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Research Article

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Posted Date: December 1st, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-118520/v1>

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A Major Outbreak of COVID-19 in the Diamond Princess Cruise Ship

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ABSTRACT

The COVID-19 pandemic broke out in Wuhan, China, and declared an international public health emergency by the World Health Organization in 2020. It mainly manifests as symptoms of respiratory infections, and severe cases can cause pneumonia and death. The Diamond Princess cruise ship outbreak cluster infection outside China during the early pandemic. The incident occurred on February 1, 2020, and an 80-year-old Hong Kong man was diagnosed with COVID-19. The cruise docked in Yokohama, Japan, for 14 days on-board quarantine; however, cluster infection outbreak rapidly. The results show that after 14 days of quarantine, 634 (17.1%) cases were diagnosed with a total of 3,711 population, and 328 (51.7%) cases were asymptomatic. As of April 24, 2020, 712 cases have been diagnosed and 14 deaths have occurred. A cumulative mortality rate reaches 1.96%. Using a nonlinear least-squares curve fitting with Microsoft Excel Solver, we obtain the parameters of the SIR mathematical model of infectious disease and the reproduction number (R_0) of the COVID-19 outbreak is 2.37 ± 0.26 . Without an emergency evacuation plan, the total infection rate will reach 88.47%. These data show "only one" COVID-19 case could still outbreak cluster infection on large cruise ships. The possible causes and countermeasures are discussed.

Keywords: public health emergency of international concern, SARS-CoV-2, 2019-nCoV, COVID-19, basic reproduction number, coronavirus, cluster infection, *Diamond Princess* cruise, *USS Theodore Roosevelt*, asymptomatic infection, nonlinear least-squares curve fitting, epidemiology, travel medicine

Introduction

Since December 8, 2019, there have been several pneumonia cases of unknown etiology in Wuhan City, Hubei Province, China. Most of these patients are merchants or nearby residents of the local South China Seafood Wholesale Market¹⁻³. On December 31, 2019, the World Health Organization (WHO) reported an outbreak of the disease. After ruled out possible influenza and other coronaviruses through laboratory tests, the Chinese authorities isolated a new coronavirus on January 7, 2020, and named by WHO as Coronavirus disease 2019 (COVID-19)⁴.

Coronaviruses are RNA viruses that can cause multiple organ system infections in humans and other mammals. They are mainly manifested as respiratory infections in humans. Although most human coronavirus infections are mild, two of coronaviruses infection are serious. They are severe acute respiratory syndrome (SARS-CoV) with a mortality rate of 10%^{5,6} and Middle-East respiratory syndrome (MERS-CoV) with a mortality rate of 37%⁷.

The incubation period of the new coronavirus COVID-19 disease varies significantly from patient to patient. The US CDC data show that the incubation period from infection to disease onset is 2-14 days⁸. A Chinese study published in the *New England Journal of Medicine* collected 425 cases and observed an average incubation of 5.2 days⁹. Another large-scale epidemiological study sponsored by the Chinese and American health research authorities showed that the average incubation period of COVID-19 was 4.75 days. The number of cases collected from January 26, 2020, totaled 8,866 cases from 30 provinces in China. Of these, 4,021 cases were confirmed by the laboratory¹⁰.

In terms of the speed of transmission of new coronaviruses, the basic reproduction number (R_0) of the virus represents the attack rate or spread of the virus (the rate at which the disease spreads) and is defined as the average number of individuals infected

by the virus. R_0 less than 1 means the disease will gradually dissipate. WHO estimates that the R_0 of COVID-19 ranges from 1.4 to 2.5¹¹. Other preliminary studies have estimated that R_0 ranges from 2.24 to 3.58¹². Large-scale epidemiological studies have estimated an average $R_0 = 3.77$ ¹⁰.

The severity of clinical manifestations ranges from asymptomatic infection or mild illness to severe or fatal illness. Most patients have a fever, dry cough, and asthma⁸. In a study of 425 patients with pneumonia confirmed COVID-19 infection, of which 57% were male⁹. About one-third to one-half of the reported patients have underlying comorbidities, including diabetes, hypertension, and cardiovascular disease.

In terms of mortality, the official data released by China on February 4, 2020: around 2.1% worldwide, Wuhan 4.9%, Hubei Province 3.1%, and other provinces 0.16%¹³. Large-scale epidemiological studies have calculated an overall mortality rate of 3.06%¹⁰. However, some studies have used Wuhan Jinyintan Hospital, which treats many patients with pneumonia confirmed COVID-19 infection and has calculated a mortality rate of 11%¹⁴. As of September 24, 2020, total of 32,110,901 confirmed cases (85,314 in China) have been reported and 982,196 deaths in worldwide (4,634 in China), the mortality rate is 3.06%¹⁵.

The *Diamond Princess* is a cruise ship owned by Princess Cruises with a displacement of 115,875 tons. Since 2014, the port of registry is London, England. The *Diamond Princess* sailed from Yokohama on January 20, 2020, to Kagoshima on the 22nd, arrived in Hong Kong on the 25th, and then passed through Vietnam, Taiwan, and Okinawa. The cruise voyage is shown in Table 1. The incident occurred on February 1, 2020. An 80 year-old Hong Kong man was diagnosed with the new coronavirus. He took a flight to Tokyo on January 17 and started having cough symptoms on January 19. After this, he boarded the cruise in Yokohama on January 20 and landed at Kai Tak Wharf in Hong Kong on January 25, fever was sought on January 31 and the diagnosis was confirmed on February 1¹⁶.

Date	Cruise ship stops	Remarks
Jan 20	Boarding in Yokohama, Japan	Hong Kong 80 year-old man gets on board
Jan 21	Sea cruise	
Jan 22	Anchored Kagoshima	
Jan 23-24	Sea cruise	
Jan 25	Anchored in Hong Kong	Hong Kong 80 year-old man disembarks
Jan 26	Sea cruise	
Jan 27	Anchor in Zhang Meigang, Da Nang, Vietnam	
Jan 28	Anchored at Cailan Port, Halong Bay, Vietnam	
Jan 29-30	Sea cruise	
Feb 1	Anchored in Naha, Okinawa, Japan	Hong Kong 80 year-old man diagnosed COVID-19
Feb 2	Sea cruise	
Feb 3	Anchored in Yokohama, Japan	

Table 1. Brief cruise diary of the *Diamond Princess* cruise.

After the outbreak of the incident, the *Diamond Princess* was anchored at the port of Yokohama, Japan on the night of February 3, and a total of 3,711 people were quarantined on-board for 14 days in private cabins. However, outbreaks of cluster infections continued to occur during the quarantine period. As of Feb 26, 705 people have been diagnosed with COVID-19, and an average of one-fifth has been diagnosed. This is the most extensive cluster infection outside China in the early pandemic ¹⁵. Thus, it is related to epidemiology and virus spread are worth studying and discussing.

The *Diamond Princess* cruise ship carried a total of 3,711 people, including 2,666 tourists (including 1,285 Japanese, 470 Hong Kong people, 425 Americans, 215 Canadians, 40 British, 25 Russians, 20 Taiwanese, 15 Israelis, and 13 New Zealanders) and 1,045 staff members (including 2 Taiwanese). The average age of the crew was 36, as well as the passengers were 69. The passengers were 55% female, while the crew was 81% male. Since February 4, many newly confirmed patients have been reported. The exact confirmation number and date are shown in Table 2 and Fig 1 ¹⁶.

Date	Newly diagnosed cases	Cumulative confirmed cases	Cumulative test cases	Remarks and references
2/5*	10	10	31	14 days quarantine started
2/6	10	20	102	
2/7	41	61	273	
2/8	3	64	279	
2/9	6	70	336	
2/10	65	135	439	
2/12	39	174	492	
2/13	44	218	713	
2/15	67	285	930	Includes 73 asymptomatic cases
2/16	70	355	1219	Includes 111 asymptomatic cases
2/17	99	454	1723	Includes 189 asymptomatic cases
2/18	88	542	2404	Includes 254 asymptomatic cases
2/19	79	621	3011	Includes 322 asymptomatic cases
2/20*	13	634	3063	Includes 328 asymptomatic cases
2/26	71	705	4061	Includes 392 asymptomatic cases

*All people are quarantined from Feb 5 to Feb 20, 2020 for 14 days.

Table 2. Number of confirmed cases and date of diagnosis on the *Diamond Princess*.

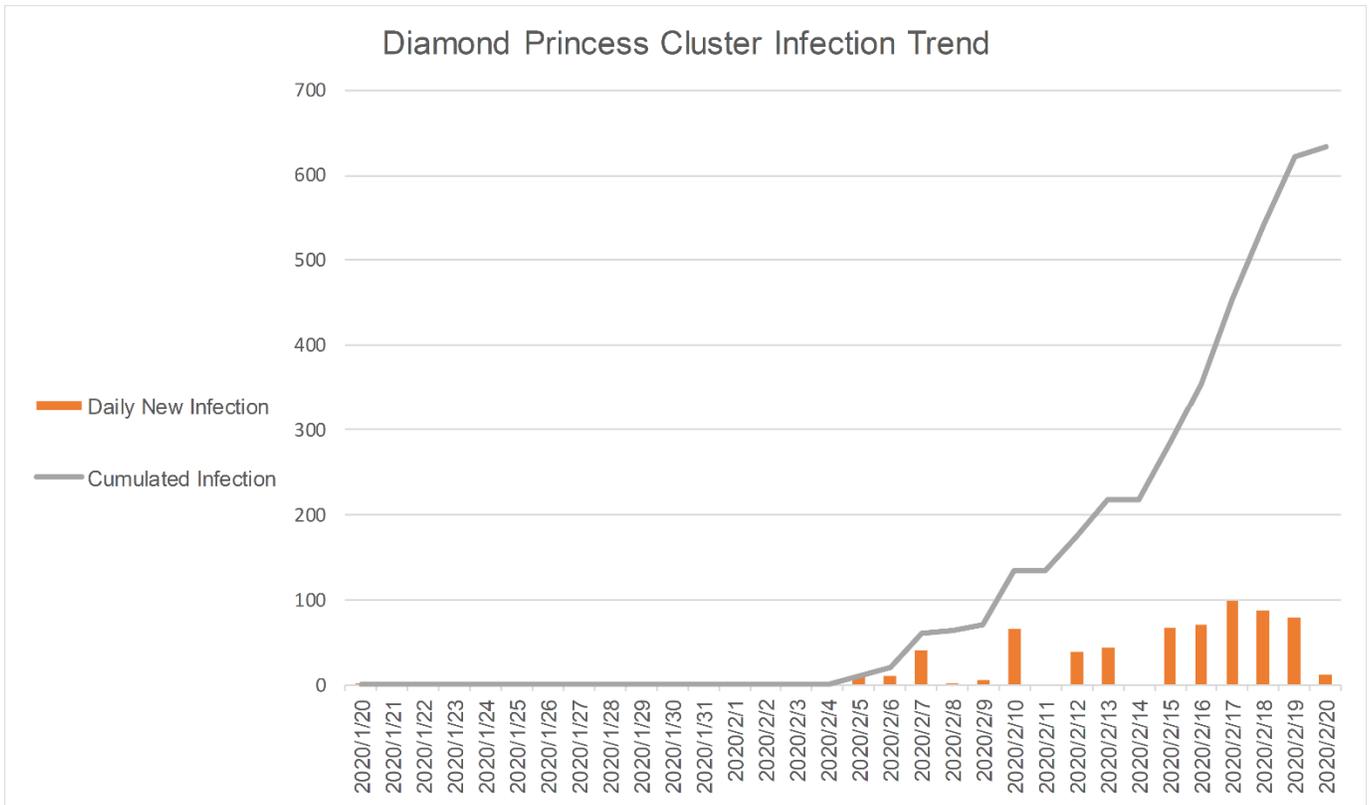


Figure 1. The trend of cluster infection of the *Diamond Princess* cruise ship.

The *Diamond Princess* Cruise cluster infection incident began after the Hong Kong elderly boarded the ship and the epidemic broke out during the 14-days quarantine at the port of Yokohama. We conducted a cohort study of this event in a confined cruise ship. The motivation of this research is to study the epidemiological transmission model of COVID-19 in large cruise ships and to estimate the basic reproduction number by nonlinear least-squares curve fitting. This research can compare the epidemiological parameters of COVID-19 in other larger ships and help to make correct preventive measures in the future when similar cluster infections occur.

Methods

This study uses the SIR epidemic model, which is composed of three parts: S denotes the susceptible population, I denotes the infectious population, and R denotes the recovered (or immune) population. It consists of the following differential equations.

$$\frac{dS}{dt} = -\frac{\beta IS}{N}, \quad (1)$$

$$\frac{dI}{dt} = \frac{\beta IS}{N} - \gamma I, \quad (2)$$

$$\frac{dR}{dt} = \gamma I. \quad (3)$$

Where N is the total population, β and γ are parameters which can be used to define the basic reproduction number as follows

$$R_0 = \frac{\beta}{\gamma}. \quad (4)$$

The SIR model satisfies the following equations

$$S(t) + I(t) + R(t) = \text{constant} = N, \quad (5)$$

$$\frac{dS}{dt} + \frac{dI}{dt} + \frac{dR}{dt} = 0. \quad (6)$$

Because the SIR model is a set of nonlinear differential equations, we use a nonlinear least-squares curve fitting with Microsoft Excel Solver 2019 to analyze the data of confirmed cases. This is a powerful tool widely available in spreadsheets providing a simple method of fitting experimental data to nonlinear functions. The procedure is so easy to use. However, it has never been used to solve the R_0 in previous literature. The operation mode is so obvious that it is an excellent way for researchers to learn the underlying principle of least squares curve fitting¹⁷.

Consider the problem of fitting the cumulative infection data in Fig 1. We let the “cumulative confirmed case” in Table 2 as the target function. The accuracy of minimizing the problem depends on the function model chosen ¹⁸.

$$y = I + R, \tag{7}$$

Where I, R can be calculated by difference series.

$$I_{n+1} = I_n + \Delta I = I_n + \left(\frac{\beta \cdot I_n S_n}{N} - \gamma I_n \right) \Delta t, \tag{8}$$

$$R_{n+1} = R_n + \Delta R = R_n + \gamma I_n \cdot \Delta t. \tag{9}$$

Where n means day 1 to day n , and we let $\Delta t = 1$ day.

Least Squares

The vertical deviation from the i th point of the “observed” curve to the “calculated” curve is

$$\begin{aligned} \text{vertical deviation} &= y_i (\text{observed}) - y_i (\text{calculated}) \\ &= y_i - (I_i + R_i). \end{aligned} \tag{13}$$

The least squares method is to find values of β, γ in equations (1)-(3) that minimize the sum of the squares of the vertical deviations of the points from the curve¹⁹:

$$\text{sum} = \sum_{i=1}^n [y_i - (I_i + R_i)]^2. \tag{14}$$

Where n is the total number of points (=32 in Fig. 1)

Here are steps to find the best values of β and γ that minimize the sum in equation (14):

1. List the reported values of “infection reported” and “cumulative infection” in columns C and D of Fig 2.
2. Temporarily assign the value 1 to β and γ at the left side of the spreadsheet in cell B2,B3.
3. In column E, calculate $y = I + R$ from column G (predicted infection: I) and H (Recovered: R).
4. In column L, compute the vertical deviation in equation (13) and then square the deviation. For example, L6=(D6-E6)^2.
5. In cell L4, compute the sum of the squares of vertical deviations in column L. The sum in cell L4 is the sum in equation (14).
6. The least squares method is to find values of β and γ that minimize the sum in cell L4. Microsoft Excel Solver is a tool that handles the problem. When Solver finishes its task in a few seconds, the spreadsheet will appear as in Fig 3. Solver has adjusted the values in cell B2,B3 to minimize the sum in cell L4. The values of β and γ in cell B2,B3 were used for plot the SIR curve in Fig 4.
7. Try some different initial values of β and γ (other than 1) to see if Solver finds the same solution. A given problem may have many local minima.

	A	B	C	D	E	F	G	H	I	J	K	L
1	N	3711										
2	β	1										
3	γ	1										SSD
4	R0	1										1463448
5		Day	Infection R	Cumulative I+R	Susceptible	Predicted I	Recovered	dS	dI	dR	SD	
6	2020/1/20	1	1	1	1	3710	1	0	-0.99973	-0.00027	1	0
7	2020/1/21	2	0	1	1.999731	3709	0.999731	1	-0.99919	-0.00054	0.999731	0.999461
8	2020/1/22	3	0	1	2.998922	3708.001	0.999192	1.999731	-0.99838	-0.00081	0.999192	3.995691
9	2020/1/23	4	0	1	3.997307	3707.003	0.998384	2.998922	-0.99731	-0.00108	0.998384	8.983847
10	2020/1/24	5	0	1	4.994616	3706.005	0.997309	3.997307	-0.99597	-0.00134	0.997309	15.956695
11	2020/1/25	6	0	1	5.990582	3705.009	0.995967	4.994616	-0.99436	-0.00161	0.995967	24.90591
12	2020/1/26	7	0	1	6.984941	3704.015	0.994359	5.990582	-0.99249	-0.00187	0.994359	35.81952
13	2020/1/27	8	0	1	7.977428	3703.023	0.992487	6.984941	-0.99035	-0.00213	0.992487	48.68451
14	2020/1/28	9	0	1	8.967782	3702.032	0.990354	7.977428	-0.98796	-0.00239	0.990354	63.48555
15	2020/1/29	10	0	1	9.955743	3701.044	0.987961	8.967782	-0.98531	-0.00265	0.987961	80.20533
16	2020/1/30	11	0	1	10.94105	3700.059	0.98531	9.955743	-0.98241	-0.0029	0.98531	98.82453
17	2020/1/31	12	0	1	11.92346	3699.077	0.982405	10.94105	-0.97925	-0.00316	0.982405	119.3219
18	2020/2/1	13	0	1	12.90271	3698.097	0.979249	11.92346	-0.97584	-0.0034	0.979249	141.6744
19	2020/2/2	14	0	1	13.87855	3697.121	0.975844	12.90271	-0.97219	-0.00365	0.975844	165.8571
20	2020/2/3	15	0	1	14.85074	3696.149	0.972194	13.87855	-0.9683	-0.00389	0.972194	191.8431
21	2020/2/4	16	0	1	15.81905	3695.181	0.968304	14.85074	-0.96418	-0.00413	0.968304	219.6042
22	2020/2/5	17	10	10	16.78322	3694.217	0.964176	15.81905	-0.95982	-0.00436	0.964176	46.01214
23	2020/2/6	18	10	20	17.74304	3693.257	0.959816	16.78322	-0.95523	-0.00459	0.959816	5.093866
24	2020/2/7	19	41	61	18.69827	3692.302	0.955227	17.74304	-0.95041	-0.00481	0.955227	1789.437
25	2020/2/8	20	3	64	19.64868	3691.351	0.950414	18.69827	-0.94538	-0.00503	0.950414	1967.04
26	2020/2/9	21	6	70	20.59406	3690.406	0.945381	19.64868	-0.94014	-0.00525	0.945381	2440.947
27	2020/2/10	22	65	135	21.5342	3689.466	0.940135	20.59406	-0.93468	-0.00546	0.940135	12874.49
28	2020/2/11	23	0	135	22.46888	3688.531	0.93468	21.5342	-0.92902	-0.00566	0.93468	12663.25
29	2020/2/12	24	39	174	23.3979	3687.602	0.92902	22.46888	-0.92316	-0.00586	0.92902	22680.99
30	2020/2/13	25	44	218	24.32106	3686.679	0.923163	23.3979	-0.91711	-0.00605	0.923163	37511.53
31	2020/2/14	26	0	218	25.23817	3685.762	0.917113	24.32106	-0.91088	-0.00624	0.917113	37157.12
32	2020/2/15	27	67	285	26.14905	3684.851	0.910876	25.23817	-0.90446	-0.00642	0.910876	67003.81
33	2020/2/16	28	70	355	27.05351	3683.946	0.904457	26.14905	-0.89786	-0.00659	0.904457	107548.9
34	2020/2/17	29	99	454	27.95137	3683.049	0.897864	27.05351	-0.8911	-0.00676	0.897864	181517.4
35	2020/2/18	30	88	542	28.84247	3682.158	0.891101	27.95137	-0.88418	-0.00693	0.891101	263330.6
36	2020/2/19	31	79	621	29.72665	3681.273	0.884175	28.84247	-0.87709	-0.00708	0.884175	349604.2
37	2020/2/20	32	13	634	30.60374	3680.396	0.877093	29.72665	-0.86986	-0.00723	0.877093	364087

Figure 2. Initial “input” spreadsheet for finding the best values of β and γ in equation (1)-(3). Numbers in columns C and D are infection reported cases and cumulative infection cases. Numbers in cell B2, B3 are initial guesses for β and γ . The SSD in L4 is the sum to be minimized in equation (14).

	A	B	C	D	E	F	G	H	I	J	K	L
1	N	3711										
2	β	0.384707										
3	γ	0.162127										SSD
4	R0	2.372879										14902.23
5		Day	Infection R	Cumulative I+R	Susceptible	Predicted I	Recovered	dS	dI	dR		SD
6	2020/1/20	1	1	1	1	3710	1	0	-0.3846	0.222477	0.162127	0
7	2020/1/21	2	0	1	1.384604	3709.615	1.222477	0.162127	-0.47012	0.271924	0.198196	0.14792
8	2020/1/22	3	0	1	1.854724	3709.145	1.494401	0.360323	-0.57462	0.332337	0.242282	0.730553
9	2020/1/23	4	0	1	2.429344	3708.571	1.826738	0.602606	-0.7023	0.406136	0.296163	2.043024
10	2020/1/24	5	0	1	3.131643	3707.868	2.232875	0.898769	-0.85828	0.49627	0.362009	4.543904
11	2020/1/25	6	0	1	3.989922	3707.01	2.729144	1.260778	-1.04879	0.606326	0.442467	8.939633
12	2020/1/26	7	0	1	5.038715	3705.961	3.33547	1.703245	-1.28144	0.740668	0.540769	16.31122
13	2020/1/27	8	0	1	6.320153	3704.68	4.076138	2.244014	-1.56545	0.904599	0.660851	28.30402
14	2020/1/28	9	0	1	7.885602	3703.114	4.980737	2.904865	-1.91205	1.104544	0.807511	47.41152
15	2020/1/29	10	0	1	9.797657	3701.202	6.085281	3.712376	-2.33487	1.348284	0.986587	77.39877
16	2020/1/30	11	0	1	12.13253	3698.867	7.433565	4.698964	-2.8504	1.645218	1.20518	123.9332
17	2020/1/31	12	0	1	14.98293	3696.017	9.078782	5.904144	-3.47857	2.006659	1.471914	195.5222
18	2020/2/1	13	0	1	18.4615	3692.539	11.08544	7.376058	-4.24344	2.446188	1.797247	304.904
19	2020/2/2	14	0	1	22.70493	3688.295	13.53163	9.173305	-5.17387	2.980028	2.19384	471.1042
20	2020/2/3	15	0	1	27.8788	3683.121	16.51166	11.36714	-6.30444	3.627453	2.676982	722.47
21	2020/2/4	16	0	1	34.18324	3676.817	20.13911	14.04413	-7.6763	4.411208	3.26509	1101.127
22	2020/2/5	17	10	10	41.85954	3669.14	24.55032	17.30922	-9.33815	5.357889	3.980265	1015.03
23	2020/2/6	18	10	20	51.19769	3659.802	29.90821	21.28948	-11.3472	6.498248	4.848922	973.2958
24	2020/2/7	19	41	61	62.54486	3648.455	36.40646	26.1384	-13.7698	7.867316	5.902462	2.386591
25	2020/2/8	20	3	64	76.31464	3634.685	44.27377	32.04087	-16.6822	9.504218	7.177965	151.6503
26	2020/2/9	21	6	70	92.99682	3618.003	53.77799	39.21883	-20.1703	11.45148	8.718854	528.8538
27	2020/2/10	22	65	135	113.1672	3597.833	65.22947	47.93769	-24.329	13.75356	10.57545	476.6731
28	2020/2/11	23	0	135	137.4962	3573.504	78.98303	58.51313	-29.2595	16.45428	12.80527	6.230822
29	2020/2/12	24	39	174	166.7557	3544.244	95.43731	71.3184	-35.0656	19.59266	15.47295	52.47976
30	2020/2/13	25	44	218	201.8213	3509.179	115.03	86.79134	-41.8462	23.19676	18.64944	261.7498
31	2020/2/14	26	0	218	243.6675	3467.332	138.2267	105.4408	-49.6852	27.27495	22.41026	658.8216
32	2020/2/15	27	67	285	293.3527	3417.647	165.5017	127.851	-58.6367	31.8044	26.83226	69.76802
33	2020/2/16	28	70	355	351.9894	3359.011	197.3061	154.6833	-68.7055	36.71688	31.9886	9.063825
34	2020/2/17	29	99	454	420.6949	3290.305	234.023	186.6719	-79.8241	41.88273	37.94139	1109.232
35	2020/2/18	30	88	542	500.519	3210.481	275.9057	224.6133	-91.827	47.09527	44.73171	1720.674
36	2020/2/19	31	79	621	592.346	3118.654	323.001	269.345	-104.426	52.05935	52.36711	821.0533
37	2020/2/20	32	13	634	696.7724	3014.228	375.0603	321.7121	-117.197	56.38972	60.80733	3940.379

Figure 3. Appearance of “output” spreadsheet from Fig 2 after Solver has finished the operation.

Estimating Uncertainties in the Least-Squares Parameters

Uncertainties in β , γ , and R_0 are as important as the values of the parameters themselves. The amount of uncertainty represents the degree to which the parameter fits the curve. The smaller the uncertainty of the parameter, the better the curve fit.

Here are steps on estimating uncertainties in β , γ , and R_0 of Fig 3 by the “jackknife” procedures^{20,21}.

1. Write the sum in cell L4 of Fig 3 in the form $L4=K6+K7+K8+\dots+K37$. Delete one term in the sum each time to generate the 32 lines of Fig 4.
2. For each column in Fig 4, compute the standard deviation with the function STDEV.
3. Find the standard error for each parameter (β , γ , and R_0) by standard deviation $/\sqrt{n}$, where n is the number of data points (=32 in Fig. 4). Standard errors are estimates of uncertainty in the least-squares parameters.
4. The final raw result and rounded result for Figs 3 and 4 are listed as follows

$$\beta = 0.384707366 \pm 0.003900661 \quad \beta = 0.3847 \pm 0.0039,$$

$$\gamma = 0.162126805 \pm 0.004553497 \quad \gamma = 0.1621 \pm 0.0046,$$

$$R_0 = 2.372879463 \pm 0.261097473 \quad R_0 = 2.37 \pm 0.26.$$

Data line deleted	β	γ	R0
L6	0.384722632	0.16212432	2.373010003
L7	0.384722633	0.16212432	2.373010006
L8	0.384722635	0.162124319	2.373010025
L9	0.384722643	0.162124319	2.373010078
L10	0.38472266	0.162124318	2.373010201
L11	0.384722694	0.162124315	2.373010456
L12	0.38472276	0.162124309	2.37301095
L13	0.384722878	0.162124296	2.373011866
L14	0.384723088	0.162124273	2.373013506
L15	0.38472345	0.16212423	2.373016365
L16	0.384778775	0.162191337	2.372375631
L17	0.386843744	0.164492665	2.35173856
L18	0.387770071	0.16552569	2.342657939
L19	0.389090391	0.166997109	2.329922908
L20	0.390942339	0.169059187	2.312458413
L21	0.39345449	0.171852999	2.289482828
L22	0.394372231	0.172870126	2.281320903
L23	0.39550094	0.174119857	2.271429271
L24	0.384724549	0.162124046	2.373025836
L25	0.390636804	0.168706525	2.315481302
L26	0.396318917	0.17500702	2.264588683
L27	0.371985155	0.147925662	2.514676301
L28	0.386590259	0.164205031	2.354314339
L29	0.380098579	0.156994582	2.421093615
L30	0.373258736	0.149398148	2.498416074
L31	0.401845909	0.180996623	2.220184573
L32	0.390405929	0.168376233	2.318652242
L33	0.383475973	0.160770837	2.38523342
L34	0.37402531	0.150722815	2.481544085
L35	0.383895758	0.162115439	2.368039467
L36	0.40045983	0.18053906	2.218134015
L37	0.267868125	0.025030036	10.70186735
Standard deviation =	0.022065473	0.025758467	1.476990347
Standard error =	0.003900661	0.004553497	0.261097473

Figure 4. Estimating uncertainties in least-squares parameters of Fig 3 by the jackknife procedures ^{20,21}

Results

As of the end of the quarantine on February 20, 2020, a total of 3,063 people has been tested by the 3,371 on the *Diamond Princess*, with a cumulative test rate of 82.5%, and 634 cases have been diagnosed with COVID-19, accounting for 17.1% of the total. It contains remarkably high asymptomatic infection cases of 328, accounted for 51.7% of all confirmed cases. As of April 24, 2020, 712 confirmed cases with 14 deaths and a cumulative mortality rate reached 1.96%. We took the older man boarding the ship on January 20 as the first case of infection, with a total population of $N = 3,711$. Using the least-squares method, the parameters β , γ , and R_0 are as follows

$$\beta = 0.3847 \pm 0.0039,$$

$$\gamma = 0.1621 \pm 0.0046,$$

$$R_0 = 2.37 \pm 0.26.$$

Using the parameters β , γ , and R_0 of SIR model, it can be further estimated that if all passengers continue to stay on the cruises when the quarantine period expires, the actively infected people in the *Diamond Princess* will reach a peak as 839 cases on Mar 1. As shown in Fig 5. Further, assuming all passengers and crews continue to extend the on-board quarantine time, we can estimate that the SIR model will reach a dynamic equilibrium in about two months. At that time, a total of 3,283 (88.47%) people will be infected. As shown in Fig 6.

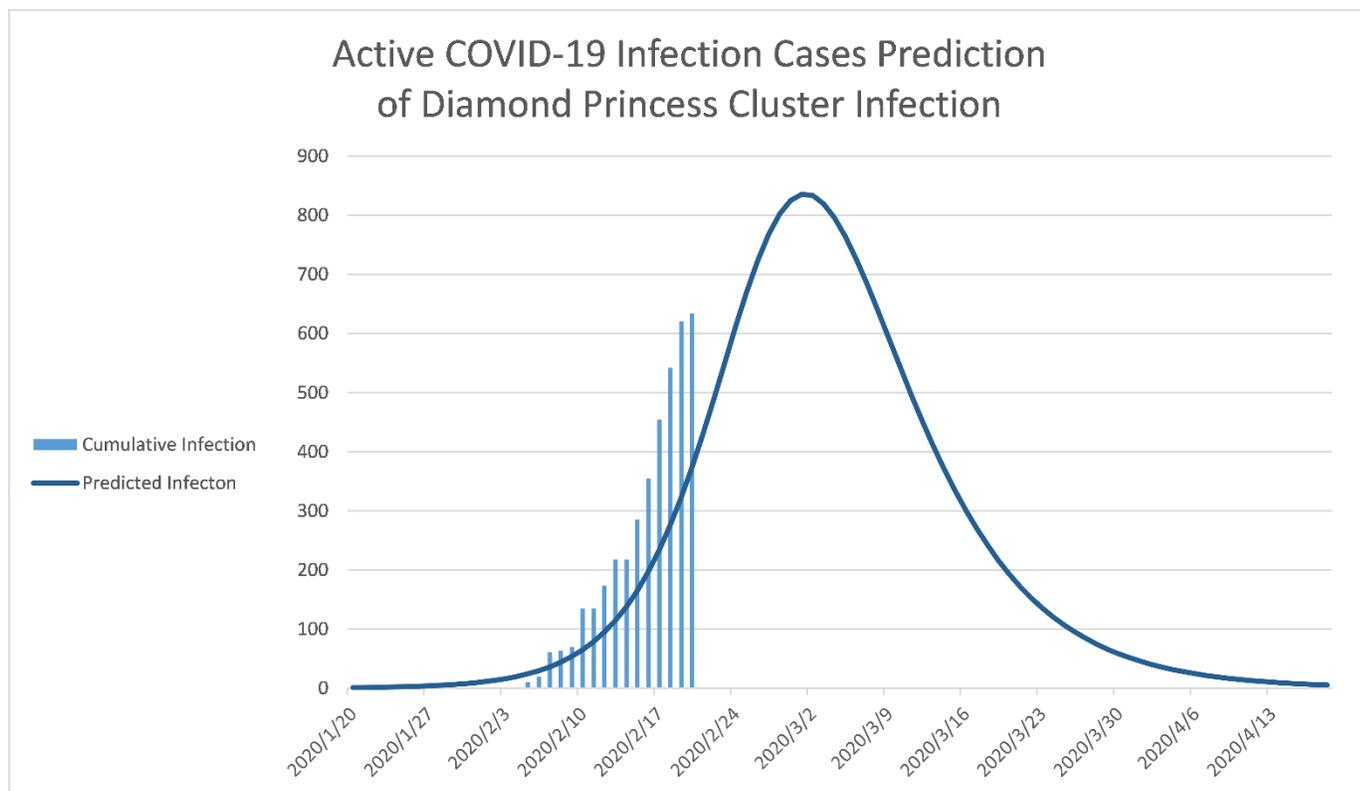


Figure 5. Estimation curve of active COVID-19 infection cases of the *Diamond Princess* cruise cluster infection

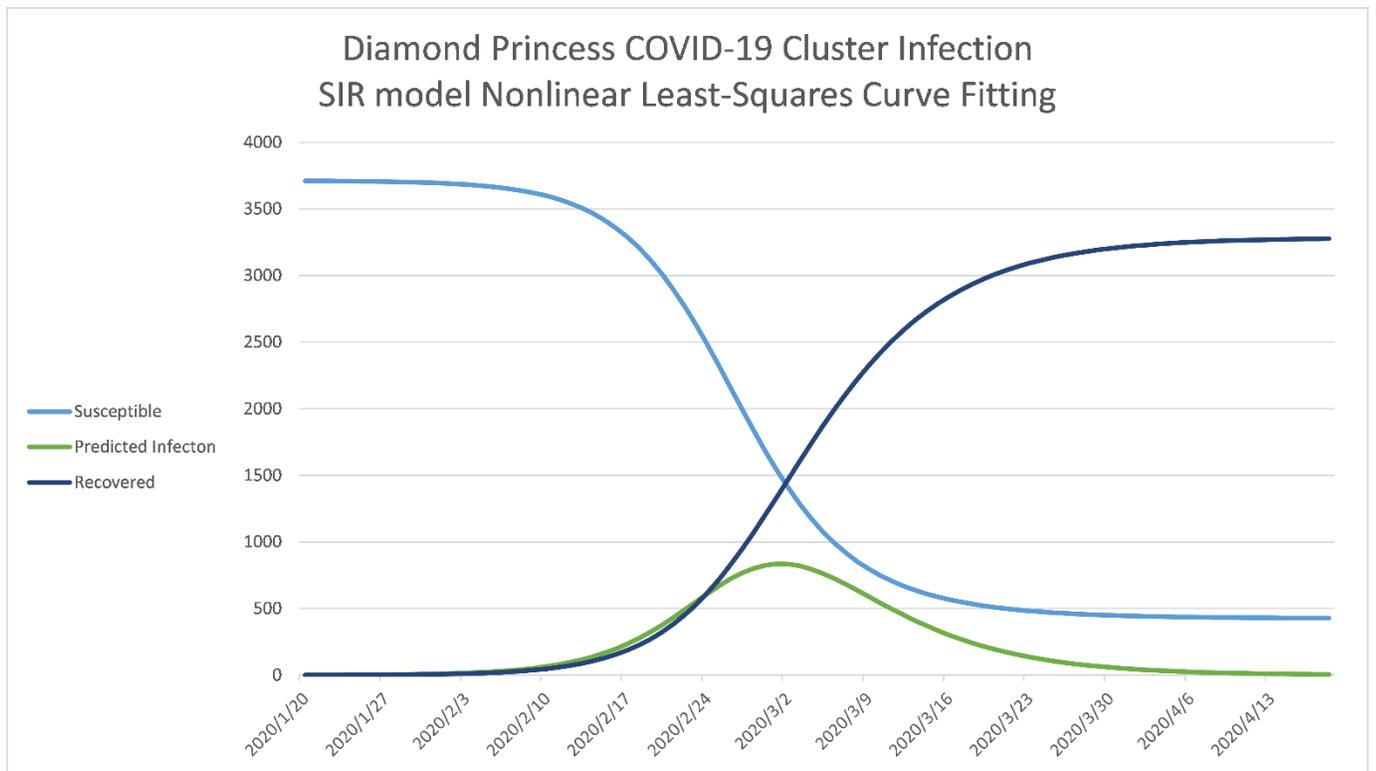


Figure 6. SIR model of the *Diamond Princess* COVID-19 cluster infection using Nonlinear Least-Squares Curve Fitting with Microsoft Excel Solver. (S: Susceptible population, I: Predicted Infection population, R: Recovered population.)

Discussion

Cruise ships isolate travelers from the world while offering ideal urban versions on land. However, problems ashore (such as large-scale coronavirus outbreaks) sometimes sneak into ships. Despite efforts to establish a strictly controlled environment on cruise ships, it is easy to spread when things like infectious diseases seep into the ship. The coronavirus outbreak on the *Diamond Princess* cruise ship also affected other ships: The *World Dream* was quarantined for four days. Royal Caribbean and Norwegian Cruise Line do not allow travelers with Chinese, Hong Kong, or Macau passports or those who have recently traveled to China. The *Westerdam* has been shut out of five countries before being allowed to dock in Cambodia. The outbreak of the COVID-19 epidemic broke the commitment and atmosphere of cruise ships sailing on the high seas independently. As the virus and fear of it spread, the problem developed rapidly, and the bubble burst. It shows how the environment reflects the medical, political, and cultural impact of the epidemic.

Several aspects of the COVID-19 cluster infection event on the *Diamond Princess* cruise ship worthy of discussion. First, is the cruise ship suitable for the isolation of infectious diseases? In the two weeks of port quarantine, the infection cases have become the largest number of people infected with the COVID-19 virus outside China. The first day that *Diamond Princess* was quarantined, 10 of the 3,711 passengers and crew members tested positive for the virus on February 4. People with symptoms left the ship and were taken to a Japanese hospital, and the remaining passengers stayed in their rooms during the quarantine. Patients without the virus allowed to disembark, and cumulative 634 cases were tested positive for the virus when quarantine was lifted on February 20. The increasing number of cases on board makes it look like it is “promoting transmission.” Indeed, without evacuation, we estimated that the cumulated infection rate will reach 88.47%.

There is no literature regarding virus sampling on the *Diamond Princess* cruise ship environment, but we can indirectly understand how viruses pollute the environment from a recent study. A virus sample was taken from the hospital environment of a patient with mild upper respiratory tract infection COVID-19 in Singapore. The results showed that the ward was extensively polluted: toilet and sink samples were positive, air samples were negative, and swabs drawn from the exhaust port were tested positive. Patients cause severe pollution to the environment through respiratory droplets and fecal discharge. Thus, the environment is a potential medium of transmission²².

Secondly, quarantine is a public health crisis for the people on board, and it can also be used as a micro-experiment: despite accelerated artificial conditions, the ship is still a small-scale model of a large-scale outbreak; even patients diagnosed in follow-up actions deserve further research. In particular, COVID-19 in addition to data from Wuhan and Hubei, China, there is also a lack of knowledge of how viruses are transmitted outside of China. As we all know, the Chinese disease prevention and control department modified the diagnostic conditions on February 13, resulting in significant data changes. Data over time for patients with the new coronavirus on the *Diamond Princess* cruise ship and the disease progression of those who are positive for the virus but not sick are extremely valuable.

A similar cluster infection occurred in the US Navy aircraft carrier Theodore Roosevelt was deployed in the Pacific Ocean, and three sailors on the ship were tested positive for COVID-19 during the preparation of this manuscript on March 24, 2020. Within a few days, this number climbed to dozens. To prevent the spread of the disease, captain Brett Crozier wanted to evacuate most of the crew ashore, but he refused. A few days later, Crozier mailed several naval officers, requesting that the ship be largely evacuated. This letter leaked to the press. Theodore Roosevelt was ordered to sail to Guam and docked on March 27²³. However, the acting naval secretary Thomas Modly relieved the captain. On March 31, more than 100 sailors tested positive. On April 1, the Navy ordered the evacuation of the aircraft carrier. The Navy stated on April 7 that 61% of Theodore Roosevelt's crew had been tested for viruses, and 173 members, including Captain Crozier, were tested positive. No one was hospitalized. 2,000 sailors have been evacuated ashore. As of April 24, 100% of members of Theodore Roosevelt aircraft carrier had been tested for viruses, including 840 positive cases, 4,098 negative cases, and one crew died. The positive rate accounted for 17.0% of the total 4,938 crew members, and 55% were asymptomatic. 4,234 sailors have moved ashore. Using the methods of this study, we estimate the basic reproduction number of the Theodore Roosevelt aircraft carrier cluster infection $R_0 = 2.53$, the relevant information is in the Appendix A. Without captain Crozier calling for help and emergency evacuation, the infection-positive rate would be much higher than 17.1% of the Diamond Princess. The US Navy released the COVID-19 mitigation and prevention framework on April 9 so that the fleet or combatant commander can improve guidance based on the latest experience, local conditions, and operational requirements²⁴. Based on the results of this study, the author suggests that large-scale ships outbreak cluster infections should dock in the shortest time, evacuate all personnel, and isolate them for testing and treatment.

In addition to the Diamond Princess, how many large cruise ships worldwide are infected with COVID-19? There are Greg Mortimer, Ruby Princess, Coral Princess, Zaandam, Grand Princess, MSC Opera, Caribbean Princess, Regal Princess, etc.

Returning to the large warships, in addition to the outbreak of COVID-19 cluster infection on the USS Theodore Roosevelt (CVN-71), there are currently the French aircraft carrier *Charles de Gaulle*, the *Chevalier Paul* air defense destroyer, and the Taiwanese *Panshi* fast combat support ship (AOE-532) reported the outbreaks.

Why are large ships prone to cluster infections? Scholars have speculated that there are five main reasons²⁵.

1. Inside the large ship, it is like a small city, and there are many social activities of thousands of people, thus facilitate more intensive and close contacts.
2. Due to long-term close contact, the spread of infectious diseases can be extended to the second or even the fourth generation and spread widely. Even if some people only stay on the ship for 1 to 3 days.
3. Thousands of people disembark from ships; these activities included playing and purchasing, which promoted the spread of different viruses worldwide.
4. Once the crew is infected, it may become a "super spreader", spread to its countrymen, and new passengers coming up one after another.
5. "Air conditioning" equipment with the poor design is added to the "narrow space" in the large ship. When a person gets infected with such a respiratory tract virus, coughs or sneezes. Especially, droplets or aerosol will be easily inhaled by another passenger.

Finally, the cluster infection data of the Diamond Princess cruise ship is consistent with the SIR transmission model, and the R_0 of COVID-19 on this cruise ship is 2.37. This value is similar to the R_0 of SARS-CoV when it broke out in Hong Kong is 2-5²⁶, and more significant than the R_0 of Mers-CoV when it broke out in the Middle East is 0.3-0.8²⁷. Due to the limitation of the detection speed and the absence of total inspection, this value may be underestimated. Besides, 51.7% of the asymptomatic patients were diagnosed on the Diamond Princess cruise ship. This data is precious because asymptomatic infected patients will not enter clinics or hospitals, or virus detection by PCR screening. This kind of data from other countries is not easily available. Besides, despite an outbreak in cruise, the mortality rate of 1.96% is far lower than the worldwide mortality rate of 3.06%. However, it is much higher than the 2009-2010 overall H1N1 influenza death rate of 0.03%²⁸. Judging from the outbreak of the COVID-19 cluster infection by the Diamond Princess, it is unwise for the Japanese government to port-quarantine all tourists on the cruise ship for two weeks, and the inaction of the British shipowner should also be responsible for this incident. According to the results of this research, "only one" passenger diagnosed with COVID-19 on a large cruise ship or warship on the high seas, epidemics will outbreak in a short time. For mitigation, it is necessary to move to the isolation dock as soon as possible. Then, evacuate all passengers and crew members to the designated isolation building on the shore, and perform the comprehensive test, and quarantine.

In conclusion, the large cruise ship travels on the high seas, and thousands of people live in densely enclosed, central air-conditioned cabins. Once the pathogen penetrates, it will become a hotbed for infectious diseases and accelerate the spreading. This study firstly uses the nonlinear least-squares curve fitting with Microsoft Excel Solver to obtain the SIR model parameters of the COVID-19 cluster infection on the Diamond Princess cruise ship. Without an emergency evacuation plan, the model estimates that the total infection rate could be as high as 88.47%. All countries should learn from this incident and work out large-scale ship quarantine procedures

Acknowledgements

Authors wishing to acknowledge assistance or encouragement from Health 101 Clinic, Beauty 101 Ltd, Taipei Medical Association, Taiwan Primary Care Association, Taiwan Medical Association, Academia Sinica colleagues, and Rear Admiral David Yang of R.O.C. Navy. The authors would like to pay the highest tribute to the frontline medical staff who fight against COVID-19.

Author contributions statement

Y.C.C. and Y.J.L. conception and design of study, H.B.T and S.S.S. acquisition of data, Y.C.C. and Y.J.L. analyzed the results, Y.C.C. and H.B.T. drafting the manuscript, H.B.T. and W.H.S. revising the manuscript critically for important intellectual content. All authors reviewed the manuscript.

Funding/supportive statement

This study was supported by the grants from the Ministry of Science and Technology (MOST 108-2511-H-002-012-), Taipei, Taiwan. The funding sources had no roles in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit this article for publication.

Competing interests

None.

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Appendix A: The *Theodore Roosevelt* aircraft carrier cluster infection SIR curve fit

The *Theodore Roosevelt* aircraft carrier has a total of 4,938 crew members. The number of daily diagnoses, the percentage of cumulative tests, asymptomatic cases, the number of people evacuated ashore are listed in Table 3^{23,24}. Using the nonlinear least-squares curve fitting to obtain the parameters of SIR model, the final rounded results of parameters β , γ , and R_0 are as follows

$$\beta = 0.3773 \pm 0.0039,$$

$$\gamma = 0.1493 \pm 0.0047,$$

$$R_0 = 2.53 \pm 0.18.$$

The model estimates that the infection peak will be reached on April 25 and the cumulative active infected cases on that day will be 1,232. Without evacuation, the infection rate will reach as high as 90.56%. The SIR model of the *Theodore Roosevelt* COVID-19 cluster infection is shown in Fig 7.

Date	Newly diagnosed cases	Cumulated positive cases	Asymptomatic cases	Cumulated negative cases	Cumulated test (%)	Evacuation ashore
3/24	3	3				
3/25	5	8				
4/1	93	101	7		26%	
4/3	36	137	42(30.7%)			
4/5	18	155				1,500
4/6	17	172			61%	
4/7	58	230			61%	2,000
4/8	56	286			92%	2,329
4/9	130	416	229(55.0%)	3,170	92%	
4/10	31	447		3,284	92%	3,155
4/11	103	550		3,673	92%	3,696
4/12	35	585		3,724	92%	3,967
4/13	0	585		3,921	92%	4,021
4/14	4	589		3,922	93%	4,024
4/15	26	615		3,958	94%	4,046
4/16	40	655		3,919	94%	4,059
4/17	14	669		3,913	94%	4,065

Date	Newly diagnosed cases	Cumulated positive cases	Asymptomatic cases	Cumulated negative cases	Cumulated test (%)	Evacuation ashore
4/19	9	678		3,904	94%	4,069
4/21	32	710		3,872	94%	4,158
4/22	67	777		3,949	99%	4,196
4/23	63	840		4,098	100%	4,234

Table 3. Number of confirmed cases and date of diagnosis on the *Theodore Roosevelt*

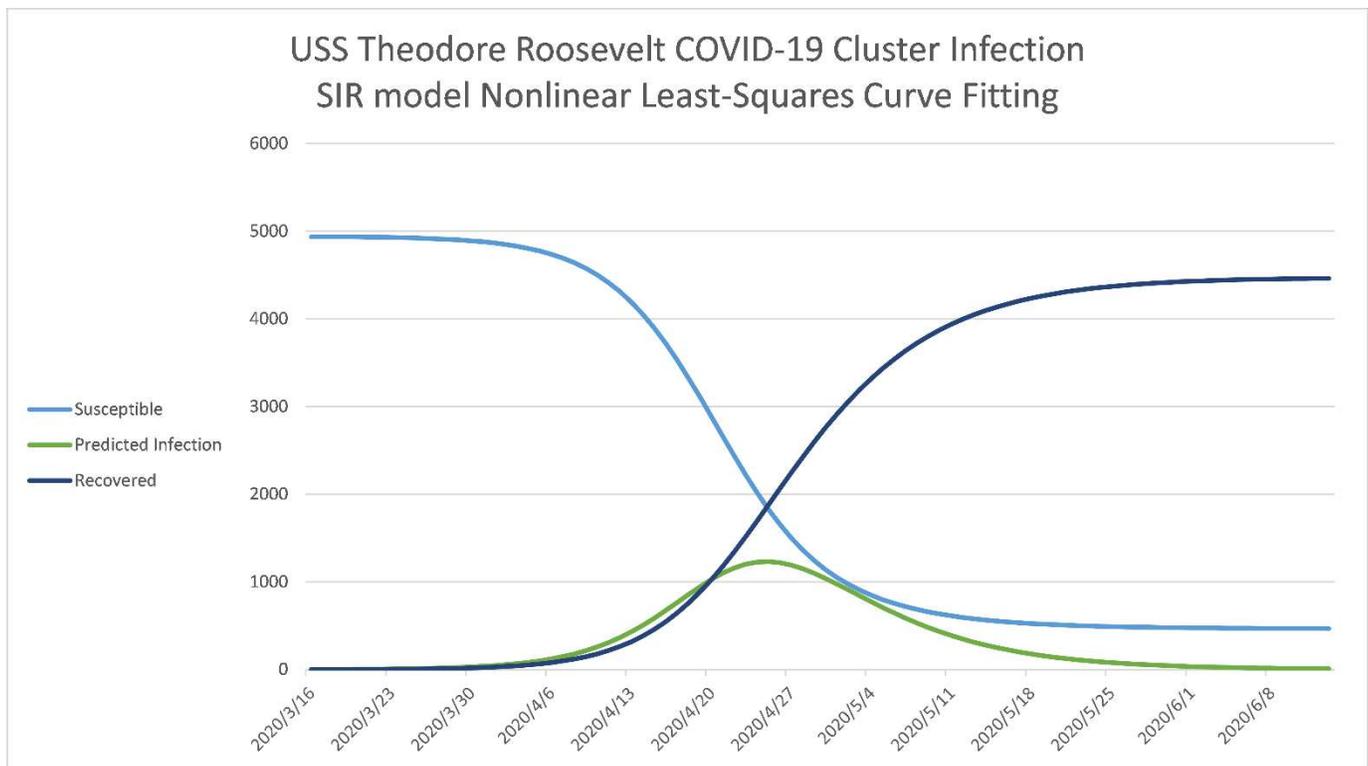


Figure 7. SIR model of the *Theodore Roosevelt* COVID-19 cluster infection using Nonlinear Least-Squares Curve Fitting with Microsoft Excel Solver

Figures

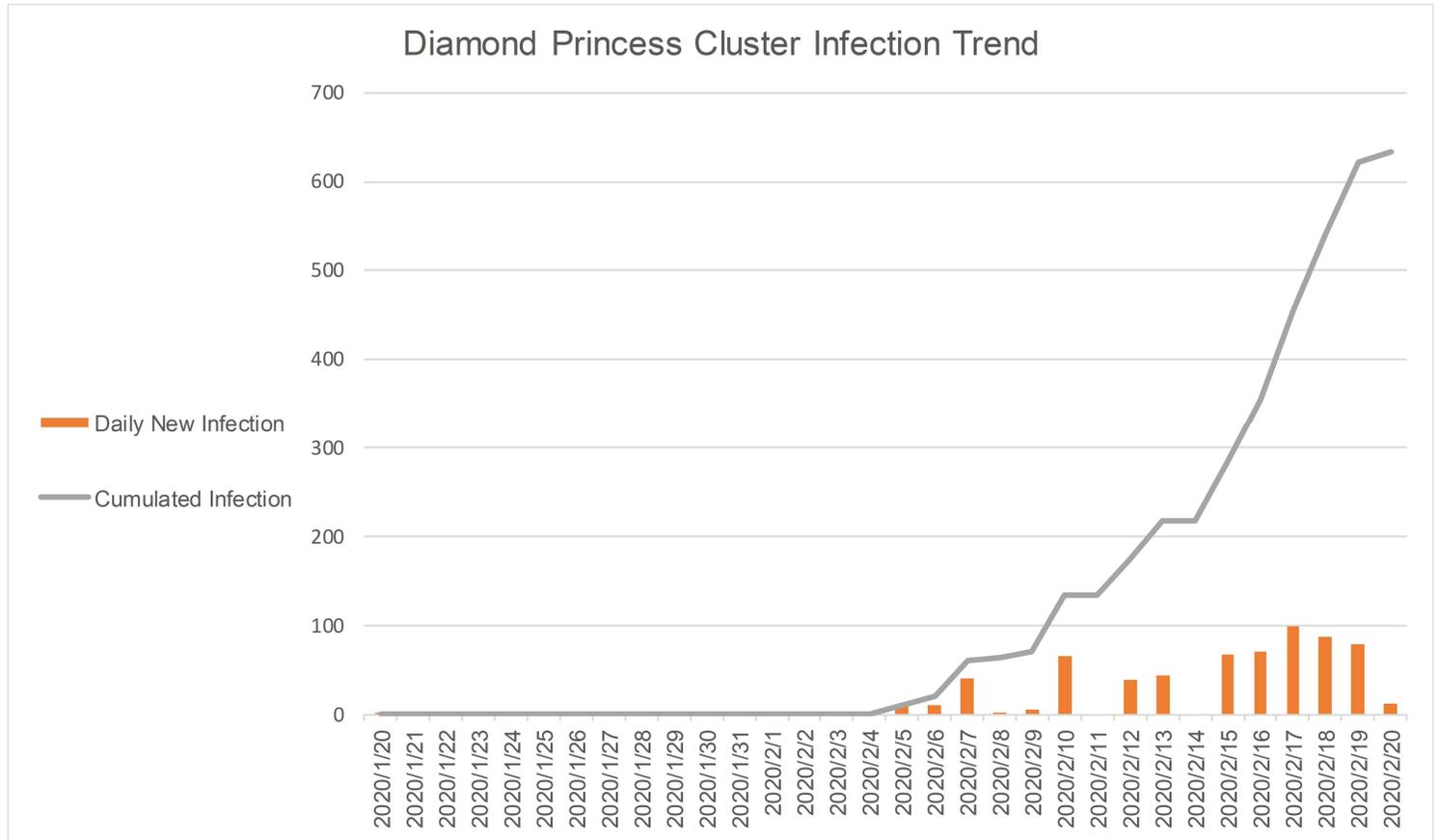


Figure 1

The trend of cluster infection of the Diamond Princess cruise ship.

	A	B	C	D	E	F	G	H	I	J	K	L
1	N	3711										
2	β	1										
3	γ	1										SSD
4	R0	1										1463448
5		Day	Infection R	Cumulative I+R	Susceptible	Predicted I	Recovered	dS	dI	dR	SD	
6	2020/1/20	1	1	1	1	3710	1	0	-0.99973	-0.00027	1	0
7	2020/1/21	2	0	1	1.999731	3709	0.999731	1	-0.99919	-0.00054	0.999731	0.999461
8	2020/1/22	3	0	1	2.998922	3708.001	0.999192	1.999731	-0.99838	-0.00081	0.999192	3.995691
9	2020/1/23	4	0	1	3.997307	3707.003	0.998384	2.998922	-0.99731	-0.00108	0.998384	8.983847
10	2020/1/24	5	0	1	4.994616	3706.005	0.997309	3.997307	-0.99597	-0.00134	0.997309	15.95695
11	2020/1/25	6	0	1	5.990582	3705.009	0.995967	4.994616	-0.99436	-0.00161	0.995967	24.90591
12	2020/1/26	7	0	1	6.984941	3704.015	0.994359	5.990582	-0.99249	-0.00187	0.994359	35.81952
13	2020/1/27	8	0	1	7.977428	3703.023	0.992487	6.984941	-0.99035	-0.00213	0.992487	48.68451
14	2020/1/28	9	0	1	8.967782	3702.032	0.990354	7.977428	-0.98796	-0.00239	0.990354	63.48555
15	2020/1/29	10	0	1	9.955743	3701.044	0.987961	8.967782	-0.98531	-0.00265	0.987961	80.20533
16	2020/1/30	11	0	1	10.94105	3700.059	0.98531	9.955743	-0.98241	-0.0029	0.98531	98.82453
17	2020/1/31	12	0	1	11.92346	3699.077	0.982405	10.94105	-0.97925	-0.00316	0.982405	119.3219
18	2020/2/1	13	0	1	12.90271	3698.097	0.979249	11.92346	-0.97584	-0.0034	0.979249	141.6744
19	2020/2/2	14	0	1	13.87855	3697.121	0.975844	12.90271	-0.97219	-0.00365	0.975844	165.8571
20	2020/2/3	15	0	1	14.85074	3696.149	0.972194	13.87855	-0.9683	-0.00389	0.972194	191.8431
21	2020/2/4	16	0	1	15.81905	3695.181	0.968304	14.85074	-0.96418	-0.00413	0.968304	219.6042
22	2020/2/5	17	10	10	16.78322	3694.217	0.964176	15.81905	-0.95982	-0.00436	0.964176	46.01214
23	2020/2/6	18	10	20	17.74304	3693.257	0.959816	16.78322	-0.95523	-0.00459	0.959816	5.093866
24	2020/2/7	19	41	61	18.69827	3692.302	0.955227	17.74304	-0.95041	-0.00481	0.955227	1789.437
25	2020/2/8	20	3	64	19.64868	3691.351	0.950414	18.69827	-0.94538	-0.00503	0.950414	1967.04
26	2020/2/9	21	6	70	20.59406	3690.406	0.945381	19.64868	-0.94014	-0.00525	0.945381	2440.947
27	2020/2/10	22	65	135	21.5342	3689.466	0.940135	20.59406	-0.93468	-0.00546	0.940135	12874.49
28	2020/2/11	23	0	135	22.46888	3688.531	0.93468	21.5342	-0.92902	-0.00566	0.93468	12663.25
29	2020/2/12	24	39	174	23.3979	3687.602	0.92902	22.46888	-0.92316	-0.00586	0.92902	22680.99
30	2020/2/13	25	44	218	24.32106	3686.679	0.923163	23.3979	-0.91711	-0.00605	0.923163	37511.53
31	2020/2/14	26	0	218	25.23817	3685.762	0.917113	24.32106	-0.91088	-0.00624	0.917113	37157.12
32	2020/2/15	27	67	285	26.14905	3684.851	0.910876	25.23817	-0.90446	-0.00642	0.910876	67003.81
33	2020/2/16	28	70	355	27.05351	3683.946	0.904457	26.14905	-0.89786	-0.00659	0.904457	107548.9
34	2020/2/17	29	99	454	27.95137	3683.049	0.897864	27.05351	-0.8911	-0.00676	0.897864	181517.4
35	2020/2/18	30	88	542	28.84247	3682.158	0.891101	27.95137	-0.88418	-0.00693	0.891101	263330.6
36	2020/2/19	31	79	621	29.72665	3681.273	0.884175	28.84247	-0.87709	-0.00708	0.884175	349604.2
37	2020/2/20	32	13	634	30.60374	3680.396	0.877093	29.72665	-0.86986	-0.00723	0.877093	364087

Figure 2

Initial “input” spreadsheet for finding the best values of β and γ in equation (1)-(3). Numbers in columns C and D are infection reported cases and cumulative infection cases. Numbers in cell B2, B3 are initial guesses for β and γ . The SSD in L4 is the sum to be minimized in equation (14).

	A	B	C	D	E	F	G	H	I	J	K	L
1	N	3711										
2	β	0.384707										
3	γ	0.162127										SSD
4	R0	2.372879										14902.23
5	Day	Infection R	Cumulative I+R	Susceptible	Predicted I	Recovered	dS	dI	dR	SD		
6	2020/1/20	1	1	1	1	3710	1	0	-0.3846	0.222477	0.162127	0
7	2020/1/21	2	0	1	1.384604	3709.615	1.222477	0.162127	-0.47012	0.271924	0.198196	0.14792
8	2020/1/22	3	0	1	1.854724	3709.145	1.494401	0.360323	-0.57462	0.332337	0.242282	0.730553
9	2020/1/23	4	0	1	2.429344	3708.571	1.826738	0.602606	-0.7023	0.406136	0.296163	2.043024
10	2020/1/24	5	0	1	3.131643	3707.868	2.232875	0.898769	-0.85828	0.49627	0.362009	4.543904
11	2020/1/25	6	0	1	3.989922	3707.01	2.729144	1.260778	-1.04879	0.606326	0.442467	8.939633
12	2020/1/26	7	0	1	5.038715	3705.961	3.33547	1.703245	-1.28144	0.740668	0.540769	16.31122
13	2020/1/27	8	0	1	6.320153	3704.68	4.076138	2.244014	-1.56545	0.904599	0.660851	28.30402
14	2020/1/28	9	0	1	7.885602	3703.114	4.980737	2.904865	-1.91205	1.104544	0.807511	47.41152
15	2020/1/29	10	0	1	9.797657	3701.202	6.085281	3.712376	-2.33487	1.348284	0.986587	77.39877
16	2020/1/30	11	0	1	12.13253	3698.867	7.433565	4.698964	-2.8504	1.645218	1.20518	123.9332
17	2020/1/31	12	0	1	14.98293	3696.017	9.078782	5.904144	-3.47857	2.006659	1.471914	195.5222
18	2020/2/1	13	0	1	18.4615	3692.539	11.08544	7.376058	-4.24344	2.446188	1.797247	304.904
19	2020/2/2	14	0	1	22.70493	3688.295	13.53163	9.173305	-5.17387	2.980028	2.19384	471.1042
20	2020/2/3	15	0	1	27.8788	3683.121	16.51166	11.36714	-6.30444	3.627453	2.676982	722.47
21	2020/2/4	16	0	1	34.18324	3676.817	20.13911	14.04413	-7.6763	4.411208	3.26509	1101.127
22	2020/2/5	17	10	10	41.85954	3669.14	24.55032	17.30922	-9.33815	5.357889	3.980265	1015.03
23	2020/2/6	18	10	20	51.19769	3659.802	29.90821	21.28948	-11.3472	6.498248	4.848922	973.2958
24	2020/2/7	19	41	61	62.54486	3648.455	36.40646	26.1384	-13.7698	7.867316	5.902462	2.386591
25	2020/2/8	20	3	64	76.31464	3634.685	44.27377	32.04087	-16.6822	9.504218	7.177965	151.6503
26	2020/2/9	21	6	70	92.99682	3618.003	53.77799	39.21883	-20.1703	11.45148	8.718854	528.8538
27	2020/2/10	22	65	135	113.1672	3597.833	65.22947	47.93769	-24.329	13.75356	10.57545	476.6731
28	2020/2/11	23	0	135	137.4962	3573.504	78.98303	58.51313	-29.2595	16.45428	12.80527	6.230822
29	2020/2/12	24	39	174	166.7557	3544.244	95.43731	71.3184	-35.0656	19.59266	15.47295	52.47976
30	2020/2/13	25	44	218	201.8213	3509.179	115.03	86.79134	-41.8462	23.19676	18.64944	261.7498
31	2020/2/14	26	0	218	243.6675	3467.332	138.2267	105.4408	-49.6852	27.27495	22.41026	658.8216
32	2020/2/15	27	67	285	293.3527	3417.647	165.5017	127.851	-58.6367	31.8044	26.83226	69.76802
33	2020/2/16	28	70	355	351.9894	3359.011	197.3061	154.6833	-68.7055	36.71688	31.9886	9.063825
34	2020/2/17	29	99	454	420.6949	3290.305	234.023	186.6719	-79.8241	41.88273	37.94139	1109.232
35	2020/2/18	30	88	542	500.519	3210.481	275.9057	224.6133	-91.827	47.09527	44.73171	1720.674
36	2020/2/19	31	79	621	592.346	3118.654	323.001	269.345	-104.426	52.05935	52.36711	821.0533
37	2020/2/20	32	13	634	696.7724	3014.228	375.0603	321.7121	-117.197	56.38972	60.80733	3940.379

Figure 3

Appearance of “output” spreadsheet from Fig 2 after Solver has finished the operation.

Data line			
deleted	β	γ	R0
L6	0.384722632	0.16212432	2.373010003
L7	0.384722633	0.16212432	2.373010006
L8	0.384722635	0.162124319	2.373010025
L9	0.384722643	0.162124319	2.373010078
L10	0.38472266	0.162124318	2.373010201
L11	0.384722694	0.162124315	2.373010456
L12	0.38472276	0.162124309	2.37301095
L13	0.384722878	0.162124296	2.373011866
L14	0.384723088	0.162124273	2.373013506
L15	0.38472345	0.16212423	2.373016365
L16	0.384778775	0.162191337	2.372375631
L17	0.386843744	0.164492665	2.35173856
L18	0.387770071	0.16552569	2.342657939
L19	0.389090391	0.166997109	2.329922908
L20	0.390942339	0.169059187	2.312458413
L21	0.39345449	0.171852999	2.289482828
L22	0.394372231	0.172870126	2.281320903
L23	0.39550094	0.174119857	2.271429271
L24	0.384724549	0.162124046	2.373025836
L25	0.390636804	0.168706525	2.315481302
L26	0.396318917	0.17500702	2.264588683
L27	0.371985155	0.147925662	2.514676301
L28	0.386590259	0.164205031	2.354314339
L29	0.380098579	0.156994582	2.421093615
L30	0.373258736	0.149398148	2.498416074
L31	0.401845909	0.180996623	2.220184573
L32	0.390405929	0.168376233	2.318652242
L33	0.383475973	0.160770837	2.38523342
L34	0.37402531	0.150722815	2.481544085
L35	0.383895758	0.162115439	2.368039467
L36	0.40045983	0.18053906	2.218134015
L37	0.267868125	0.025030036	10.70186735
Standard			
deviation =	0.022065473	0.025758467	1.476990347
Standard			
error =	0.003900661	0.004553497	0.261097473

Figure 4

Estimating uncertainties in least-squares parameters of Fig 3 by the jackknife procedures

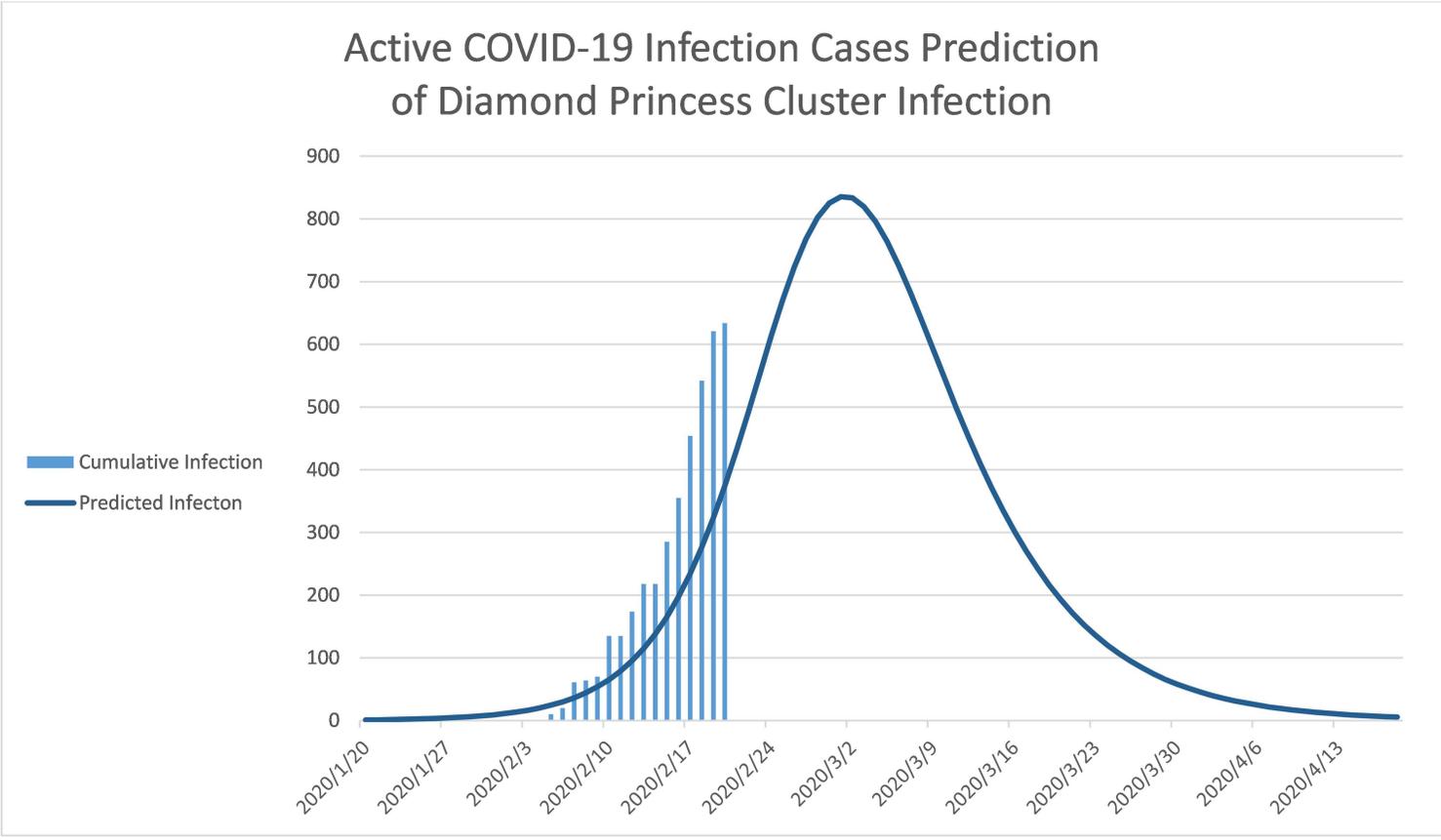


Figure 5

Estimation curve of active COVID-19 infection cases of the Diamond Princess cruise cluster infection

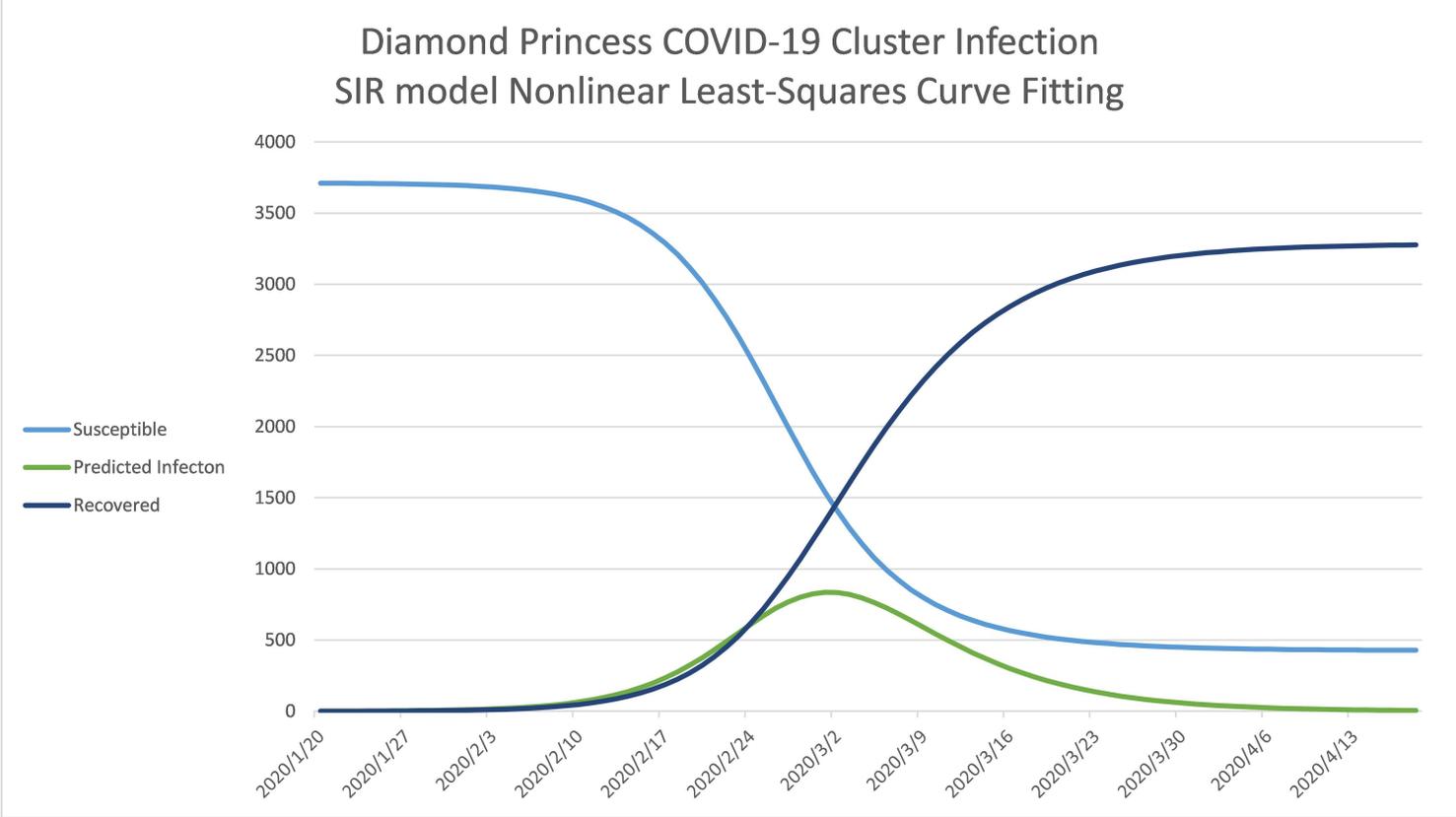


Figure 6

SIR model of the Diamond Princess COVID-19 cluster infection using Nonlinear Least-Squares Curve Fitting with Microsoft Excel Solver. (S: Susceptible population, I: Predicted Infection population, R: Recovered population.)

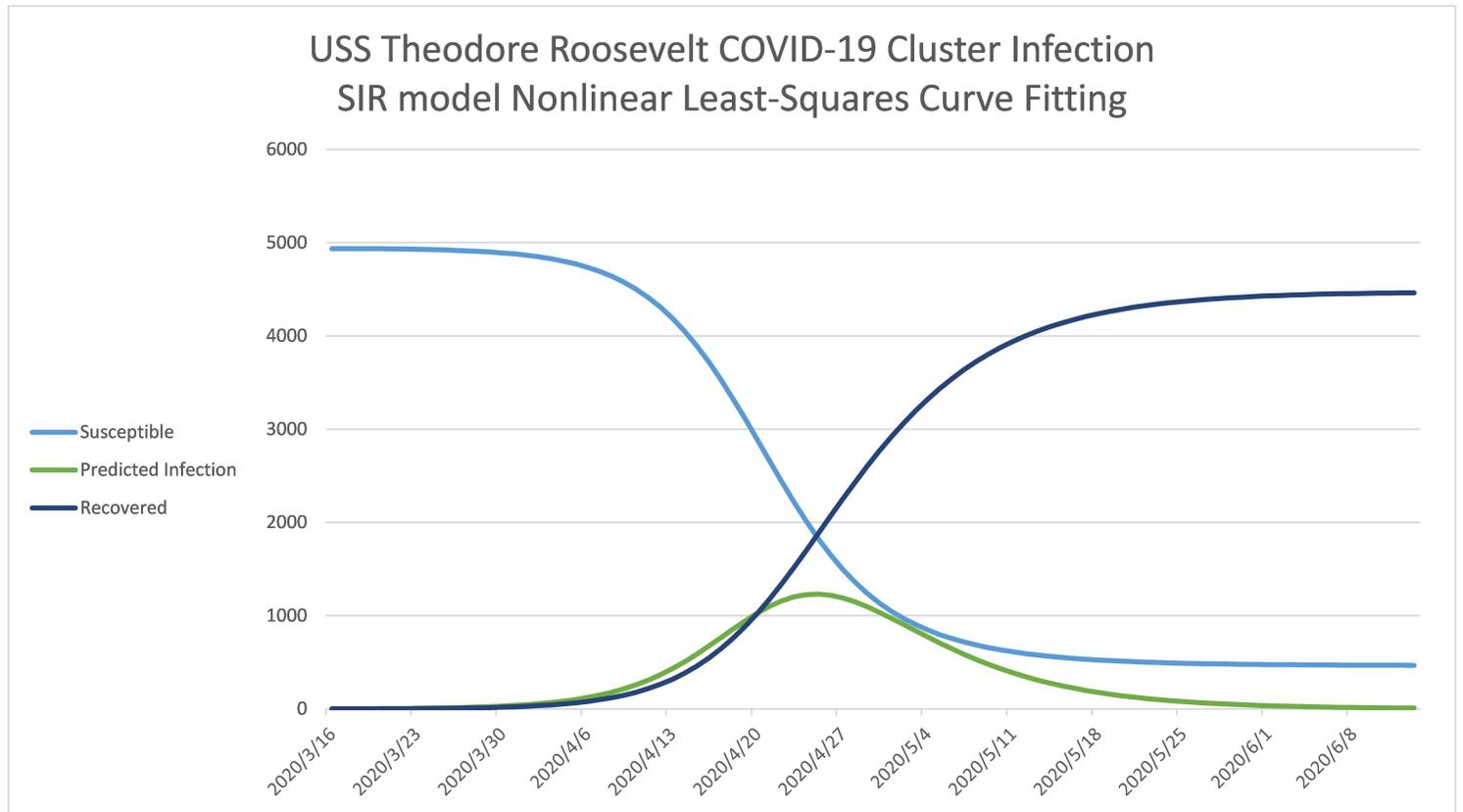


Figure 7

SIR model of the Theodore Roosevelt COVID-19 cluster infection using Nonlinear Least-Squares Curve Fitting with Microsoft Excel Solver

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [COVID19intheDiamondPrincesssuppdata.xlsx](#)