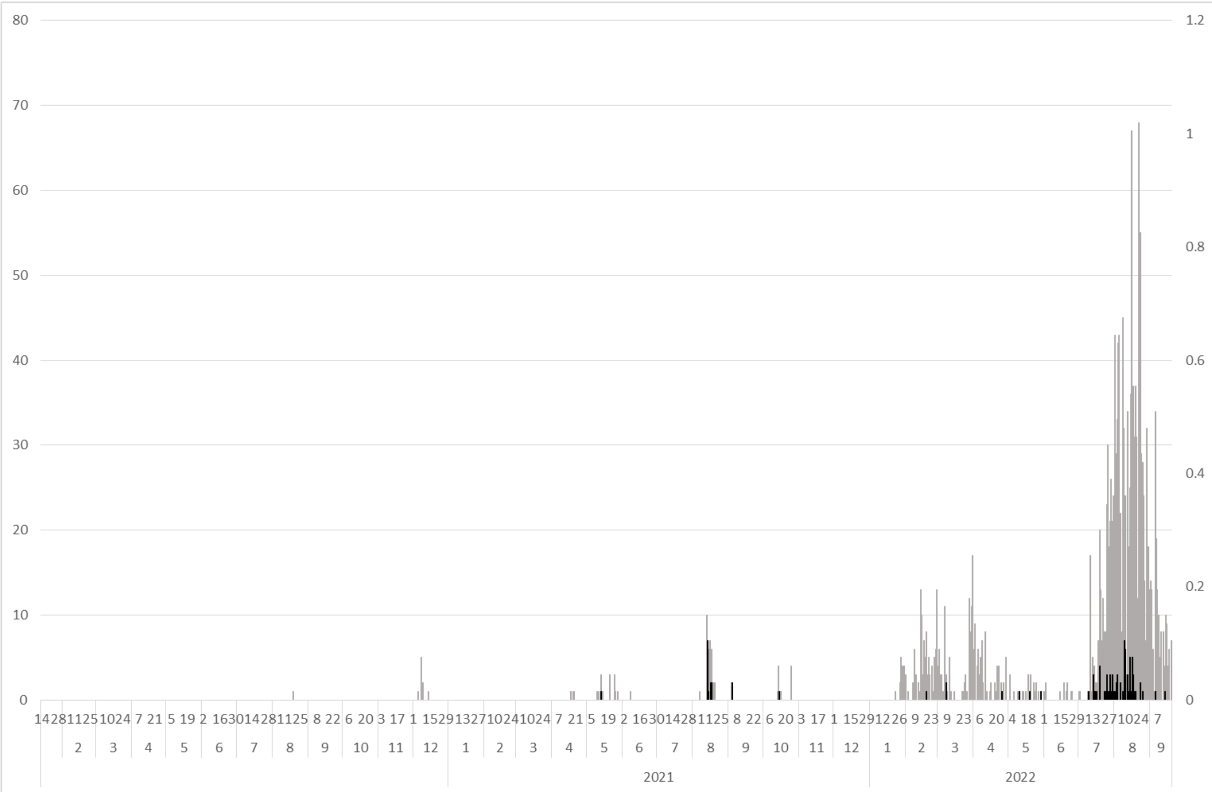
Share of omicron BA.1 variant strain (%)	-0.10585	0.007	-0.0107774	0.649
Share of omicron BA.2 variant strain (%)	-0.06045	0.005	-0.0540998	0
Share of omicron BA.5 variant strain (%)	-0.02509	0.061	-0.0278712	0
constant	-83.5659	0.363	139.3548	0.07
Adjusted R^2	0.6688		0.5381	

Note: Number of observation was 196.

Figure 1: Map of Kagoshima prefecture and Yakushima island

Figure 2: Newly confirmed patients in Yakushima until August 10, 2022

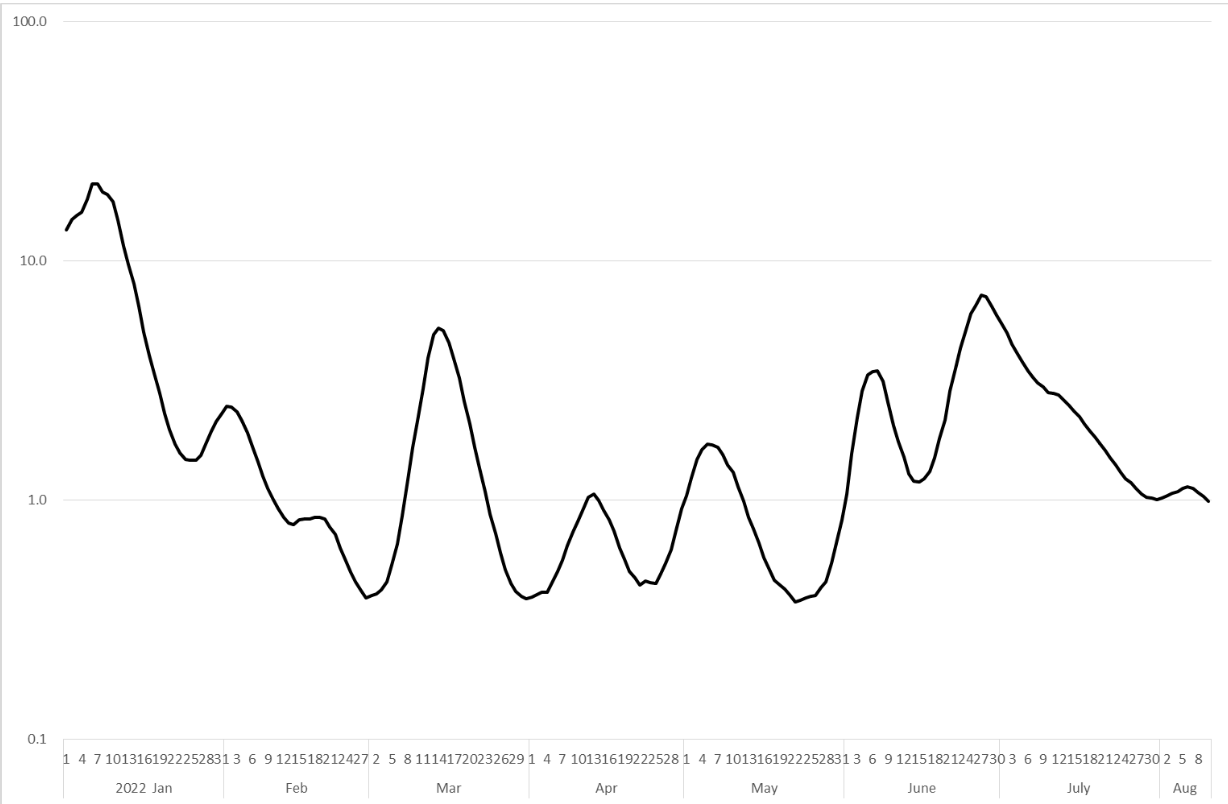
(persons)



Note: Black bars was newly confirmed patients who did not live at Yakushima and gray bars was newly confirmed patients in Yakushima residents. Source of newly confirmed patients was http://www.town.yakushima.kagoshima.jp/info-living/31331/

Figure 3: Estimated R(t) since January 1 to August 10, 2022

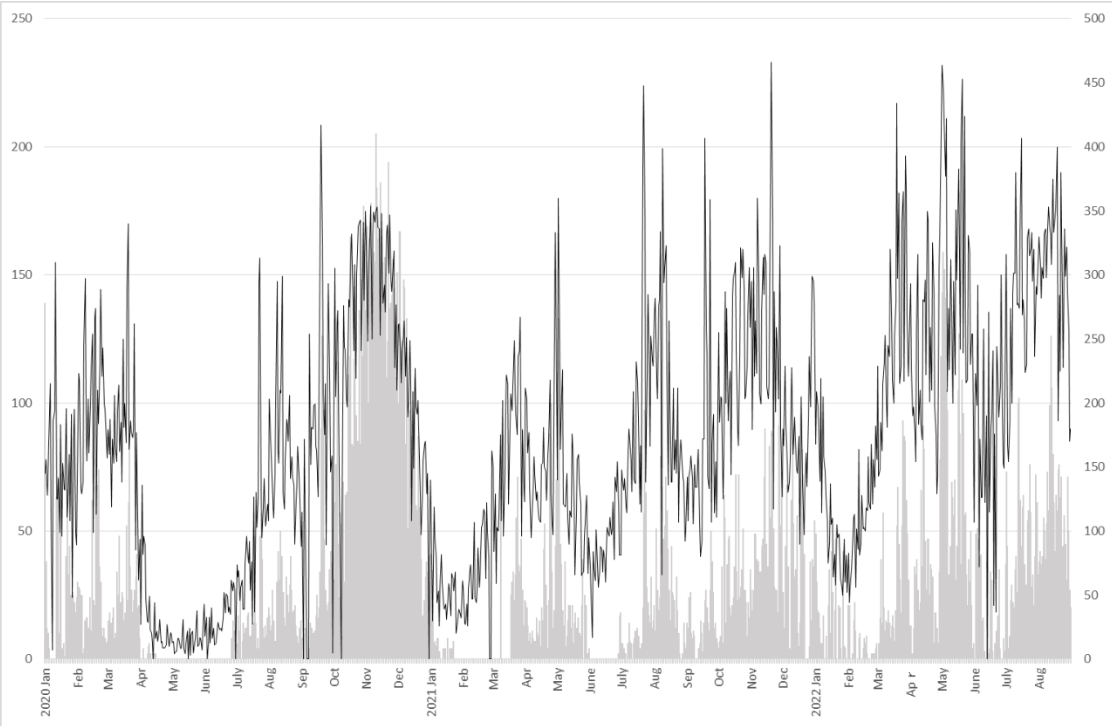
(R(t))



Not: Black line indicates $\log_{10}$ transformed estimated R(t) measured by left scale. If R(t) was less than 0.1, we omitted to show. If R(t) cannot be calculates in some period, it was not shown.

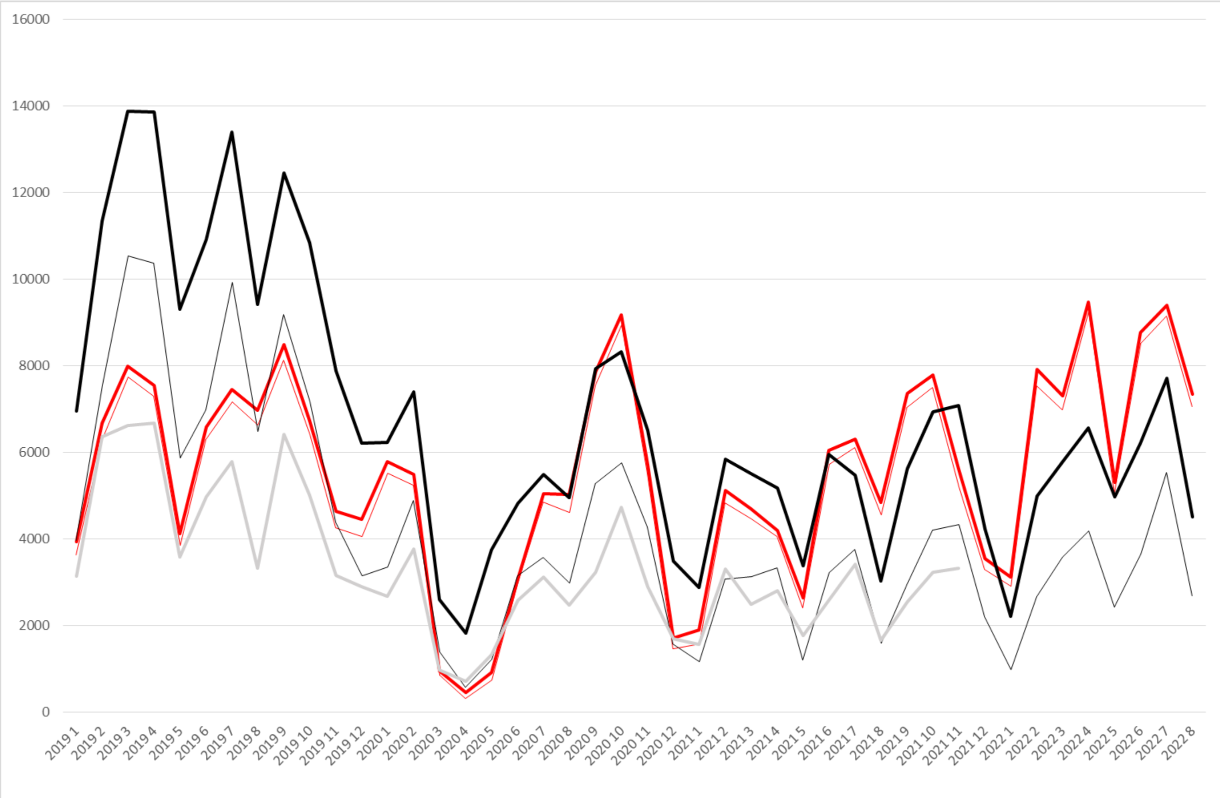
Figure 4: Yakushima airport users and hotel visitors

(hotel visitor) (Yakushima airport users)



Note: Gray bar indicate number of visitor in a corporate hotel. Black line indicates number of Yakushima airport users.

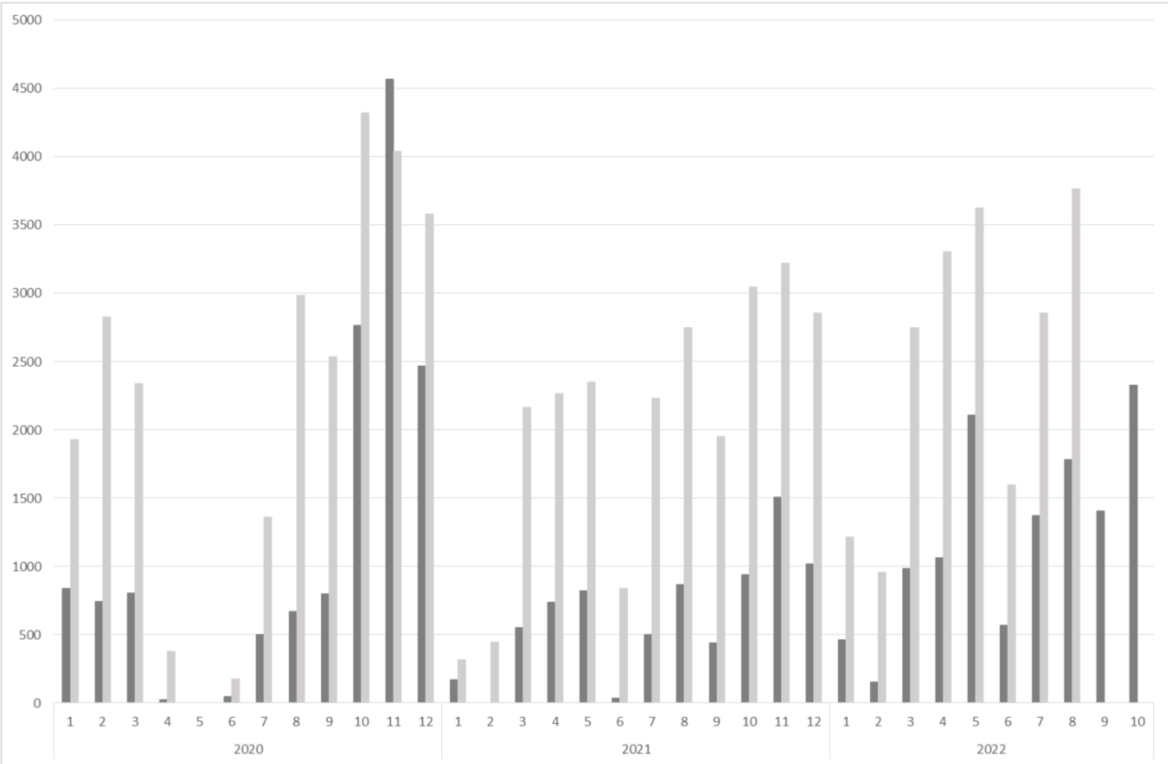
Figure 5: Monthly number of visitors by means of transport, airline, jet foil and ferry, by Yakushima residents or not



Note: Red line indicates Yakushima airport users including Yakushima residents and red thin line indicates Yakushima airport users excluding Yakushima residents. Similarly, black line indicates jetfoil users including Yakushima residents and black thin line indicates jetfoil users excluding Yakushima residents. Gray line indicates ferry users which cannot be separate it to be Yakushima residents or not. Correlation coefficient among airport users including Yakushima residents and all visitors including Yakushima residents during the period since January, 2019 to December, 2021, was 0.8858 and its p-value was 0.000. Correlation coefficient among airport users including Yakushima residents and sum of visitors using airline or jetfoil excluding Yakushima residents during the period since January, 2019 to September, 2022,was 0.9236 and its *p*-value was 0.000. Unfortunately, because ferry users excluding Yakushima residents was not identified, we cannot define all visitors excluding Yakushima residents. Moreover, data about ferry users in 2022 were not available, all visitors including ferry users were not defined in 2022.

Figure 6: Comparison corporate hotel and other two major hotels in Yakushima

(persons)



Note: Black bar indicates visitors at corporate hotel and gray bar indicates visitors at other two major hotels in Yakushima. Correlation coefficients among them since January 2020 to October 2022 was 0.7365 and its *p*-value was 0.000.