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for National Plant Biosecurity

Final Report

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Network Theory and Invasive Species – 'Six Degrees of Preparation'

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1. Executive Summary

Two types of models were created during this project:

1. The first model analysed an international shipping network, with the aim of generating arrival likelihoods for invasive species in shipping containers. The model was a first order Markov model and all pathways were broken up into individual port to port segments. This allowed an infected container to be transferred from one ship to another at any port. The model was applied to the distribution of Khapra beetle in order to identify the most likely foreign sources for this invasive species to arrive into Australia, and also those Australian ports most likely to receive a container infected with this species. The model predicted that Taiwan and the Republic of Korea were clearly the most likely sources for Khapra beetle, while the port of Melbourne was the most likely Australian port to receive this species. Sensitivity analysis demonstrated that this model was stable in response to possible variations in parameters, while a Khapra beetle incursion that occurred in Perth in 2007 confirmed the most likely sources for this species. This section is now in review with the peer reviewed journal, PLoS ONE.

2. The second model analysed the same international shipping network, but was used to predict arrival likelihood for a large number of insect pest species (564) on ships themselves. The model combined arrival likelihood with establishment likelihoods generated from a SOM analysis (CRC10001) to determine invasion likelihoods for all species. This enabled the ranking of all invasive species at all Australian ports by invasion likelihood. In addition, invasion likelihoods were further delineated by distinguishing arriving ships' last port of call. Sensitivity analysis showed this model also to be resilient to significant changes in model parameters. These model outputs could then be used by quarantine inspection officers to prioritise ship inspection protocols, though further work is needed to modify the model so as to be operationalised by DAFF and incorporated into a 'real time' analysis of all incoming ships to Australian ports.

2. Aims and objectives

Two potential vectors for invasive species to arrive into Australia are within shipping containers or on ships themselves. This work therefore had two main aims:

1. Develop a model that will analyse an international shipping container network in order to:
    a. Identify those foreign countries/ports with the highest likelihood of being a source for an invasive species to invade Australia
    b. Identify those Australian ports with the highest likelihood of receiving an invasive species
    c. Estimate the likelihood of arrival to Australia for an invasive species
2. Develop a model that will analyse an international shipping network in order to:
    a. Identify those foreign countries/ports with the highest likelihood of being a source for an invasive species to invade Australia
    b. Identify those Australian ports with the highest likelihood of receiving an invasive species
    c. Estimate the likelihood of arrival to Australia for an invasive species

The main beneficiary of this work will be DAFF, who run the inspection and interception system for all incoming ships and shipping containers. In addition, any industry can use the outputs of these models to identify high invasion threats from particular pests or diseases (as illustrated for a stored grain pest, the Khapra beetle).

3. Key findings

3.1. Invasive species in shipping containers

Ideally, to estimate invasive species arrival in shipping containers it would be necessary to analyse the international shipping container network. Unfortunately, this data is not collected by any agency or organisation and is only held by the shipping companies themselves, who are unwilling or unable to provide this data. As an alternative it is possible to analyse the international network of container ships using a Markov model, which is presented below. The model is applied to the Khapra beetle (*Trodogerma granarium*) as a case study to illustrate the application of this model.

Methods

Data was obtained from the Lloyd's Maritime Intelligence Unit (LMIU) detailing every fully cellular container ship that arrived into Australian ports between 1 January 2002 and 31 December 2007. This data set contained the previous ten ports of call for these container ships before arriving into one of 30 Australian ports, documenting 25,507 arrivals and departures of 557 container ships, with many ships arriving multiple times during this period. These ships travelled from and to 553 foreign ports in 126 countries.

I analysed this complex network of international shipping routes to identify potential origins of introduction (i.e. source countries and international foreign ports) for the highly invasive Khapra beetle (*Trogoderma granarium*) to Australia. I also identify and rank those Australian ports most likely to receive this invasive species. The Khapra beetle is a pest of stored grain, causing significant economic damage across the world (Plant Health Australia 2005), and has been nominated as among 100 of the 'World's Worst' invaders (Global Invasive Species Database 2012). If the Khapra beetle became established in Australia, it could have a significant impact on the Australian grain industry via reduced yields and increased treatment costs (Ridsill-Smith et al. 2008, Cook, unpublished data).

As such, the Khapra beetle has been identified as a high priority exotic pest of the Australian grains industry by Plant Health Australia who have developed an industry biosecurity plan should there be an incursion (Plant Health Australia 2005). This study aims to identify those countries and overseas ports most likely to be the source of a potential incursion thereby aiding in the development of more effective surveillance and inspection efforts in order to prevent this pest arriving to Australian shores.

In order to build the network of potential pathways of Khapra beetle (*Trogoderma granarium*) introductions to Australian ports, I used the world wide distribution of Khapra beetle from the CABI Crop Protection Compendium (CABI CPC 2011). This distribution was used to identify the ports within the known species range. While the pest is found in 36 countries, the container ships arriving into Australian ports during this period only travelled to 24 of them (87 ports).

Pathway model

This study focused exclusively on long-distance movement of the Khapra beetle with containerised marine shipments. I estimated the potential of Khapra beetle to arrive with marine container vessels via the application of a pathway-based model of Khapra beetle spread with marine container vessels through an international marine shipping network.

For this study, I assumed that some transmission potential existed between all intermediate locations within the shipment route. Consider a vessel route A-B-C-D, where A, B, and C denote the foreign ports of call and D is a destination port in Australia. Given that the ship has taken and unloaded containerised cargoes at each port, it is feasible to assume that the pest could be moved through the segments A-B, B-C, C-D, as well as segments A-C, B-D and A-D. Hence, I decomposed all routes that included more than two nodes in to the combinations of unique segments *i* to *j*. This information then was used to assemble a database of unique pairs of 'origin'-'destination' ports, *ij* and the associated numbers of vessels travelled through each particular segment *i* to *j*.

The records did not detail the actual number of containers that have been unloaded or loaded at each particular port; hence we assumed that each vessel would have similar capacity to carry the pest in a containerized cargo. We acknowledge that more detailed information on the cargo types in cellular containers and the tonnages of loaded/unloaded containers could improve the accuracy of the pathway predictions however this information was not available.

In summary, each unique pathway segment, *i* to *j* had an associated number of trips between two given ports, *i* and *j*, m_{ij}. I then rescaled the number of trips to the transmission rate value, p_{ij}, of the beetle being moved from *i* to *j* over the survey period (2002-2007) based on the total number of container vessels travelling from *i* to *j*:

$$p_{ij} = m_{ij}\lambda_t \qquad [1]$$

where λ_t is the rate of Khapra beetle transmission with one container vessel over the survey period *t*. Essentially, λ_t is a scaling coefficient that translates the number of trips to a transmission rate value so the sum of the transmission rates is below 1:

$$\sum_{j=1}^{n} m_{ij}\lambda_t < 1 \qquad [2]$$

The transmission matrix, $\mathbf{P}_t$ of the pest being moved along each pathway segment was then estimated accordingly:

$$\mathbf{P}_t = \begin{bmatrix} 0 & \lambda_t m_{12} & \dots & \lambda_t m_{1n} \\ \lambda_t m_{21} & 0 & \dots & \lambda_t m_{2n} \\ \dots & \dots & \dots & \dots \\ \lambda_t m_{n1} & \lambda_t m_{n2} & \dots & 0 \end{bmatrix} \qquad [3]$$

Note that the value of λ_t is relative only to the number of vessels recorded in the Lloyds data between 2002 and 2007. Because the pathway model was only used in a relative context – to order the foreign ports by their *relative* potential to be the source of Khapra beetle incursions at Australian ports (i.e., that the port X has a higher potential to be the source of beetle incursions than the port Y) – a precise estimation of λ_t was unnecessary.

In our case, we selected the λ_t value to ensure any row in the matrix $\mathbf{P}_t$ satisfies the condition in Eq. 2 (so the row sum of the transmission rates is below 1).

The matrix had a size, Y, equal to the number of port locations in the Lloyds register data (i.e. the nodes of the shipping network). The data did not provide information about the number of containers unloaded/loaded at intermediate ports, so the diagonal elements of $\mathbf{P}_t$ were set to 0.

I also added an extra column to the matrix $\mathbf{P}_t$ that describes the potential of the Khapra beetle not surviving transit from *i* to *j*, i.e.:

$$\mathbf{P}_t = \begin{bmatrix} 0 & p_{12} & \cdots & p_{1n} & 1-\sum_{j=1}^{n} p_{1j} \\ p_{21} & 0 & \cdots & p_{2n} & 1-\sum_{j=1}^{n} p_{2j} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_{n1} & p_{n2} & \cdots & 0 & 1-\sum_{j=1}^{n} p_{nj} \end{bmatrix} \quad [4]$$

where the elements $1-\sum_{j=1}^{n} p_{ij}$ describe the mortality of an invasive organism during transit from *i* to *j*.

The pathway matrix $\mathbf{P}_t$ was then used to generate stochastic realisations of potential movements of the beetle from the foreign ports in regions where the Khapra beetle is known to exist. Starting at each port in the countries with Khapra beetle (one port at a time), the model simulated the subsequent movements of the beetle to other locations by extracting the associated vector of transmission rates from the matrix $\mathbf{P}_t$ at each port's location and using it to select the next port. The process continued until the chosen location had no outgoing paths recorded in the $\mathbf{P}_t$ or a terminal state was selected based on the elements $1-\sum_{j=1}^{n} p_{ij}$ in Eq. 4. Finally, I estimated the rates of pest arrival from the location *i* from *j*, φ_{ij}, from the number of times, J_i the pathways originated at a given port *i* within a Khapra beetle range arrived at the port *j* over the multiple stochastic pathway simulations:

$$\varphi_{ij} = J_i/K \quad [5]$$

where *K* is the total number of individual simulations of the pathway spread from *i* (*K* = $2x10^6$ for each port of origin *i*). Note that the value of φ_{ij} was also estimated for each port in the network *i* outside of the Khapra beetle known range, however this study focuses on Australian ports only. Notably, the value of φ_{ij} is conditional on the value of λ chosen. However, since λ was a linear multiplier applied to each element of the matrix $\mathbf{P}_t$, changes in its value did not affect the partial order relationships based on the estimated arrival rate values, φ_{ij} and consecutively, the ranking of the individual ports by the Khapra beetle incursion potential.

Reverse pathway analysis with the pathway model

The forward-looking simulations provided for each port within the Khapra beetle range, *i*, list the arrival rates, φ_{ij} to the destination ports *j* in Australia. For each port of origin *i* within the Khapra beetle range, I then compiled the lists of the arrival rate values, φ_{ij} for all other 'destination' locations in Australia, *j*, $j = 1,..., n, j \neq i$. I then tabulated the φ_{ij} values in a way so each 'destination' location in the shipping network, *j* (i.e., an Australian port) had a corresponding list of the ports-potential origins, *i* (i.e. from where the pathway simulations were originally started) with the corresponding arrival rate values from the origin *i* to a destination *j*. Formally, this step required assembling a table of the φ_{ij} values in dimensions of the origin and destination ports (see example in Table 3-1). In short, Table 3-1 stores the results of forward-looking pathway simulations from individual locations, *i*, $i = 1, ..., n$ by rows (i.e., each row 'Port 1, 2, ..., *n'* stores the results of forward-looking pathway simulations from a single node). Each row in Table 3-1 lists the arrival rates, φ_{ij} and their relative values versus the shipping network's mean rate of the pest being moved from the port of origin, *i*, (marked as 'origin' in Table 3-1) to the other ports. Each column in Table 3-1 summarizes the rates of pest's transmission to a given 'destination' *j* (shown in the column's head) if it was present at the point of origin, *i*. Because the pathway simulations from each 'origin' node (*i*) used the same number of replications (*K*, see Eq.5) the φ_{ij} values in Table 3-1 columns are comparable each with other. For example, row 2 ('Port 1', Table 3-1a) shows the pest's arrival rates from the port 1 to the ports 2, 3, ..., *n* (i.e. the summary of pathway simulations from the port 1). Alternatively, column 3 (Table 3-1b) shows the rates of the pest arriving to the port 3 from other ports in the network, (i.e. ports 1, 2, ..., *n*). In broad terms, the φ_{ij} values in the column 3 depict the likely origins of the potential arrivals of Khapra beetle to port 3.

Table 3-1. An illustration of the reverse pathway assessment: (a) – a table's rows (e.g., the φ_{ij} values in the shaded area) denote the rates of the pest being moved from a given origin location (i.e., the 'Origin port 1') to other locations in the shipping network (i.e., the columns 2, 3, ..., *n*); (b) – columns in the table (e.g., the φ_{ij} values in column 4 outlined in bold) show the rates of the pest being moved to a given destination location (e.g. Destination port 3) from the other origin locations (i.e., the Origin ports 1, 2, ..., *n*).

	Locations (ports) in the marine shipping network					
"Origin" location (starting point of pathway simulations)	Destination port 1	Destination port 2	Destination port 3	...	Destination port *n*	
Origin port 1	1 (origin)	$\varphi_{1\to2}$	$\varphi_{1\to3}$	...	$\varphi_{1\to n}$	← (a)
Origin port 2	$\varphi_{2\to1}$	1 (origin)	$\varphi_{2\to3}$	...	$\varphi_{2\to n}$	
Origin port 3	$\varphi_{3\to1}$	$\varphi_{3\to2}$	1 (origin)	...	$\varphi_{3\to n}$	
...	...	...	...	...	...	
Origin port *n*	$\varphi_{n\to1}$	$\varphi_{n\to2}$	$\varphi_{n\to3}$ ...	...	1 (origin)	
			← (b) →			

I further summarised movement of the pest through the shipping network in two ways. First, for each Australian port, *j*, I generated an overall arrival rate of the Khapra beetle from all foreign ports as:

$$\varphi_j = 1 - \prod_{j=1}^{n, j\neq i} \left[1 - \varphi_{ij}\right] \qquad [6]$$

where equation [6] is the product of all the beetle arrival rate values from all foreign ports to an Australian port, *j*.

I then used φ_j to rank the Australian ports by their potential to receive containers from the ports in the regions infested with Khapra beetle. Similarly, we generated overall beetle arrival rates from each foreign port to all Australian ports combined. These values were then used to rank foreign ports by their potential to be the origin of a Khapra beetle infestation to Australian ports.

Sensitivity analysis

While uncertainties are intrinsic to all model-based assessments of ecological invasions (Andrews et al. 2004) it is important to estimate the impact of uncertainties on the arrival rate values. Uncertainty in the structure of the pathway model as well as key parameters can propagate in the model outputs (Walker et al. 2003, Li and Wu 2006) and need to be properly estimated.

In this study I estimated the impact of the uncertainty in key pathway model assumptions on the port-specific arrival rates. We have tested two scenarios that considered somewhat different aspects of the uncertainty around the transmission rate values p_{ij}. The first scenario added increasing variation bounds around the p_{ij} values but did not change the mean p_{ij} values. Each pair of $\pm 0.3 p_{ij}$ bounds defined the endpoints for a symmetric uniform distribution (with an upper bound of $p_{ij} = 1.0$ and lower bound of $p_{ij} = 0$) from which I sampled values randomly for input into the model. This scenario explored the impact of multiplicative errors in p_{ij}. In general terms, these errors can be interpreted as uncertainty associated with the measurement of the transmission rates but holding the assumption that the general structure of the shipping network and the average trade flow values are well known.

The second scenario estimated the impact of additive errors by adding a small uniform random variate to p_{ij} regardless of their absolute values and observing the impact on the location-specific arrival rate, φ_j. This scenario changes the mean values of p_{ij} (and subsequently, the configuration of the shipping network) by adding the geographically uniform random variation to each network segment with a set of bounds [0; 0.05]. In broad terms, this depicts an increasing lack of knowledge about the p_{ij} that shifts the p_{ij} values towards a uniform random distribution and thus changes the patterns of commodity flows considerably (the latter aspect was also the reason of choosing a relatively low upper bound, 0.05, of uniform distributions of p_{ij} values).

The third scenario explored the impact of uncertainty about the configuration of the transportation network. This approach goes beyond the traditional sensitivity analysis (Swartzman and Kaluzny 1987, Henderson-Sellers and Henderson-Sellers 1996) and focuses on changes in the network's topology and connectivity (Krammer and Taubig 2005). To keep the analysis consistent with the abovementioned scenarios we used a relatively simple technique and simulated changes in the network's configuration by temporarily removing a random portion of interlinked paths *ij* from the Monte-Carlo pathway simulations and observed the corresponding changes of the arrival rate values. At each pathway simulation event, the proportion of nodes to be removed randomly was drawn from a uniform distribution [0; 0.3].

Results

Country threats

I found the two countries; Taiwan and Republic of Korea have the highest potential of being a source for Khapra beetle (Trogoderma granarium) incursions (Figure 3-1 and Table 3-2; for the full list see Table A8-1). The arrival rate from these two countries to Australian ports was considerably higher (more than three times) than the third highest-ranked country (Egypt).

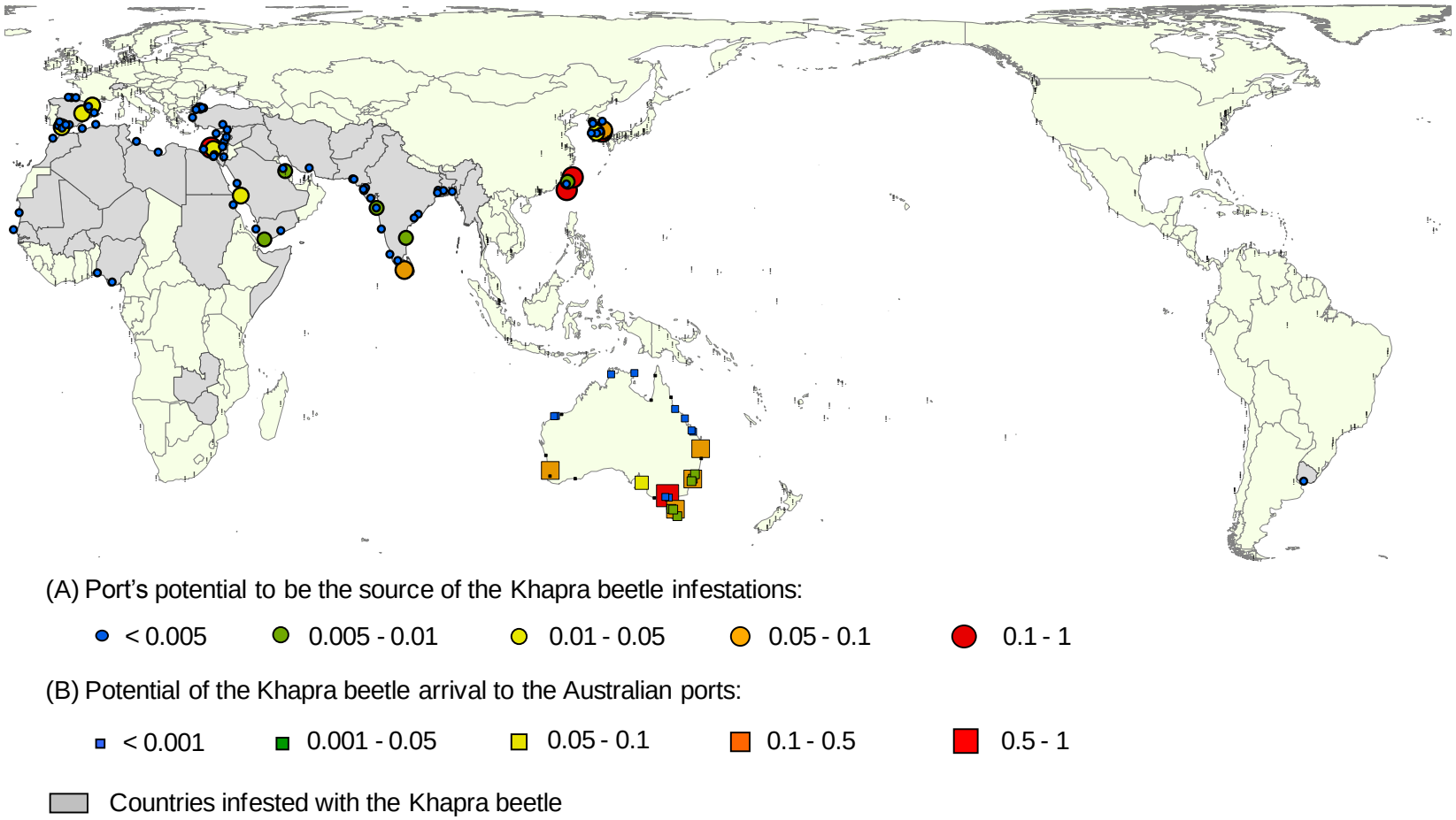

Figure 3-1. A geographical distribution of the Khapra beetle arrival potential to Australian ports: (A) Potential of foreign ports to be the source of Khapra beetle arrival at an Australian port; (B) The potential of Australian ports to receive Khapra beetle from foreign ports infested with the pest.

Table 3-2. Top ten ranked source countries for Khapra beetle infestations at Australian ports. Countries ranked by the arrival rate (φ_{ij}) to all Australian ports from the ports in a given country.

Country	φ_{ij}	relative φ_{ij}*
Taiwan	0.639	9.054
Republic of Korea	0.594	8.413
Egypt	0.155	2.197
Spain	0.096	1.355
Saudi Arabia	0.067	0.953
Sri Lanka	0.066	0.939
India	0.022	0.315
Yemen	0.013	0.186
Turkey	0.012	0.168
Pakistan	0.009	0.121

* denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations ($\overline{\varphi}_{ij}$ = 0.0706)

Port threats

I found the port of Melbourne to have the greatest potential to receive containerized cargoes infested with Khapra beetle, with Botany Bay and Brisbane being the next two highest ranked ports, respectively (Figure 3-1 and Table 3-3; for a full list see Table A8-2).

I then examined the rankings of foreign ports for each of the ten Australian ports in Table 3-4 and found the ports of Busan (Republic of Korea) and Kaohsiung (Taiwan) to be ranked first and second (respectively) for nine of the ten Australian ports, with their order reversed at Botany Bay (Table 3-3; for full lists see Table A8-3 to A8-12). The rates of the Khapra beetle arrival to Australian ports from these two foreign ports are generally three or more times higher than from the third ranked foreign port.

Table 3-3. Top ten ranked Australian ports for receiving the Khapra beetle from foreign ports. Ports ranked by arrival rate of Khapra beetle (φ_{ij}) from foreign ports in the countries with known beetle presence.

Australian Port	φ_{ij}	**relative** φ_{ij} *
Melbourne	0.547	8.921
Botany Bay	0.398	6.487
Brisbane	0.390	6.369
Bell Bay	0.217	3.537
Fremantle	0.154	2.517
Adelaide	0.095	1.548
Burnie	0.050	0.808
Sydney	0.026	0.418
Hobart	0.014	0.225
Newcastle	0.003	0.047

* denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations ($\overline{\varphi}_{ij}$ = 0.0613)

Table 3-4. Top ten ranked source ports for Khapra beetle introduction to the ten most threatened Australian ports (see the rankings of Australian ports).

Melbourne			**Botany Bay**			**Brisbane**			**Bell Bay**			**Fremantle**		
Port of origin *i*	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*
Busan (KOR)	0.245	94.601	Kaohsiung (TWN)	0.159	61.473	Busan (KOR)	0.160	61.541	Busan (KOR)	0.084	32.346	Busan (KOR)	0.051	19.612
Kaohsiung (TWN)	0.227	87.532	Busan (KOR)	0.158	61.020	Kaohsiung (TWN)	0.158	61.098	Kaohsiung (TWN)	0.070	27.181	Kaohsiung (TWN)	0.042	16.364
Keelung (TWN)	0.075	28.912	Keelung (TWN)	0.053	20.370	Keelung (TWN)	0.052	20.153	Keelung (TWN)	0.023	8.947	Damietta (EGY)	0.012	4.653
Damietta (EGY)	0.039	14.925	Damietta (EGY)	0.025	9.702	Damietta (EGY)	0.023	9.043	Damietta (EGY)	0.012	4.681	Keelung (TWN)	0.012	4.614
Colombo (LKA)	0.021	8.025	Colombo (LKA)	0.013	5.029	Colombo (LKA)	0.012	4.453	Ulsan (KOR)	0.010	3.849	Valencia (ESP)	0.009	3.369
Jeddah (SAU)	0.019	7.157	Jeddah (SAU)	0.012	4.704	Jeddah (SAU)	0.010	3.715	Colombo (LKA)	0.007	2.511	Colombo (LKA)	0.008	2.917
Valencia (ESP)	0.018	6.916	Valencia (ESP)	0.012	4.593	Valencia (ESP)	0.009	3.388	Jeddah (SAU)	0.006	2.307	Jeddah (SAU)	0.007	2.847
Ulsan (KOR)	0.017	6.510	Port Said (EGY)	0.007	2.673	Port Said (EGY)	0.005	2.084	Valencia (ESP)	0.006	2.234	Port Said (EGY)	0.004	1.623
Port Said (EGY)	0.011	4.160	Barcelona (ESP)	0.005	1.737	Gwangyang (KOR)	0.004	1.611	Port Said (EGY)	0.003	1.274	Barcelona (ESP)	0.003	1.014
Barcelona (ESP)	0.007	2.569	Ulsan (KOR)	0.004	1.500	Ulsan (KOR)	0.004	1.497	Barcelona (ESP)	0.002	0.803	Gwangyang (KOR)	0.002	0.814

Adelaide			**Burnie**			**Sydney**			**Hobart**			**Newcastle**		
Port of origin *i*	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*	**Port of origin *i***	φ_{ij}	relative φ_{ij}*
Busan (KOR)	0.029	11.092	Busan (KOR)	0.0177	6.8258	Busan (KOR)	0.0084	3.2404	Busan (KOR)	0.0049	1.8767	Busan (KOR)	0.00089	0.34454
Kaohsiung (TWN)	0.024	9.246	Kaohsiung (TWN)	0.0149	5.7627	Kaohsiung (TWN)	0.0077	2.9682	Kaohsiung (TWN)	0.0041	1.5825	Kaohsiung (TWN)	0.00082	0.31716
Damietta (EGY)	0.009	3.558	Keelung (TWN)	0.0049	1.8764	Keelung (TWN)	0.0025	0.9821	Keelung (TWN)	0.0014	0.5427	Keelung (TWN)	0.00028	0.10701
Keelung (TWN)	0.007	2.678	Damietta (EGY)	0.0026	0.9920	Damietta (EGY)	0.0018	0.6922	Damietta (EGY)	0.0007	0.2684	Damietta (EGY)	0.00018	0.06883
Colombo (LKA)	0.006	2.197	Ulsan (KOR)	0.0021	0.8098	Colombo (LKA)	0.0009	0.3436	Ulsan (KOR)	0.0005	0.2113	Colombo (LKA)	0.00009	0.03605
Jeddah (SAU)	0.005	2.022	Colombo (LKA)	0.0014	0.5356	Jeddah (SAU)	0.0007	0.2680	Colombo (LKA)	0.0004	0.1521	Valencia (ESP)	0.00009	0.03335
Valencia (ESP)	0.005	1.919	Jeddah (SAU)	0.0012	0.4785	Valencia (ESP)	0.0007	0.2535	Valencia (ESP)	0.0004	0.1357	Jeddah (SAU)	0.00007	0.02564
Port Said (EGY)	0.003	1.270	Valencia (ESP)	0.0012	0.4650	Port Said (EGY)	0.0005	0.1909	Jeddah (SAU)	0.0004	0.1350	Barcelona (ESP)	0.00005	0.01947
Barcelona (ESP)	0.002	0.615	Port Said (EGY)	0.0007	0.2591	Ulsan (KOR)	0.0004	0.1463	Port Said (EGY)	0.0002	0.0833	Port Said (EGY)	0.00004	0.01504
Algeciras (ESP)	0.001	0.444	Barcelona (ESP)	0.0004	0.1726	Barcelona (ESP)	0.0003	0.1126	Barcelona (ESP)	0.0001	0.0488	Karachi (PAK)	0.00004	0.01407

* denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations ($\overline{\varphi}_{ij}$ = 0.00259)

Sensitivity analysis

Multiplicative errors (increasing error with an unchanged mean p_{ij})

I found the introduction of this type of error to the p_{ij} values had little effect on the rankings of foreign ports, particularly those ports that were ranked in the top half of the list (Figure 3-2a: linear regression, $t_{85} = 110.64$, $p < 0.001$, $R^2 = 0.997$). A similar pattern was found with the ranking of Australian ports by their likelihoods to receive the Khapra beetle from foreign ports (Figure 3-2b: linear regression, $t_{29} = 42.40$, $p < 0.001$, $R^2 = 0.992$).

Additive errors (increasing error with an altered mean p_{ij})

This introduced error changed the rankings of foreign and Australian ports considerably (Figure 3-2c & d), though the rankings were still significantly correlated (foreign ports: linear regression, $t_{85} = 15.19$, $p < 0.001$, $R^2 = 0.855$; Australian ports: linear regression, $t_{29} = 6.37$, $p < 0.001$, $R^2 = 0.764$).

Node removal

The random removal of a proportion of nodes from the shipping network (and associated pairs of origin-destination ports) had little impact on the rankings. In particular, the rankings of the top 30 foreign ports remained unchanged (Figure 3-2e: linear regression, $t_{85} = 155.22$, $p < 0.001$, $R^2 = 0.998$). A similar pattern was observed for the rankings of Australian ports (linear regression, $t_{29} = 114.23$ at $p < 0.001$, $R^2 = 0.999$), with the ranks of the top 20 Australian ports remaining unchanged (Figure 3-2f).

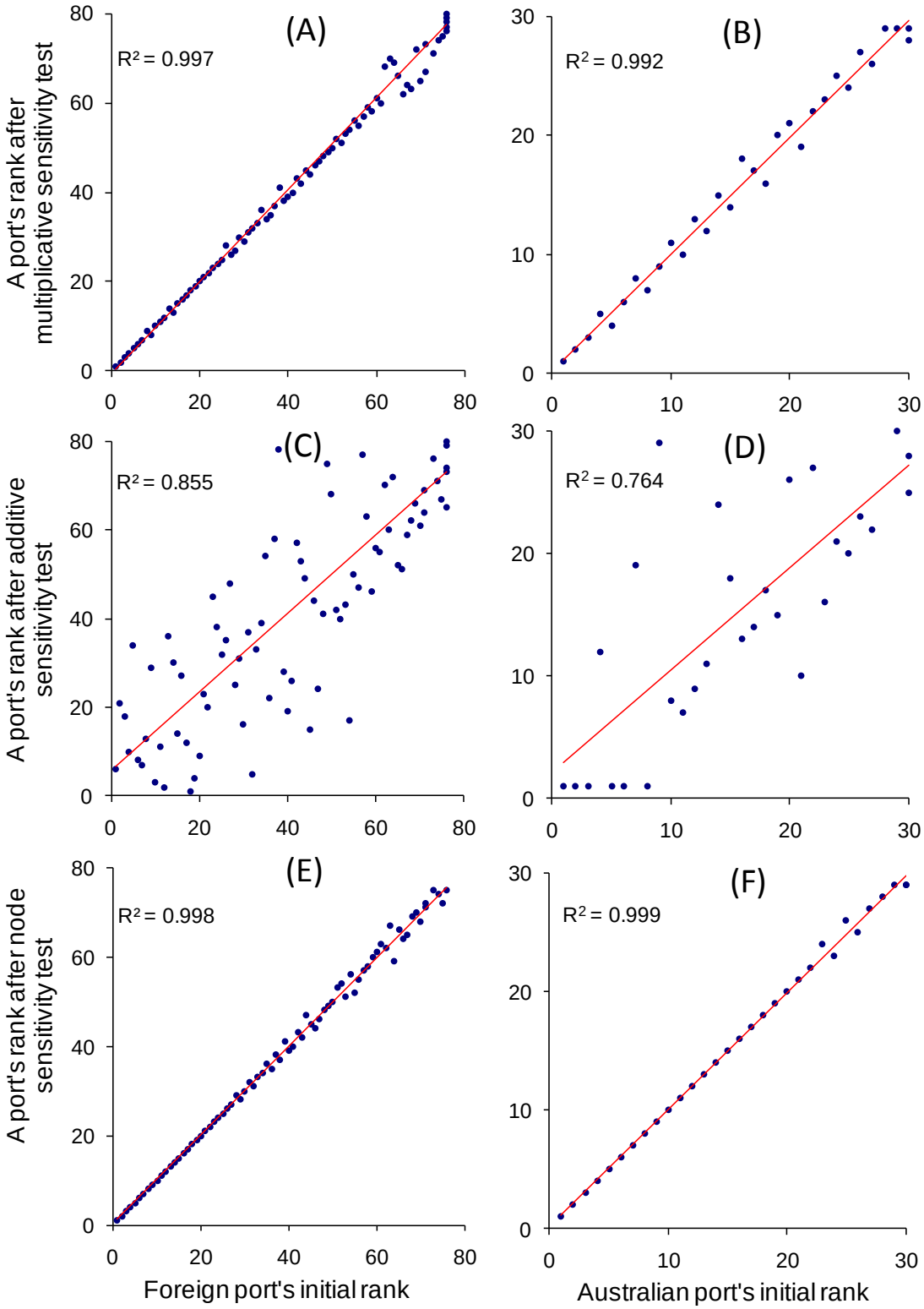

Figure 3-2. Changes in port rankings after the introduction of multiplicative errors (A-B), additive errors (C-D), and the random removal of a portion of the nodes from the transportation network (E-F). All figures show significant ($p<0.001$) rank correlations (see Results for details). The lowest rank values (starting from 1) indicate the highest risk.

Discussion

The two ports, Busan (Republic of Korea) and Kaohsiung (Taiwan) represent substantially greater threats than any other international ports, for the arrival of Khapra beetle to Australia. Taiwan, as a country, represents the greatest threat to Australia, and has two of its ports (Kaohsiung and Keelung) ranked in the top three or four as potential sources of Khapra beetle arrivals to Australia (depending on the Australian port considered: Table 3-3). The high likelihood of ports in Taiwan and the Republic of Korea being a source of Khapra beetle is a result of a large number of container ships travelling through these two ports before arriving into Australia. We also examined the port rankings by degree centrality (the total number of ship arrivals and departures at a given port). Notably, Busan and Kaoshing had approximately four times the degree centrality (3086 and 2979, respectively) of the third ranked port, Keelung (758). A similar pattern was observed when pooling degree centrality to the country level and examining the rankings. Again Taiwan and the Republic of Korea were the top two ranked by degree centrality.

While the combined number of arrivals and departures in this marine transportation network might be enough to identify ports (or countries) of high infestation risk, this may not always be sufficient to identify the gateways of pest introduction. The particular corridor of pest arrival will be a result of the configuration of the shipping routes (i.e. it becomes a function of a network's topology). For example, the degree centrality could be distributed evenly within the network while some specific nodes (ports) may be part of a well-travelled transportation corridor that connects particular regions with considerable trade flows. In this case, undertaking the simulations of individual shipping pathways through the network (as we have done in this study) may be the only way to identify high ranked ports. Yemen is ranked 8th, above Turkey and Pakistan, for arrival rate of Khapra beetle. However, using degree centrality, Yemen would be ranked below these two countries, with less than half the degree centrality (Yemen = 57 degree centrality, Pakistan = 125, Turkey = 113).

The sensitivity analysis revealed that the rankings of Australian and foreign ports are relatively stable. Despite the uniform random variance introduced into the p_{ij} values, the rankings remained relatively unchanged. Further research will be required to better determine how p_{ij} (i.e. the transmission rate from one port to the next) might vary with season and geographical location. A better understanding of the value of p_{ij} could mean these arrival likelihood values could be combined with establishment likelihoods (Paini et al. 2010b) and serve as inputs into economic analyses and risk assessments associated with the particular groups of imports (Cook et al. 2011a, Cook et al. 2011b, Yemshanov et al. 2012).

Indirect supportive evidence for this model comes from a Khapra beetle incursion in Perth, Western Australia in 2007. The beetle was found in the personal belongings of a family migrating to Australia from Scotland. A trace back of the container, which carried the family's belongings revealed that the container had visited the following ports (in reverse order), Fremantle (Australia), Grangemouth (Scotland), Felixstowe (England), Pt Qasim (Pakistan), Gwangyang (South Korea), Busan (South Korea), Hamburg (Germany), Bangkok (Thailand) (personal communication – Rob Emery, Dept of Agriculture and Food, Western Australia, 2011). Although it was not possible to identify exactly the source port of infection, Busan, the highest and Gwangyang, the tenth highest ranked source port for Fremantle (Table 3-3), were both visited by this container.

Currently, Australian government biosecurity agencies do not identify a container's previous ports (other than the immediate one in which the container was loaded before

arriving to Australia). Considering the high risk posed by Khapra beetle and its ability to survive for long periods, undetected (Bell 1994), biosecurity agencies should expand their screening efforts to collect a container's pathway history from shipping companies and use it to evaluate a container's risk profile. It would then be possible to optimise current inspection protocols and more efficiently allocate resources for biosecurity screening and surveillance.

Although the dataset used in our study documents the previous ten ports visited prior to the arrival of a ship to Australian ports, it is possible that the Khapra beetle could infest a container previous to these ten ports. The data show the average number of days at sea between ports is 7.9 days. Any ten-port steps would therefore cover, on average, 71 days. While this time frame would normally encompass the lifecycle of the Khapra beetle, its ability to go into a prolonged period of diapause could result in this species surviving long periods on a shipping journey (Hurlock 1961, Bell 1994).

The model presented here is a first-order Markov chain in which the next pathway segment taken by a container vessel is independent of its previous path. In short, when a container arrives into a port on a ship, its future path is not bound to that ship, but is considered a function of the number of ships travelling from that port to other ports. Clearly, this assumption could vary from port to port. For large hub ports, such as Singapore, where many arriving ships unload their containers for transfer to other ships, this is likely to be a valid assumption. However, for smaller non-hub ports, most containers are likely to remain on a ship and continue along the predetermined path that ship travels. While presently, the vessel-specific data on a container transfer were unavailable, we acknowledge that adding the port-specific estimates of the likelihood of a container being transferred to another ship after the arrival at the port would improve the pathway model and likely refine its predictions and rankings.

Conclusions

The analysis of a marine shipping network represents a significant step forward in the assessment of pathways of entry and identification of potential source locations for invasive species, which previously only assessed direct pathways of entry from a source country. Considering the increasingly connected nature of the world's transportation and trade networks, and the increasing multitude of potential carriers of invasive organisms from one part of the world to another, this more sophisticated evaluation of potential pathways seems necessary and justified. Analysing trade and transportation networks using pathway model simulations enables the geographical identification and ranking of potential sources of invasive pest incursions, which can be applied to any invasive species of concern and any country at risk from invasion. Given the stability of the outputs of this model in the presence of uncertainty about the Khapra beetle's port-to-port transmission potential, the analytic approach presented in this study helps improve and make more effective the current risk screening procedures of shipping containers undertaken by government agencies and industry stakeholders aimed to prevent the introduction of new emerging invasive threats.

3.2. Invasive species on ships

The work presented here analyses an international shipping network to determine arrival likelihood for an invasive species on a ship (as opposed to a shipping container – see section 3.1). The analysis is extended to a large number of potentially invasive species to Australia (564) and combined with establishment likelihoods to generate invasion likelihoods for all species. These invasion likelihoods are then used to rank all species as well as Australian ports.

Methods

DATA

I used the same data from the Lloyd's Maritime Intelligence Unit (LMIU) as mentioned in Section 3.1, detailing every container ship that arrived into Australian ports between 1 January 2002 and 31 December 2007. This data set contained the previous ten ports of call for these container ships before arriving into one of 22 Australian ports, documenting 25,510 arrivals and departures of 556 container ships, with many ships arriving multiple times during this period. These ships travelled from and to 504 foreign ports in 125 countries. In conjunction with this, we obtained the worldwide distribution of 564 insect pest species that are not present in Australia (CABI 2003).

ARRIVAL LIKELIHOOD

The pathways of every container ship in this network was assessed to determine if it passed through a port in a country in which one of these invasive insect pests is found (infected port). If a ship travelled to an infected port we assumed an infection likelihood (i.e. the likelihood of a boat becoming infected with the pest) to be 0.0001. We also assumed the survival likelihood for any species at sea was 0.90 per day. Both these parameters remained unchanged between species.

Arrival likelihood was then calculated by combining infection likelihood with survival likelihood, which was calculated from the number of days the ship took to arrive into an Australian port (Figure 3-3).

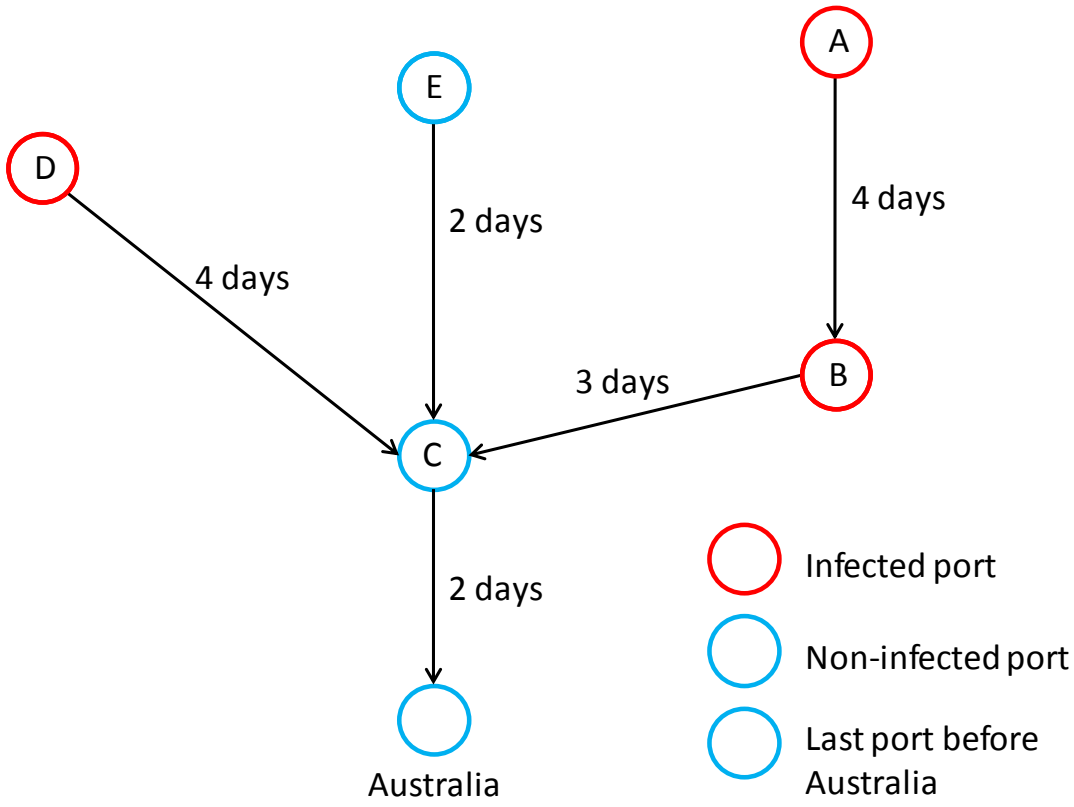

Figure 3-3. Example illustration of the shipping network analysis. There are three possible sources (infected ports) in this network. A ship stopping at port A will travel nine days to Australia. With an infection likelihood of 0.0001, and survival likelihood of 0.39 (0.90^9), the arrival likelihood will be 0.000039.

ESTABLISHMENT LIKELIHOOD

Establishment likelihood for all species at all Australian ports was extracted from a SOM analysis of the world wide distribution of a species dataset that included the same 564 insect pest species (Paini et al. 2010b). Note that (Paini et al. 2010b) only presented establishment likelihoods for Australia as a whole. Here we use the establishment likelihoods generated from that same analysis but for each of Australia's states and territories. This gives a more refined estimate of establishment likelihood and was applied to each Australian port depending on which state or territory they are found. For a full description of this analysis refer to (Paini et al. 2010b), but essentially the SOM identifies similarities in species assemblages between regions/countries and then ranks species according to their likelihood of establishing in a particular region based on these species associations. By considering that species grouping are non-random, any species that commonly occurs with a particular set of species is more likely to establish in a region where elements of that species assemblage are found. The SOM analysis therefore captures the anthropogenic, biotic, and abiotic factors that determine the makeup and distribution of species assemblages (Worner and Gevrey 2006, Paini et al. 2010a). In addition, a SOM analysis has been found to be resilient to significant errors in the data (Paini et al. 2010b) and capable of successfully ranking a high proportion of those species that can invade a region above those that cannot (Paini et al. 2011).

INVASION LIKELIHOOD

For every species, on every ship arriving to an Australian port, the arrival likelihood was combined with establishment likelihood to generate an invasion likelihood for that species with that particular ship arrival. As it was possible that the same species could arrive to an Australian port via multiple ship arrivals, an overall invasion likelihood was generated using conditional probability:

$$P_n(\text{invasion}_j) = 1 - \prod(1 - P(S_{ij})) \quad (1)$$

where $P_n(\text{invasion}_j)$ is the probability of species *n* invading Australian port *j*, and $P(S_{ij})$ is the probability of the species arriving on ship *i* and invading the Australian port *j*.

Once this was calculated, three different types of rankings were generated:

List type 1 For each Australian port, the ranking of all species by invasion likelihood

List type 2 For each species, the ranking of all Australian ports by invasion likelihood of that species

List type 3 For each species and each Australian port, the ranking of the last port of call

It should be noted that when a ship arrives into an Australian port, biosecurity agencies only know the last international port of call before arrival. Nothing will be known of the ship's previous pathway and the 'infected' ports it could have visited. For this reason, we have generated List type 3, which allows the previous port of call to be used as another parameter in the profiling of arriving ships.

SENSITIVITY TESTING

Both parameters (infection likelihood and survival likelihood) were varied simultaneously in a fully factorial design in order to compare every possible combination of parameters with every other combination. Infection likelihood had four variations (0.000001, 0.00001, 0.0001, and 0.001), while survival likelihood (per day) had five variations (0.8, 0.85, 0.9, 0.95, and 0.99). This generated 20 different parameter combinations and for each combination all three types of lists (see Invasion Likelihood section above) were generated.

We compared the rankings generated within each list type across all 20 parameter combinations using Spearman's rank correlation. Within each list type there were a number of lists generated and only those lists with 10 or greater members were compared:

List type 1 = 22 lists

List type 2 = 525 lists (Note: though there were 564 insect pest species in the analysis, only 525 species generated lists of 10 or more ports)

List type 3 = 1717 lists

Each list within a list type was compared with its match across all parameter combinations using Spearman's rank correlation. The proportion of lists that were significantly correlated was recorded as well as the correlation value. For example, for *Lymantria dispar* (Asian gypsy moth), one list could be generated, ranking all 22 Australian ports by invasion likelihood (list type 2) (see Results - Table 3-6a). This list was generated with infection likelihood = 0.0001, and survival likelihood = 0.90/day. There were 19 other combinations of infection and survival likelihood parameters and for each combination the same list was generated for Asian gypsy moth. A Spearman's rank correlation test was then performed comparing all combinations with all others (190 comparisons). This was repeated for all species and for each of the 190 comparisons, the proportion of Spearman's tests that were significant were calculated as well as the mean correlation value (rho).

Results

SPECIES RANKINGS AT AUSTRALIAN PORTS

For each of the 22 Australian ports, all 564 insect pest species were ranked by invasion likelihood (Table A8-13 – Table A8-34) and an overall ranking of invasion likelihood for Australia for all 564 insect pest species was calculated from invasion likelihoods for each species at each of the 22 Australian ports (Table 3-5).

AUSTRALIAN PORT RANKINGS

It is possible to rank every Australian port for every one of the 564 insect pest species. There are a number of these species that have been identified as pests of plants and plant products by the Australian Department of Agriculture, Forestry, and Fisheries (DAFF). These species have been identified as those with the potential to have significant impacts on the Australian economy and inspection protocols are designed to maximise detection of these species if they arrive into the country (AQIS 2005). Four of these species were included in this analysis (Asian gypsy moth, Khapra beetle, Asian longhorn beetle, and Papaya fruit fly) and it is possible to identify those Australian ports of greatest threat of invasion for each species (Table 3-6). Generally, those Australian ports of capital cities, which will be receiving greater numbers of ships will be ranked higher. However, there can be significant differences in which of these ports are highly ranked. For example, Melbourne is ranked first or second for three of the four species, while for the fourth species, Papaya fruit fly, Melbourne has an invasion likelihood of zero.

LAST PORT OF CALL RANKINGS

For every species and every Australian port it is possible to rank incoming ships by the last port of call (i.e. the last foreign port visited before arriving into an Australian port). This is the only information provided to Australian quarantine officers regarding an arriving ship's port visitation history. This information can therefore be used to further refine any inspection protocols. To illustrate, each of the four invasive pest species identified by DAFF and listed in Table 3-6 have a top ranked Australian port in which the invasion likelihood is the highest. For each of these four ports (one for each species), the last ports of call for any arriving ships have been ranked (Table 3-7). As with Table 3-6, there are significant

similarities in the last ports of call for three of the four species, with many Chinese ports highly ranked, while for Papaya fruit fly, the highly ranked last ports of call do not include any Chinese ports.

Table 3-5. Top 100 ranked insect pests for likelihood of invasion to any Australian port.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Xylosandrus compactus*	0.7886	51	*Hypomeces squamosus*	0.2234
2	*Agrotis segetum*	0.7512	52	*Opogona sacchari*	0.2233
3	*Trichoplusia ni*	0.6277	53	*Helopeltis theivora*	0.2218
4	*Pinnaspis strachani*	0.5825	54	*Cryptoblabes gnidiella*	0.2202
5	*Liriomyza trifolii*	0.5697	55	*Nipaecoccus nipae*	0.2173
6	*Diaphorina citri*	0.5674	56	*Ceroplastes rusci*	0.2120
7	*Sesamia inferens*	0.5496	57	*Acronicta rumicis*	0.2082
8	*Orthezia insignis*	0.5495	58	*Planococcus lilacinus*	0.2020
9	*Leucinodes orbonalis*	0.5050	59	*Pseudococcus comstocki*	0.2006
10	*Oryctes rhinoceros*	0.4860	60	*Orgyia postica*	0.1990
11	*Toxoptera odinae*	0.4842	61	*Oulema melanopus*	0.1982
12	*Aleurocanthus woglumi*	0.4623	62	*Diuraphis noxia*	0.1971
13	*Aphis fabae*	0.4574	63	*Ceratovacuna lanigera*	0.1969
14	*Dialeurodes citri*	0.4551	64	*Attacus atlas*	0.1968
15	*Aproaerema modicella*	0.4402	65	*Aphis pomi*	0.1928
16	*Liriomyza huidobrensis*	0.4075	66	*Liriomyza sativae*	0.1913
17	*Sitobion avenae*	0.3897	67	*Zeuzera coffeae*	0.1908
18	*Chromatomyia horticola*	0.3894	68	*Rhipiphorothrips cruentatus*	0.1898
19	*Acherontia styx*	0.3860	69	*Omphisa anastomosalis*	0.1892
20	*Brachycaudus helichrysi*	0.3803	70	*Batocera rufomaculata*	0.1865
21	*Hadula trifolii*	0.3798	71	*Liriomyza bryoniae*	0.1841
22	*Pelopidas mathias*	0.3402	72	*Papilio polytes*	0.1791
23	*Stephanitis typica*	0.3387	73	*Omiodes indicata*	0.1761
24	*Lymantria dispar*	0.3371	74	*Henosepilachna pusillanima*	0.1750
25	*Sinoxylon conigerum*	0.3288	75	*Xylotrechus quadripes*	0.1742
26	*Aulacophora lewisii*	0.3085	76	*Pyrilla perpusilla*	0.1735
27	*Chilo infuscatellus*	0.3051	77	*Bombyx mori*	0.1706
28	*Philaenus spumarius*	0.3040	78	*Urentius hystricellus*	0.1702
29	*Chilo auricilius*	0.3026	79	*Minthea rugicollis*	0.1699
30	*Dicladispa armigera*	0.2927	80	*Trialeurodes vaporariorum*	0.1685
31	*Atherigona soccata*	0.2920	81	*Hypothenemus hampei*	0.1676
32	*Aleurothrixus floccosus*	0.2855	82	*Acanthiophilus helianthi*	0.1651
33	*Nephotettix virescens*	0.2802	83	*Anarsia lineatella*	0.1609
34	*Phyllotreta striolata*	0.2753	84	*Peridroma saucia*	0.1607
35	*Erionota thrax*	0.2724	85	*Euproctis chrysorrhoea*	0.1605
36	*Laodelphax striatellus*	0.2631	86	*Lopholeucaspis japonica*	0.1594
37	*Hydrellia philippina*	0.2584	87	*Mamestra brassicae*	0.1577
38	*Rastrococcus invadens*	0.2582	88	*Atherigona pulla*	0.1565
39	*Odoiporus longicollis*	0.2582	89	*Plocaederus obesus*	0.1553
40	*Deilephila elpenor*	0.2536	90	*Idioscopus clypealis*	0.1549
41	*Pieris brassicae*	0.2480	91	*Fulmekiola serrata*	0.1523
42	*Bactrocera dorsalis*	0.2463	92	*Eupoecilia ambiguella*	0.1495
43	*Xyleborus ferrugineus*	0.2425	93	*Rastrococcus iceryoides*	0.1456
44	*Bactrocera latifrons*	0.2374	94	*Aulacophora foveicollis*	0.1455
45	*Orseolia oryzae*	0.2361	95	*Prostephanus truncatus*	0.1435
46	*Sesamia cretica*	0.2326	96	*Delia antiqua*	0.1406
47	*Batocera rubus*	0.2315	97	*Frankliniella intonsa*	0.1378
48	*Parasa lepida*	0.2289	98	*Hieroglyphus banian*	0.1350
49	*Parlatoria oleae*	0.2249	99	*Parabemisia myricae*	0.1301
50	*Chilo sacchariphagus*	0.2241	100	*Malacosoma neustria*	0.1298

Table 3-6. Ranking of all 22 Australian ports by invasion likelihood for (a) *Lymantria dispar* (Asian gypsy moth), (b) *Trogoderma granarium* (Khapra beetle), (c) *Anoplophora glabripennis* (Asian longhorn beetle), and (d) *Bactrocera papaya* (Papaya fruit fly).

	(a) Asian gypsy moth		(b) Khapra beetle		(c) Asian longhorn beetle		(d) Papaya fruit fly	
rank	Australian Port	invasion likelihood	Australian Port	invasion likelihood	Australian Port	invasion likelihood	Australian Port	invasion likelihood
1	Melbourne	0.032973	Melbourne	0.0042947	Botany Bay	0.002393	Brisbane	0.006451
2	Botany Bay	0.005405	Botany Bay	0.0035121	Melbourne	0.001788	Botany Bay	0.000949
3	Fremantle	0.003222	Fremantle	0.0004156	Fremantle	0.000327	Sydney	0.000324
4	Brisbane	0.000627	Brisbane	0.0001630	Brisbane	0.000305	Townsville	0.000059
5	Dampier	0.000045	Sydney	0.0000258	Sydney	0.000014	Fremantle	0.000044
6	Sydney	0.000037	Dampier	0.0000201	Geraldton	0.000005	Port Alma	0.000013
7	Adelaide	0.000016	Gove	0.0000110	Port Kembla	0.000001	Darwin	0.000010
8	Geraldton	0.000011	Darwin	0.0000097	Port Alma	0.000001	Port Kembla	0.000007
9	Port Hedland	0.000011	Port Hedland	0.0000039	Dampier	0.000001	Gove	0.000007
10	Launceston	0.000007	Portland	0.0000014	Darwin	4.44E-07	Newcastle	5.72E-06
11	Hastings	0.000006	Port Kembla	0.0000009	Launceston	4.37E-07	Dampier	9.00E-08
12	Burnie	0.000004	Geelong	0.0000001	Hastings	3.88E-07	Port Hedland	6.84E-08
13	Gove	0.000003	Adelaide	0.0000001	Burnie	2.38E-07	Geraldton	2.12E-08
14	Portland	0.000003	Port Alma	0.0000001	Adelaide	1.82E-07	Adelaide	0
15	Darwin	0.000003	Newcastle	2.20E-08	Geelong	9.32E-08	Burnie	0
16	Geelong	0.000002	Geraldton	1.31E-08	Gladstone	6.73E-08	Esperance	0
17	Port Kembla	0.000002	Gladstone	1.62E-10	Gove	6.56E-12	Geelong	0
18	Port Alma	0.000002	Burnie	0	Esperance	0	Gladstone	0
19	Gladstone	0.000001	Esperance	0	Newcastle	0	Hastings	0
20	Newcastle	2.96E-07	Hastings	0	Port Hedland	0	Launceston	0
21	Esperance	0	Launceston	0	Portland	0	Melbourne	0
22	Townsville	0	Townsville	0	Townsville	0	Portland	0

Table 3-7. Top ten last ports of call for (a) *Lymantria dispar* (Asian gypsy moth) arriving to Melbourne port, (b) *Trogoderma granarium* (Khapra beetle) arriving to Melbourne port, (c) *Anoplophora glabripennis* (Asian longhorn beetle) arriving to Botany Bay port, and (d) *Bactrocera papaya* (Papaya fruit fly) arriving to Brisbane. The Australian ports used were identified as the ports with the highest invasion likelihood for each species (Table 3-6). Last port of call is the last foreign port a ship has visited before arriving into an Australian port.

	(a) Asian gypsy moth (Melbourne)		(b) Khapra beetle (Melbourne)	
rank	last port of call	invasion likelihood	last port of call	invasion likelihood
1	Hong Kong (CHN)	0.01021	Kaohsiung (TWN)	0.002153
2	Kaohsiung (TWN)	0.01000	Hong Kong (CHN)	0.001164
3	Chiwan (CHN)	0.00199	Damietta (EGY)	0.000258
4	Shekou (CHN)	0.00159	Shekou (CHN)	0.000189
5	Ningbo (CHN)	0.00155	Chiwan (CHN)	0.000153
6	Tauranga (NZL)	0.00133	Shanghai (CHN)	0.000077
7	La Spezia (ITA)	0.00110	Ningbo (CHN)	0.000075
8	Damietta (EGY)	0.00097	Keelung (TWN)	0.000051
9	Auckland (NZL)	0.00090	Busan (KOR)	0.000043
10	Shanghai (CHN)	0.00072	Yantian (CHN)	0.000039
	(c) Asian longhorn beetle (Botany Bay)		(d)Papaya fruit fly (Brisbane)	
rank	last port of call	invasion likelihood	last port of call	invasion likelihood
1	Hong Kong (CHN)	0.0012367	Singapore (SGP)	0.004806
2	Kaohsiung (TWN)	0.0006559	Port Klang (MYS)	0.001142
3	Shanghai (CHN)	0.0001328	Noumea (NCL)	0.000097
4	Ashdod (ISR)	0.0001236	New Plymouth (NZL)	0.000084
5	Ningbo (CHN)	0.0000733	Lae (PNG)	0.000073
6	Noumea (NCL)	0.0000320	Port Moresby (PNG)	0.000056
7	Los Angeles (USA)	0.0000293	Jakarta (IDN)	0.000031
8	Busan (KOR)	0.0000173	Tanjung Pelepas (MYS)	0.000027
9	Chiwan (CHN)	0.0000169	Lihir Is. (PNG)	0.000024
10	Tauranga (NZL)	0.0000149	Wellington (NZL)	0.000020

SENSITIVITY ANALYSIS

All list types were shown to remain significantly unchanged despite the changes in both infection and survival parameters.

For list type 1 (ranking of all species at each Australian port), all lists (22), in all comparisons (190) were significant and the mean correlation value across all lists and all comparisons was 0.926 (Table 3-8).

For list type 2 (ranking of all Australian ports for each species), the overall proportion of Spearman's correlation tests that were significant was 0.988 and the mean correlation value was 0.976 (Table 3-9).

For list type 3 (ranking of last ports of call for all species at all Australian ports), the overall proportion of Spearman correlation tests that were significant was 0.973, while the mean correlation value was 0.928 (Table 3-10).

Discussion

Many of the species identified as those most likely to invade Australia are significant pests of crops and/or forests, though many may not be likely to be transported on ships without the presence of a host. For example, *Diaphorina citri*, which is ranked 6th for invasion likelihood (Table 3-5) and is a vector of Huanglongbing or citrus greening disease, which has been identified as a disease of major concern to DAFF should it arrive in Australia (http://www.daff.gov.au/aqis/quarantine/naqs/naqs-fact-sheets/citrus-greening). However, this species is likely to only be transported via the movement of host plants and may not therefore be of serious concern to quarantine officials inspecting ships. In addition, this model assumed equal infection and survival likelihood between species. This is unlikely to be the case and should be considered when examining species rankings as it is possible that a highly ranked species may not be so highly ranked if its survival likelihood on a ship is very low.

Another species, *Lymantria dispar* (Asian gypsy moth), has had a major impact on forestry products, and is ranked 24th by invasion likelihood (Table 3-5). The females of this species are attracted to bright lights and can fly up to 40 km, so they could oviposit on ships in port. Interestingly, the Australian port most likely to be invaded by this species is the port of Melbourne and the invasion likelihood is more than six times greater for this port than for the second ranked Australian port (Botany Bay). Further analysis can allow the identification of last ports of call for incoming ships to the port of Melbourne (Table 3-7). For this species invading Melbourne, ships arriving from Hong Kong (China) and Kaohsiung (Taiwan) present substantially greater threats than ships arriving from any other foreign port (at least 5x greater).

Identification of Australian ports and last ports of call can give greater detail in determining which ships to inspect for these particular species. It should be noted that the last port of call may not necessarily be a port in which this species is found, but a reflection of the pathways these ships travelled before arriving into Australia. For example, the Papaya fruit fly is not found in Singapore or Malaysia, but ships arriving to Brisbane from ports of these two countries have been ranked the highest for invasion likelihood (Table 3-7d).

In addition to identifying Australian ports and last ports of call to target for a particular species, this work also identifies those ports which AQIS officers need not consider when determining inspection regimes. For example, Esperance and Townsville are two ports in which the invasion likelihood for Asian gypsy moth is 0 (Table 3-6). While these two ports are minor ports anyway and may not already be considered high risk, Darwin could also be classified as low risk for this species as its invasion likelihood is 10,000x lower than the top ranked port, Melbourne.

While many of the species listed in Table 3-5 are significant pests, further ranking of these pests using economic impact risk assessments (Cook et al. 2007, Cook and Matheson 2008, Cook et al. 2011a, Cook et al. 2011b) would be appropriate. It is possible that highly ranked species for invasion likelihood would have little economic impact and need not be seriously considered in any quarantine inspection protocols.

This model and methodology gives the opportunity to quantitatively estimate and rank a large number of potentially invasive species and their possible pathways simultaneously. Sensitivity analysis indicates that rankings in all of the three list types remain extremely stable. This is despite the infection likelihood varying from 0.001 to 0.000001, which is a 1,000 fold difference.

Subsequent analyses could include the 564 invasive crop pest species considered here or any number of other invasive species of concern. In addition, rankings could be made based solely on arrival likelihood or, as presented here, combined with establishment likelihoods to generate invasion likelihoods.

Further work could examine within year and between year variations in the shipping network to determine how consistent these shipping routes are from season to season and year to year. Further validation of the model could be also obtained from interception records.

There are a number of modifications that may be appropriate before this model could be used effectively by DAFF to assess incoming ships. Firstly, the likelihood of an invasive species infecting a ship is likely to vary as a function of the time a ship spends in an infected port, or the abundance of the organism in the source country. Secondly, infection likelihood is likely to be influenced by season, with certain times of the year being a greater risk than others. The model could be modified to include both these factors. Finally, this analysis only considered container ships arriving into Australia. DAFF are concerned with all arriving ships and a full data set including all arriving ships, should be incorporated into future analyses. The outputs from this model could then be used by DAFF to plan and prioritise inspection protocols in order to optimise risk return and maximise the chances of intercepting invasive species on arriving ships.

This model represents a significant step forward in the assessment of the risk profile of arriving ships to Australian ports. Further modifications and refinement in the model will help to improve the assessment of the risk profile for an arriving ship. In addition, this model could potentially be incorporated into a ship tracking computer system, such as that used by AMSA (Australian Maritime Safety Authority), which would allow 'real time' and instantaneous quantitative assessment of all incoming ships to Australian ports.

Table 3-8. Spearman rank correlations for list type 1 (ranking of all species at each Australian port). Values above the diagonal are the proportion of correlations that were significant in each pair wise comparison (the overall proportion significant was 1.00). Values below the diagonal are the mean correlation values (Rho) for all correlations within a pair wise comparison (the overall mean correlation value was 0.926). Parameter values were infection rate (i) and survival rate (s).

	i=0.000001 s=0.80	i=0.000001 s=0.85	i=0.000001 s=0.90	i=0.000001 s=0.95	i=0.000001 s=0.99	i=0.00001 s=0.80	i=0.00001 s=0.85	i=0.00001 s=0.90	i=0.00001 s=0.95	i=0.00001 s=0.99	i=0.0001 s=0.80	i=0.0001 s=0.85	i=0.0001 s=0.90	i=0.0001 s=0.95	i=0.0001 s=0.99	i=0.001 s=0.80	i=0.001 s=0.85	i=0.001 s=0.90	i=0.001 s=0.95	i=0.001 s=0.99
i=0.000001, s=0.80		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.000001, s=0.85	0.993		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.000001, s=0.90	0.966	0.989		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.000001, s=0.95	0.891	0.930	0.972		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.000001, s=0.99	0.779	0.827	0.890	0.966		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.00001, s=0.80	1.000	0.993	0.966	0.891	0.779		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.00001, s=0.85	0.993	1.000	0.989	0.930	0.827	0.993		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.00001, s=0.90	0.966	0.989	1.000	0.972	0.890	0.966	0.989		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.00001, s=0.95	0.891	0.930	0.972	1.000	0.966	0.891	0.930	0.972		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.00001, s=0.99	0.779	0.827	0.890	0.966	1.000	0.779	0.827	0.890	0.966		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.0001, s=0.80	1.000	0.993	0.966	0.891	0.779	1.000	0.993	0.966	0.891	0.779		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.0001, s=0.85	0.993	1.000	0.989	0.930	0.827	0.993	1.000	0.989	0.930	0.827	0.993		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.0001, s=0.90	0.966	0.989	1.000	0.972	0.890	0.966	0.989	1.000	0.972	0.890	0.966	0.989		1.000	1.000	1.000	1.000	1.000	1.000	1.000
i=0.0001, s=0.95	0.810	0.856	0.915	0.980	0.997	0.810	0.856	0.915	0.981	0.997	0.810	0.857	0.915		1.000	1.000	1.000	1.000	1.000	1.000
i=0.0001, s=0.99	0.778	0.826	0.889	0.966	1.000	0.778	0.826	0.889	0.966	1.000	0.778	0.826	0.890	0.998		1.000	1.000	1.000	1.000	1.000
i=0.001, s=0.80	1.000	0.994	0.967	0.892	0.780	1.000	0.994	0.967	0.892	0.780	1.000	0.993	0.967	0.812	0.780		1.000	1.000	1.000	1.000
i=0.001, s=0.85	0.973	0.983	0.975	0.920	0.819	0.973	0.983	0.975	0.920	0.820	0.973	0.984	0.976	0.853	0.822	0.977		1.000	1.000	1.000
i=0.001, s=0.90	0.963	0.986	0.998	0.971	0.890	0.963	0.986	0.998	0.971	0.890	0.963	0.986	0.999	0.916	0.890	0.965	0.983		1.000	1.000
i=0.001, s=0.95	0.883	0.923	0.966	0.996	0.963	0.883	0.923	0.966	0.996	0.963	0.883	0.923	0.967	0.980	0.965	0.886	0.929	0.971		1.000
i=0.001, s=0.99	0.763	0.812	0.876	0.954	0.989	0.763	0.812	0.876	0.954	0.989	0.763	0.813	0.877	0.990	0.992	0.767	0.828	0.883	0.964	

Table 3-9. Spearman rank correlations for list type 2 (ranking of all Australian ports for each species). Values above the diagonal are the proportion of correlations that were significant in each pair wise comparison (the overall proportion significant was 0.988). Values below the diagonal are the mean correlation values (Rho) for all correlations within a pair wise comparison (the overall mean correlation value was 0.976). Parameter values were infection rate (i) and survival rate (s).

	i=0.000001 s=0.80	i=0.000001 s=0.85	i=0.000001 s=0.90	i=0.000001 s=0.95	i=0.000001 s=0.99	i=0.00001 s=0.80	i=0.00001 s=0.85	i=0.00001 s=0.90	i=0.00001 s=0.95	i=0.00001 s=0.99	i=0.0001 s=0.80	i=0.0001 s=0.85	i=0.0001 s=0.90	i=0.0001 s=0.95	i=0.0001 s=0.99	i=0.001 s=0.80	i=0.001 s=0.85	i=0.001 s=0.90	i=0.001 s=0.95	i=0.001 s=0.99
i=0.000001, s=0.80		1.000	0.987	0.975	0.950	1.000	1.000	0.987	0.975	0.950	1.000	1.000	0.987	0.954	0.950	1.000	1.000	0.987	0.975	0.950
i=0.000001, s=0.85	0.994		0.994	0.985	0.971	1.000	1.000	0.994	0.985	0.971	1.000	1.000	0.994	0.983	0.971	1.000	1.000	0.994	0.985	0.971
i=0.000001, s=0.90	0.976	0.992		1.000	0.998	0.987	0.994	1.000	1.000	0.998	0.987	0.994	1.000	0.998	0.998	0.987	0.994	1.000	1.000	0.998
i=0.000001, s=0.95	0.952	0.973	0.993		1.000	0.975	0.985	1.000	1.000	1.000	0.975	0.985	1.000	1.000	1.000	0.975	0.985	1.000	1.000	1.000
i=0.000001, s=0.99	0.927	0.952	0.978	0.994		0.950	0.971	0.998	1.000	1.000	0.950	0.971	0.998	1.000	1.000	0.950	0.971	0.998	1.000	1.000
i=0.00001, s=0.80	1.000	0.994	0.976	0.952	0.927		1.000	0.987	0.975	0.950	1.000	1.000	0.987	0.954	0.950	1.000	1.000	0.987	0.975	0.950
i=0.00001, s=0.85	0.994	1.000	0.992	0.973	0.952	0.994		0.994	0.985	0.971	1.000	1.000	0.994	0.983	0.971	1.000	1.000	0.994	0.985	0.971
i=0.00001, s=0.90	0.976	0.992	1.000	0.993	0.978	0.976	0.992		1.000	0.998	0.987	0.994	1.000	0.998	0.998	0.987	0.994	1.000	1.000	0.998
i=0.00001, s=0.95	0.952	0.973	0.993	1.000	0.994	0.952	0.973	0.993		1.000	0.975	0.985	1.000	1.000	1.000	0.975	0.985	1.000	1.000	1.000
i=0.00001, s=0.99	0.927	0.952	0.978	0.994	1.000	0.927	0.952	0.978	0.994		0.950	0.971	0.998	1.000	1.000	0.950	0.971	0.998	1.000	1.000
i=0.0001, s=0.80	1.000	0.994	0.976	0.952	0.927	1.000	0.994	0.976	0.952	0.927		1.000	0.987	0.954	0.950	1.000	1.000	0.987	0.975	0.950
i=0.0001, s=0.85	0.994	1.000	0.992	0.973	0.952	0.994	1.000	0.992	0.973	0.952	0.994		0.994	0.983	0.971	1.000	1.000	0.994	0.985	0.971
i=0.0001, s=0.90	0.976	0.992	1.000	0.993	0.978	0.976	0.992	1.000	0.993	0.978	0.976	0.992		0.998	0.998	0.987	0.994	1.000	1.000	0.998
i=0.0001, s=0.95	0.934	0.958	0.982	0.996	1.000	0.934	0.958	0.982	0.996	1.000	0.934	0.958	0.982		1.000	0.954	0.983	0.998	1.000	1.000
i=0.0001, s=0.99	0.928	0.952	0.978	0.994	1.000	0.928	0.952	0.978	0.994	1.000	0.928	0.952	0.978	1.000		0.950	0.971	0.998	1.000	1.000
i=0.001, s=0.80	1.000	0.994	0.976	0.951	0.927	1.000	0.994	0.976	0.951	0.927	1.000	0.994	0.976	0.934	0.928		1.000	0.987	0.975	0.950
i=0.001, s=0.85	0.995	1.000	0.992	0.973	0.952	0.995	1.000	0.992	0.973	0.952	0.995	1.000	0.992	0.958	0.952	0.995		0.994	0.985	0.971
i=0.001, s=0.90	0.976	0.992	1.000	0.993	0.977	0.976	0.992	1.000	0.993	0.977	0.976	0.992	1.000	0.982	0.978	0.976	0.992		1.000	0.998
i=0.001, s=0.95	0.952	0.973	0.993	0.999	0.994	0.952	0.973	0.993	0.999	0.994	0.952	0.973	0.993	0.996	0.994	0.952	0.973	0.993		1.000
i=0.001, s=0.99	0.927	0.950	0.975	0.991	0.998	0.927	0.950	0.975	0.991	0.998	0.927	0.950	0.975	0.998	0.998	0.927	0.951	0.976	0.993	

Table 3-10. Spearman rank correlations for list type 3 (ranking of all last ports of call for all species at all Australian ports). Values above the diagonal are the proportion of correlations that were significant in each pair wise comparison (the overall proportion significant was 0.973). Values below the diagonal are the mean correlation values (Rho) for all correlations within a pair wise comparison (the overall mean correlation value was 0.928). Parameter values were infection rate (i) and survival rate (s).

	i=0.000001 s=0.80	i=0.000001 s=0.85	i=0.000001 s=0.90	i=0.000001 s=0.95	i=0.000001 s=0.99	i=0.00001 s=0.80	i=0.00001 s=0.85	i=0.00001 s=0.90	i=0.00001 s=0.95	i=0.00001 s=0.99	i=0.0001 s=0.80	i=0.0001 s=0.85	i=0.0001 s=0.90	i=0.0001 s=0.95	i=0.0001 s=0.99	i=0.001 s=0.80	i=0.001 s=0.85	i=0.001 s=0.90	i=0.001 s=0.95	i=0.001 s=0.99
i=0.000001, s=0.80		1.000	0.994	0.953	0.871	1.000	1.000	0.994	0.953	0.871	1.000	1.000	0.994	0.910	0.872	1.000	1.000	0.994	0.953	0.875
i=0.000001, s=0.85	0.984		1.000	0.984	0.926	1.000	1.000	1.000	0.984	0.926	1.000	1.000	1.000	0.953	0.926	1.000	1.000	1.000	0.984	0.926
i=0.000001, s=0.90	0.942	0.984		0.999	0.971	0.994	1.000	1.000	0.999	0.971	0.994	1.000	1.000	0.980	0.971	0.994	1.000	1.000	0.999	0.971
i=0.000001, s=0.95	0.870	0.929	0.976		0.999	0.953	0.984	0.999	1.000	0.999	0.953	0.984	0.999	1.000	0.999	0.953	0.984	0.999	1.000	0.999
i=0.000001, s=0.99	0.783	0.845	0.905	0.968		0.872	0.926	0.971	0.999	1.000	0.872	0.926	0.971	1.000	1.000	0.872	0.926	0.971	0.999	1.000
i=0.00001, s=0.80	1.000	0.984	0.942	0.870	0.783		1.000	0.994	0.953	0.872	1.000	1.000	0.994	0.910	0.872	1.000	1.000	0.994	0.953	0.875
i=0.00001, s=0.85	0.984	1.000	0.984	0.929	0.845	0.984		1.000	0.984	0.926	1.000	1.000	1.000	0.953	0.926	1.000	1.000	1.000	0.984	0.926
i=0.00001, s=0.90	0.942	0.984	1.000	0.976	0.905	0.942	0.984		0.999	0.971	0.994	1.000	1.000	0.980	0.971	0.994	1.000	1.000	0.999	0.971
i=0.00001, s=0.95	0.870	0.929	0.976	1.000	0.968	0.870	0.929	0.976		0.999	0.953	0.984	0.999	1.000	0.999	0.953	0.984	0.999	1.000	0.999
i=0.00001, s=0.99	0.783	0.845	0.905	0.968	1.000	0.783	0.845	0.905	0.968		0.872	0.926	0.971	1.000	1.000	0.872	0.926	0.971	0.999	1.000
i=0.0001, s=0.80	1.000	0.984	0.942	0.870	0.783	1.000	0.984	0.942	0.870	0.783		1.000	0.994	0.910	0.872	1.000	1.000	0.994	0.953	0.875
i=0.0001, s=0.85	0.984	1.000	0.984	0.929	0.845	0.984	1.000	0.984	0.929	0.845	0.984		1.000	0.953	0.926	1.000	1.000	1.000	0.984	0.926
i=0.0001, s=0.90	0.942	0.984	1.000	0.976	0.905	0.942	0.984	1.000	0.976	0.905	0.942	0.984		0.980	0.971	0.994	1.000	1.000	0.999	0.971
i=0.0001, s=0.95	0.809	0.871	0.928	0.982	0.998	0.809	0.871	0.928	0.982	0.998	0.809	0.871	0.928		1.000	0.910	0.953	0.980	1.000	1.000
i=0.0001, s=0.99	0.783	0.845	0.905	0.968	1.000	0.783	0.845	0.905	0.968	1.000	0.783	0.845	0.905	0.998		0.872	0.926	0.971	0.999	1.000
i=0.001, s=0.80	1.000	0.984	0.942	0.870	0.783	1.000	0.984	0.942	0.870	0.783	1.000	0.984	0.942	0.809	0.783		1.000	0.994	0.953	0.875
i=0.001, s=0.85	0.984	1.000	0.984	0.929	0.845	0.984	1.000	0.984	0.929	0.845	0.984	1.000	0.984	0.871	0.845	0.984		1.000	0.984	0.926
i=0.001, s=0.90	0.942	0.984	1.000	0.976	0.905	0.942	0.984	1.000	0.976	0.905	0.942	0.984	1.000	0.928	0.905	0.942	0.984		0.999	0.971
i=0.001, s=0.95	0.870	0.929	0.975	1.000	0.968	0.870	0.929	0.975	1.000	0.968	0.870	0.929	0.975	0.982	0.968	0.870	0.929	0.976		0.999
i=0.001, s=0.99	0.782	0.845	0.904	0.967	1.000	0.782	0.845	0.904	0.967	1.000	0.782	0.845	0.904	0.997	1.000	0.782	0.845	0.905	0.967	

4. Implications for stakeholders

4.1. Model reliability and applicability

Both models presented (shipping container model and shipping model) show low sensitivity to the uncertainties tested and are therefore reliable in their rankings. Though it should be noted that the model for predicting invasive species in shipping containers will be difficult for DAFF to interpret and include in operational procedures as no information on a container's previous history is usually obtained. The model developed for predicting invasive species on ships, however, would be significantly easier to operationalise and should be seriously considered by DAFF. Identification of highly threatened ports and a ship's last foreign port of call provide valuable information for inspection officers, and could be used to prioritise inspection regimes. In addition, identification of ports of low threat provide additional information in this prioritisation process.

4.2. Model outputs

The shipping container model has identified two main sources for the arrival of Khapra beetle (Republic of Korea and Taiwan). Unfortunately, there is no way at present to identify if an arriving container has travelled through these two regions making it difficult to target certain shipping containers over others.

The shipping model analysed a large number of invasive species and ranked them all based on invasion likelihood. Serious consideration should be given to those species ranked at the top of the list and an economic impact assessment should be produced for each to determine their final risk ranking. Further detailing of model outputs is not appropriate here, other than to say that model outputs for any species of concern can be used to prioritise inspection protocols for incoming ships to Australian ports.

5. Recommendations

5.1. Model validation

Both models could benefit from validation with interception and incursion data if available. Further, these models should continue to be evaluated over the short to medium term against future interception data

5.2. Container movement data

DAFF should seriously consider collecting container movement data for all containers arriving into Australia. Failing this, the model for shipping containers could be modified to incorporate the likelihood of a container being unloaded to another ship at particular ports. For example, at central hub ports such as Singapore, a container may have a higher likelihood of being unloaded and transferred to another ship, while other ports are less likely to have ships unload their containers.

5.3. Model modifications

Further modifications to the ship model should improve its outputs. These modifications include:

1. Greater focus on the subset of species that are likely to pose the greatest threat to Australia
2. Incorporation of a seasonal element (i.e. some invasive species will only be active at certain times of the year and their likelihood to be transported on a ship will be altered)
3. Incorporation of the days a ship spends in a harbour into the infection likelihood parameter
4. An attempt to determine differences in infection and survival likelihood between invasive species
5. Determine changes in shipping routes and networks from season to season and year to year. This may involve the purchase of further ship movement data from Lloyds Registry
6. The analysis should be expanded to all ships, not just container ships, and an attempt to determine differences in infection and survival likelihoods between ship types should be made

5.4. Real time ship analysis

The ship model developed could be incorporated into the automatic ship monitoring system run by AMSA (Australian Maritime Safety Authority). This would enable 'real time' analysis of all incoming ships to Australian ports. DAFF inspection officers could therefore identify high 'threat' ships before they actually arrive into port, which would allow pre-emptive planning and optimise inspection protocols.

6. Abbreviations/glossary

ABBREVIATION	FULL TITLE
AMSA	Australian Maritime Safety Authority
CRCNPB	Cooperative Research Centre for National Plant Biosecurity
DAFF	Department of Agriculture, Fisheries and Forestry
EPP	Emergency plant pest
LMIU	Lloyd's Maritime Intelligence Unit
SOM	Self Organizing Map

7. Plain English website summary

CRC project no:	CRC10161
Project title:	Six degrees of preparation
Project leader:	Dean Paini
Project team:	Dean Paini, Paul De Barro
Research outcomes:	Models developed in this project, which enable the analysis of complex shipping networks, provide a significant step forward in the risk profiling of incoming ships to Australian ports. These models enable the identification of pathways of greatest threat from invasive species as well as those Australian ports most likely to receive these invasive species
Research implications:	These models could be incorporated into the current inspection protocols and enable further refinement and prioritisations for these procedures
Research publications:	Paini, DR and Yemshanov, D (2012) Modelling the arrival of invasive organisms via the international marine shipping network: A Khapra beetle study. PLoS ONE. In review
Acknowledgements:	Simon Barry, Peter Caley, Paul De Barro, Tom Harwood, Greg Hood, Rieks Van Klinken, Denys Yemshanov

8. Appendix

Table A8-1. Ranking of source countries for Khapra beetle infestations at Australian ports. Countries ranked by the arrival rate (φ_{ij}) to all Australian ports from the ports in a given country.

Country	φ_{ij}	relative φ_{ij} *
Taiwan	0.63928	9.05356
Republic of Korea	0.59408	8.41335
Egypt	0.15516	2.19732
Spain	0.09571	1.35546
Saudi Arabia	0.06730	0.95308
Sri Lanka	0.06634	0.93949
India	0.02222	0.31466
Yemen	0.01316	0.18635
Turkey	0.01184	0.16767
Pakistan	0.00852	0.12065
Israel	0.00576	0.08160
Iran	0.00419	0.05936
Nigeria	0.00308	0.04368
Sudan	0.00268	0.03791
Cypress	0.00229	0.03242
Uruguay	0.00099	0.01399
Lebanon	0.00075	0.01067
Bangladesh	0.00072	0.01018
Algeria	0.00032	0.00452
Libya	0.00026	0.00370
Mauritania	0.00003	0.00038
Morocco	0	0
Senegal	0	0
Syria	0	0
Mean	**0.07061**	

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations ($\overline{\varphi}_{ij}$ = 0.07061)

Table A8-2. Ranking of Australian ports for receiving the Khapra beetle from foreign ports. Ports ranked by arrival rate of Khapra beetle (φ_{ij}) from foreign ports in the countries with known beetle presence.

Australian Port	φ_{ij}	**relative** φ_{ij} *
Melbourne	0.5468195	8.9207194
Botany Bay	0.3976133	6.4865950
Brisbane	0.3904312	6.3694273
Bell Bay	0.2167836	3.5365693
Fremantle	0.1542654	2.5166590
Adelaide	0.0948990	1.5481657
Burnie	0.0495321	0.8080579
Sydney	0.0256229	0.4180071
Hobart	0.0137925	0.2250078
Newcastle	0.0029091	0.0474581
Port Kembla	0.0019770	0.0322521
Gove	0.0011788	0.0192313
Darwin	0.0010695	0.0174480
Devonport	0.0010211	0.0166579
Townsville	0.0007663	0.0125008
Gladstone	0.0003115	0.0050810
Geelong	0.0002875	0.0046896
Hastings	0.0002180	0.0035561
Port Alma	0.0002170	0.0035398
Port Walcott	0.0001810	0.0029526
Dampier	0.0001180	0.0019249
Mackay	0.0001145	0.0018678
Weipa	0.0000440	0.0007178
Bunbury	0.0000400	0.0006525
Port Hedland	0.0000065	0.0001060
Yamba	0.0000060	0.0000979
Portland	0.0000020	0.0000326
Karumba	0.0000010	0.0000163
Cairns	0.0000005	0.0000082
Geraldton	0	0
Esperance	0	0
Mean	**0.0612977**	

* denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations ($\overline{\varphi}_{ij}$ = 0.0613)

Table A8-3. Ranking of all source ports for Khapra beetle introduction to the Australian port of Melbourne.

Melbourne											
Port of origin *i*	**Country**	φ_{ij}	**relative φ_{ij} ***	**Port of origin *i***	**Country**	φ_{ij}	**relative φ_{ij} ***	**Port of origin *i***	**Country**	φ_{ij}	**relative φ_{ij} ***
Busan	KOR	0.2453320	94.60130	Limassol	CYP	0.0006685	0.25778	Ain Sukhna Term.	EGY	0.0000245	0.00945
Kaohsiung	TWN	0.2270000	87.53239	Ambarli	TUR	0.0006450	0.24872	Malaga	ESP	0.0000135	0.00521
Keelung	TWN	0.0749780	28.91191	Bilbao	ESP	0.0006245	0.24081	Pasajes	ESP	0.0000125	0.00482
Damietta	EGY	0.0387065	14.92543	Istanbul	TUR	0.0005905	0.22770	Mai-Liao	TWN	0.0000110	0.00424
Colombo	LKA	0.0208125	8.02541	Mumbai	IND	0.0004950	0.19087	Yanbu	SAU	0.0000085	0.00328
Jeddah	SAU	0.0185600	7.15683	New Tuticorin	IND	0.0004805	0.18528	Jubail	SAU	0.0000080	0.00308
Valencia	ESP	0.0179365	6.91641	Izmir	TUR	0.0004795	0.18490	Mongla	BGD	0.0000080	0.00308
Ulsan	KOR	0.0168835	6.51037	Ashkelon	ISR	0.0003970	0.15309	Tuzla	TUR	0.0000070	0.00270
Port Said	EGY	0.0107895	4.16049	Yarimca	TUR	0.0003790	0.14614	Nouakchott	MRT	0.0000070	0.00270
Barcelona	ESP	0.0066630	2.56929	Suez	EGY	0.0003680	0.14190	Eilat	ISR	0.0000050	0.00193
Gwangyang	KOR	0.0057465	2.21588	Alexandria	EGY	0.0003540	0.13650	Algiers	DZA	0.0000035	0.00135
Algeciras	ESP	0.0041430	1.59756	Gemlik	TUR	0.0003325	0.12821	Mundra	IND	0.0000030	0.00116
Aden	YEM	0.0029465	1.13619	Yosu	KOR	0.0003265	0.12590	Santander	ESP	0.0000015	0.00058
Jawaharlal Nehru	IND	0.0028640	1.10437	Montevideo	URY	0.0002960	0.11414	Samho	KOR	0.0000010	0.00039
Taichung	TWN	0.0024035	0.92680	Beirut	LBN	0.0002610	0.10064	Bandirma	TUR	0.0000005	0.00019
Dammam	SAU	0.0022440	0.86530	Cadiz	ESP	0.0002025	0.07809	Ceuta	ESP	0.0000005	0.00019
Masan	KOR	0.0017755	0.68464	Visakhapatnam	IND	0.0001770	0.06825	Mukalla	YEM	0	0
Karachi	PAK	0.0017660	0.68098	Chittagong	BGD	0.0001640	0.06324	Ras Lanuf	LBY	0	0
Chennai	IND	0.0017560	0.67712	Kolkata	IND	0.0001015	0.03914	Pyeongtaek	KOR	0	0
Incheon	KOR	0.0012730	0.49088	Kandla	IND	0.0000940	0.03625	Donghae	KOR	0	0
Bandar Abbas	IRN	0.0011800	0.45501	Kochi	IND	0.0000885	0.03413	Lattakia	SYR	0	0
Mersin	TUR	0.0010690	0.41221	Tripoli	LBY	0.0000800	0.03085	Alang	IND	0	0
Apapa-Lagos	NGA	0.0010510	0.40527	Arzew	DZA	0.0000680	0.02622	Karwar	IND	0	0
El Dekheila	EGY	0.0007785	0.30019	Derince	TUR	0.0000650	0.02506	Sikka	IND	0	0
Port Sudan	SDN	0.0007315	0.28207	Kakinada	IND	0.0000590	0.02275	Onne	NGA	0	0
Port Muhammad Bin Qasim	PAK	0.0007240	0.27918	Palma	ESP	0.0000575	0.02217	Dakar	SEN	0	0
Hodeidah	YEM	0.0007015	0.27050	Haldia	IND	0.0000495	0.01909	Casablanca	MAR	0	0
Haifa	ISR	0.0006945	0.26780	Sokhna	EGY	0.0000420	0.01620	Motril	ESP	0	0
Ashdod	ISR	0.0006710	0.25874	Tarragona	ESP	0.0000415	0.01600	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-4. Ranking of all source ports for Khapra beetle introduction to the Australian port of Botany Bay.

Botany Bay (Sydney)											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Kaohsiung	TWN	0.1594200	61.47318	Port Sudan	SDN	0.0004350	0.16774	Tripoli	LBY	0.0000250	0.00964
Busan	KOR	0.1582450	61.02010	Bilbao	ESP	0.0004220	0.16273	Pasajes	ESP	0.0000110	0.00424
Keelung	TWN	0.0528270	20.37037	Ambarli	TUR	0.0004090	0.15771	Eilat	ISR	0.0000090	0.00347
Damietta	EGY	0.0251605	9.70202	Istanbul	TUR	0.0003840	0.14807	Mai-Liao	TWN	0.0000080	0.00308
Colombo	LKA	0.0130410	5.02868	New Tuticorin	IND	0.0003455	0.13323	Jubail	SAU	0.0000065	0.00251
Jeddah	SAU	0.0121995	4.70419	Yarimca	TUR	0.0003070	0.11838	Sokhna	EGY	0.0000050	0.00193
Valencia	ESP	0.0119115	4.59314	Izmir	TUR	0.0002890	0.11144	Yanbu	SAU	0.0000045	0.00174
Port Said	EGY	0.0069330	2.67340	Mumbai	IND	0.0002795	0.10778	Tuzla	TUR	0.0000045	0.00174
Barcelona	ESP	0.0045050	1.73715	Alexandria	EGY	0.0002520	0.09717	Nouakchott	MRT	0.0000040	0.00154
Ulsan	KOR	0.0038910	1.50039	Ashkelon	ISR	0.0002505	0.09659	Mongla	BGD	0.0000035	0.00135
Gwangyang	KOR	0.0037305	1.43850	Montevideo	URY	0.0002415	0.09312	Bandirma	TUR	0.0000030	0.00116
Algeciras	ESP	0.0027970	1.07854	Suez	EGY	0.0002365	0.09120	Algiers	DZA	0.0000020	0.00077
Jawaharlal Nehru	IND	0.0022665	0.87397	Gemlik	TUR	0.0002125	0.08194	Mundra	IND	0.0000015	0.00058
Aden	YEM	0.0017740	0.68406	Yosu	KOR	0.0002100	0.08098	Samho	KOR	0.0000010	0.00039
Taichung	TWN	0.0016185	0.62410	Beirut	LBN	0.0001625	0.06266	Ceuta	ESP	0.0000005	0.00019
Dammam	SAU	0.0014595	0.56279	Cadiz	ESP	0.0001060	0.04087	Mukalla	YEM	0	0
Chennai	IND	0.0012015	0.46330	Chittagong	BGD	0.0000945	0.03644	Santander	ESP	0	0
Karachi	PAK	0.0011920	0.45964	Visakhapatnam	IND	0.0000860	0.03316	Ras Lanuf	LBY	0	0
Masan	KOR	0.0011635	0.44865	Kandla	IND	0.0000675	0.02603	Pyeongtaek	KOR	0	0
Incheon	KOR	0.0009235	0.35611	Kochi	IND	0.0000635	0.02449	Donghae	KOR	0	0
Bandar Abbas	IRN	0.0007375	0.28438	Kolkata	IND	0.0000535	0.02063	Lattakia	SYR	0	0
Mersin	TUR	0.0006605	0.25469	Ain Sukhna Term.	EGY	0.0000500	0.01928	Alang	IND	0	0
Apapa-Lagos	NGA	0.0006470	0.24949	Malaga	ESP	0.0000450	0.01735	Karwar	IND	0	0
Ashdod	ISR	0.0005245	0.20225	Palma	ESP	0.0000360	0.01388	Sikka	IND	0	0
Port Muhammad Bin Qasim	PAK	0.0005210	0.20090	Arzew	DZA	0.0000335	0.01292	Onne	NGA	0	0
El Dekheila	EGY	0.0004940	0.19049	Derince	TUR	0.0000325	0.01253	Dakar	SEN	0	0
Hodeidah	YEM	0.0004780	0.18432	Haldia	IND	0.0000315	0.01215	Casablanca	MAR	0	0
Haifa	ISR	0.0004755	0.18336	Kakinada	IND	0.0000265	0.01022	Motril	ESP	0	0
Limassol	CYP	0.0004520	0.17429	Tarragona	ESP	0.0000250	0.00964	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-5. Ranking of all source ports for Khapra beetle introduction to the Australian port of Brisbane.

Brisbane											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.1595950	61.54067	Haifa	ISR	0.0004110	0.15848	Tarragona	ESP	0.0000265	0.01022
Kaohsiung	TWN	0.1584480	61.09838	New Tuticorin	IND	0.0003730	0.14383	Ain Sukhna Term.	EGY	0.0000245	0.00945
Keelung	TWN	0.0522620	20.15250	Yarimca	TUR	0.0003695	0.14248	Mongla	BGD	0.0000085	0.00328
Damietta	EGY	0.0234515	9.04302	Istanbul	TUR	0.0003410	0.13149	Nouakchott	MRT	0.0000085	0.00328
Colombo	LKA	0.0115480	4.45297	Bilbao	ESP	0.0003315	0.12783	Pasajes	ESP	0.0000080	0.00308
Jeddah	SAU	0.0096345	3.71511	Ambarli	TUR	0.0003110	0.11992	Malaga	ESP	0.0000070	0.00270
Valencia	ESP	0.0087870	3.38831	Ashkelon	ISR	0.0003005	0.11587	Tuzla	TUR	0.0000065	0.00251
Port Said	EGY	0.0054050	2.08420	Mumbai	IND	0.0002540	0.09794	Eilat	ISR	0.0000045	0.00174
Gwangyang	KOR	0.0041785	1.61125	Yosu	KOR	0.0002390	0.09216	Yanbu	SAU	0.0000030	0.00116
Ulsan	KOR	0.0038815	1.49673	Montevideo	URY	0.0002230	0.08599	Sokhna	EGY	0.0000025	0.00096
Barcelona	ESP	0.0035510	1.36928	Alexandria	EGY	0.0002075	0.08001	Bandirma	TUR	0.0000020	0.00077
Aden	YEM	0.0026040	1.00412	Izmir	TUR	0.0002065	0.07963	Samho	KOR	0.0000010	0.00039
Algeciras	ESP	0.0023015	0.88747	Suez	EGY	0.0002025	0.07809	Santander	ESP	0.0000010	0.00039
Jawaharlal Nehru	IND	0.0021695	0.83657	Beirut	LBN	0.0001630	0.06285	Mundra	IND	0.0000005	0.00019
Dammam	SAU	0.0014890	0.57417	Gemlik	TUR	0.0001515	0.05842	Algiers	DZA	0.0000005	0.00019
Taichung	TWN	0.0013300	0.51285	Chittagong	BGD	0.0001445	0.05572	Ceuta	ESP	0.0000005	0.00019
Karachi	PAK	0.0012760	0.49203	Cadiz	ESP	0.0001180	0.04550	Mukalla	YEM	0	0
Masan	KOR	0.0011040	0.42571	Kochi	IND	0.0001155	0.04454	Ras Lanuf	LBY	0	0
Chennai	IND	0.0009095	0.35071	Visakhapatnam	IND	0.0001115	0.04299	Pyeongtaek	KOR	0	0
Incheon	KOR	0.0009080	0.35013	Kolkata	IND	0.0001050	0.04049	Donghae	KOR	0	0
Bandar Abbas	IRN	0.0006665	0.25701	Kandla	IND	0.0000775	0.02988	Lattakia	SYR	0	0
Mersin	TUR	0.0006610	0.25489	Palma	ESP	0.0000705	0.02719	Alang	IND	0	0
Hodeidah	YEM	0.0005765	0.22230	Derince	TUR	0.0000600	0.02314	Karwar	IND	0	0
Port Sudan	SDN	0.0004965	0.19145	Mai-Liao	TWN	0.0000485	0.01870	Sikka	IND	0	0
Apapa-Lagos	NGA	0.0004935	0.19030	Arzew	DZA	0.0000400	0.01542	Onne	NGA	0	0
Ashdod	ISR	0.0004915	0.18952	Jubail	SAU	0.0000390	0.01504	Dakar	SEN	0	0
El Dekheila	EGY	0.0004745	0.18297	Kakinada	IND	0.0000315	0.01215	Casablanca	MAR	0	0
Limassol	CYP	0.0004475	0.17256	Tripoli	LBY	0.0000295	0.01138	Motril	ESP	0	0
Port Muhammad Bin Qasim	PAK	0.0004200	0.16195	Haldia	IND	0.0000270	0.01041	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-6. Ranking of all source ports for Khapra beetle introduction to the Australian port of Bell Bay.

Bell Bay											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.0838840	32.34611	Ashdod	ISR	0.0002095	0.08078	Ain Sukhna Term.	EGY	0.0000055	0.00212
Kaohsiung	TWN	0.0704900	27.18131	Limassol	CYP	0.0002075	0.08001	Malaga	ESP	0.0000050	0.00193
Keelung	TWN	0.0232015	8.94662	Bilbao	ESP	0.0002045	0.07886	Pasajes	ESP	0.0000040	0.00154
Damietta	EGY	0.0121385	4.68067	Mumbai	IND	0.0001860	0.07172	Mai-Liao	TWN	0.0000040	0.00154
Ulsan	KOR	0.0099830	3.84950	Istanbul	TUR	0.0001820	0.07018	Nouakchott	MRT	0.0000035	0.00135
Colombo	LKA	0.0065110	2.51068	New Tuticorin	IND	0.0001560	0.06015	Yanbu	SAU	0.0000025	0.00096
Jeddah	SAU	0.0059830	2.30708	Izmir	TUR	0.0001545	0.05958	Mongla	BGD	0.0000025	0.00096
Valencia	ESP	0.0057930	2.23381	Ashkelon	ISR	0.0001350	0.05206	Jubail	SAU	0.0000020	0.00077
Port Said	EGY	0.0033045	1.27423	Yarimca	TUR	0.0001235	0.04762	Tuzla	TUR	0.0000020	0.00077
Barcelona	ESP	0.0020815	0.80264	Suez	EGY	0.0001125	0.04338	Eilat	ISR	0.0000010	0.00039
Gwangyang	KOR	0.0019605	0.75598	Gemlik	TUR	0.0001100	0.04242	Algiers	DZA	0.0000010	0.00039
Algeciras	ESP	0.0012865	0.49608	Alexandria	EGY	0.0001095	0.04222	Mundra	IND	0.0000005	0.00019
Aden	YEM	0.0011750	0.45309	Yosu	KOR	0.0000950	0.03663	Santander	ESP	0.0000005	0.00019
Jawaharlal Nehru	IND	0.0009720	0.37481	Montevideo	URY	0.0000925	0.03567	Bandirma	TUR	0	0
Taichung	TWN	0.0007920	0.30540	Beirut	LBN	0.0000865	0.03335	Mukalla	YEM	0	0
Dammam	SAU	0.0007145	0.27551	Visakhapatnam	IND	0.0000690	0.02661	Samho	KOR	0	0
Chennai	IND	0.0006020	0.23213	Cadiz	ESP	0.0000600	0.02314	Ceuta	ESP	0	0
Karachi	PAK	0.0005835	0.22500	Chittagong	BGD	0.0000540	0.02082	Ras Lanuf	LBY	0	0
Masan	KOR	0.0005640	0.21748	Kolkata	IND	0.0000350	0.01350	Pyeongtaek	KOR	0	0
Incheon	KOR	0.0004010	0.15463	Kochi	IND	0.0000345	0.01330	Donghae	KOR	0	0
Bandar Abbas	IRN	0.0003980	0.15347	Kandla	IND	0.0000295	0.01138	Lattakia	SYR	0	0
Apapa-Lagos	NGA	0.0003550	0.13689	Tripoli	LBY	0.0000275	0.01060	Alang	IND	0	0
Mersin	TUR	0.0003430	0.13226	Derince	TUR	0.0000265	0.01022	Karwar	IND	0	0
El Dekheila	EGY	0.0002460	0.09486	Arzew	DZA	0.0000260	0.01003	Sikka	IND	0	0
Port Muhammad Bin Qasim	PAK	0.0002395	0.09235	Kakinada	IND	0.0000245	0.00945	Onne	NGA	0	0
Port Sudan	SDN	0.0002315	0.08927	Haldia	IND	0.0000200	0.00771	Dakar	SEN	0	0
Haifa	ISR	0.0002235	0.08618	Palma	ESP	0.0000195	0.00752	Casablanca	MAR	0	0
Ambarli	TUR	0.0002195	0.08464	Tarragona	ESP	0.0000135	0.00521	Motril	ESP	0	0
Hodeidah	YEM	0.0002150	0.08291	Sokhna	EGY	0.0000130	0.00501	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-7. Ranking of all source ports for Khapra beetle introduction to the Australian port of Fremantle.

Fremantle											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.0508600	19.61188	Port Muhammad Bin Qasim	PAK	0.0002420	0.09332	Ain Sukhna Term.	EGY	0.0000080	0.00308
Kaohsiung	TWN	0.0424370	16.36393	Istanbul	TUR	0.0002210	0.08522	Mongla	BGD	0.0000070	0.00270
Damietta	EGY	0.0120660	4.65271	Ashdod	ISR	0.0002180	0.08406	Yanbu	SAU	0.0000045	0.00174
Keelung	TWN	0.0119650	4.61377	Gemlik	TUR	0.0001885	0.07269	Mai-Liao	TWN	0.0000030	0.00116
Valencia	ESP	0.0087365	3.36884	Haifa	ISR	0.0001855	0.07153	Sokhna	EGY	0.0000030	0.00116
Colombo	LKA	0.0075645	2.91691	Mumbai	IND	0.0001745	0.06729	Jubail	SAU	0.0000025	0.00096
Jeddah	SAU	0.0073830	2.84692	Apapa-Lagos	NGA	0.0001730	0.06671	Malaga	ESP	0.0000025	0.00096
Port Said	EGY	0.0042090	1.62301	Visakhapatnam	IND	0.0001490	0.05746	Eilat	ISR	0.0000025	0.00096
Barcelona	ESP	0.0026285	1.01356	Suez	EGY	0.0001435	0.05533	Mundra	IND	0.0000025	0.00096
Gwangyang	KOR	0.0021120	0.81440	Hodeidah	YEM	0.0001245	0.04801	Nouakchott	MRT	0.0000015	0.00058
Ulsan	KOR	0.0016460	0.63471	Cadiz	ESP	0.0001035	0.03991	Samho	KOR	0.0000015	0.00058
Jawaharlal Nehru	IND	0.0015365	0.59248	Alexandria	EGY	0.0000980	0.03779	Bandirma	TUR	0.0000010	0.00039
Algeciras	ESP	0.0014915	0.57513	Yarimca	TUR	0.0000935	0.03605	Algiers	DZA	0.0000005	0.00019
Aden	YEM	0.0013055	0.50341	Haldia	IND	0.0000860	0.03316	Tuzla	TUR	0	0
Dammam	SAU	0.0009410	0.36285	Chittagong	BGD	0.0000835	0.03220	Mukalla	YEM	0	0
Bandar Abbas	IRN	0.0006760	0.26067	Montevideo	URY	0.0000600	0.02314	Santander	ESP	0	0
Taichung	TWN	0.0005735	0.22114	Kakinada	IND	0.0000535	0.02063	Ceuta	ESP	0	0
Karachi	PAK	0.0005505	0.21228	Ashkelon	ISR	0.0000520	0.02005	Ras Lanuf	LBY	0	0
Masan	KOR	0.0005080	0.19589	Tripoli	LBY	0.0000495	0.01909	Pyeongtaek	KOR	0	0
Chennai	IND	0.0004770	0.18393	Yosu	KOR	0.0000430	0.01658	Donghae	KOR	0	0
Port Sudan	SDN	0.0003920	0.15116	Kolkata	IND	0.0000430	0.01658	Lattakia	SYR	0	0
El Dekheila	EGY	0.0002980	0.11491	Kandla	IND	0.0000370	0.01427	Alang	IND	0	0
Bilbao	ESP	0.0002900	0.11183	Beirut	LBN	0.0000320	0.01234	Karwar	IND	0	0
Incheon	KOR	0.0002795	0.10778	Pasajes	ESP	0.0000320	0.01234	Sikka	IND	0	0
New Tuticorin	IND	0.0002590	0.09987	Kochi	IND	0.0000280	0.01080	Onne	NGA	0	0
Limassol	CYP	0.0002540	0.09794	Derince	TUR	0.0000255	0.00983	Dakar	SEN	0	0
Ambarli	TUR	0.0002520	0.09717	Arzew	DZA	0.0000220	0.00848	Casablanca	MAR	0	0
Izmir	TUR	0.0002475	0.09544	Palma	ESP	0.0000220	0.00848	Motril	ESP	0	0
Mersin	TUR	0.0002420	0.09332	Tarragona	ESP	0.0000185	0.00713	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-8. Ranking of all source ports for Khapra beetle introduction to the Australian port of Adelaide.

Adelaide											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.0287645	11.09174	Istanbul	TUR	0.0001320	0.05090	Malaga	ESP	0.0000045	0.00174
Kaohsiung	TWN	0.0239790	9.24643	Port Muhammad Bin Qasim	PAK	0.0001250	0.04820	Pasajes	ESP	0.0000040	0.00154
Damietta	EGY	0.0092280	3.55837	Haifa	ISR	0.0001155	0.04454	Yanbu	SAU	0.0000030	0.00116
Keelung	TWN	0.0069460	2.67841	Ashdod	ISR	0.0001110	0.04280	Eilat	ISR	0.0000020	0.00077
Colombo	LKA	0.0056965	2.19660	Suez	EGY	0.0001095	0.04222	Jubail	SAU	0.0000015	0.00058
Jeddah	SAU	0.0052435	2.02192	Apapa-Lagos	NGA	0.0001015	0.03914	Sokhna	EGY	0.0000015	0.00058
Valencia	ESP	0.0049775	1.91935	Kandla	IND	0.0000810	0.03123	Mai-Liao	TWN	0.0000010	0.00039
Port Said	EGY	0.0032930	1.26980	Gemlik	TUR	0.0000700	0.02699	Nouakchott	MRT	0.0000010	0.00039
Barcelona	ESP	0.0015950	0.61504	Hodeidah	YEM	0.0000620	0.02391	Mundra	IND	0.0000010	0.00039
Algeciras	ESP	0.0011510	0.44383	New Tuticorin	IND	0.0000615	0.02371	Samho	KOR	0.0000010	0.00039
Gwangyang	KOR	0.0010540	0.40643	Yarimca	TUR	0.0000595	0.02294	Bandirma	TUR	0.0000005	0.00019
Ulsan	KOR	0.0009120	0.35167	Cadiz	ESP	0.0000595	0.02294	Mongla	BGD	0.0000005	0.00019
Aden	YEM	0.0005870	0.22635	Alexandria	EGY	0.0000570	0.02198	Algiers	DZA	0.0000005	0.00019
Jawaharlal Nehru	IND	0.0005160	0.19897	Ashkelon	ISR	0.0000340	0.01311	Tuzla	TUR	0	0
Dammam	SAU	0.0004090	0.15771	Chittagong	BGD	0.0000315	0.01215	Mukalla	YEM	0	0
Bandar Abbas	IRN	0.0003680	0.14190	Yosu	KOR	0.0000305	0.01176	Santander	ESP	0	0
Masan	KOR	0.0003225	0.12436	Visakhapatnam	IND	0.0000290	0.01118	Ceuta	ESP	0	0
Karachi	PAK	0.0003055	0.11780	Montevideo	URY	0.0000275	0.01060	Ras Lanuf	LBY	0	0
Chennai	IND	0.0002775	0.10701	Kolkata	IND	0.0000270	0.01041	Pyeongtaek	KOR	0	0
Taichung	TWN	0.0002260	0.08715	Haldia	IND	0.0000165	0.00636	Donghae	KOR	0	0
Port Sudan	SDN	0.0002170	0.08368	Kochi	IND	0.0000145	0.00559	Lattakia	SYR	0	0
El Dekheila	EGY	0.0001895	0.07307	Beirut	LBN	0.0000135	0.00521	Alang	IND	0	0
Incheon	KOR	0.0001880	0.07249	Tripoli	LBY	0.0000120	0.00463	Karwar	IND	0	0
Bilbao	ESP	0.0001835	0.07076	Kakinada	IND	0.0000120	0.00463	Sikka	IND	0	0
Limassol	CYP	0.0001765	0.06806	Arzew	DZA	0.0000115	0.00443	Onne	NGA	0	0
Ambarli	TUR	0.0001700	0.06555	Palma	ESP	0.0000095	0.00366	Dakar	SEN	0	0
Mersin	TUR	0.0001590	0.06131	Tarragona	ESP	0.0000095	0.00366	Casablanca	MAR	0	0
Izmir	TUR	0.0001425	0.05495	Derince	TUR	0.0000090	0.00347	Motril	ESP	0	0
Mumbai	IND	0.0001385	0.05341	Ain Sukhna Term.	EGY	0.0000055	0.00212	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-9. Ranking of all source ports for Khapra beetle introduction to the Australian port of Burnie.

Burnie											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.0177015	6.82579	Istanbul	TUR	0.0000440	0.01697	Haldia	IND	0.0000015	0.00058
Kaohsiung	TWN	0.0149445	5.76268	Hodeidah	YEM	0.0000435	0.01677	Ain Sukhna Term.	EGY	0.0000015	0.00058
Keelung	TWN	0.0048660	1.87636	Limassol	CYP	0.0000385	0.01485	Mai-Liao	TWN	0.0000015	0.00058
Damietta	EGY	0.0025725	0.99197	Ambarli	TUR	0.0000375	0.01446	Algiers	DZA	0.0000010	0.00039
Ulsan	KOR	0.0021000	0.80977	Mumbai	IND	0.0000345	0.01330	Pasajes	ESP	0.0000005	0.00019
Colombo	LKA	0.0013890	0.53561	Izmir	TUR	0.0000320	0.01234	Yanbu	SAU	0.0000005	0.00019
Jeddah	SAU	0.0012410	0.47854	New Tuticorin	IND	0.0000295	0.01138	Nouakchott	MRT	0.0000005	0.00019
Valencia	ESP	0.0012060	0.46504	Yarimca	TUR	0.0000255	0.00983	Eilat	ISR	0.0000005	0.00019
Port Said	EGY	0.0006720	0.25913	Ashkelon	ISR	0.0000240	0.00925	Malaga	ESP	0	0
Barcelona	ESP	0.0004475	0.17256	Gemlik	TUR	0.0000230	0.00887	Bandirma	TUR	0	0
Gwangyang	KOR	0.0003970	0.15309	Yosu	KOR	0.0000210	0.00810	Tuzla	TUR	0	0
Taichung	TWN	0.0003950	0.15231	Montevideo	URY	0.0000210	0.00810	Mukalla	YEM	0	0
Chennai	IND	0.0003105	0.11973	Alexandria	EGY	0.0000205	0.00790	Mongla	BGD	0	0
Algeciras	ESP	0.0002655	0.10238	Suez	EGY	0.0000185	0.00713	Mundra	IND	0	0
Aden	YEM	0.0002460	0.09486	Beirut	LBN	0.0000160	0.00617	Samho	KOR	0	0
Jawaharlal Nehru	IND	0.0001935	0.07461	Cadiz	ESP	0.0000150	0.00578	Santander	ESP	0	0
Dammam	SAU	0.0001510	0.05823	Chittagong	BGD	0.0000120	0.00463	Ceuta	ESP	0	0
Karachi	PAK	0.0001350	0.05206	Visakhapatnam	IND	0.0000120	0.00463	Ras Lanuf	LBY	0	0
Masan	KOR	0.0001170	0.04512	Tripoli	LBY	0.0000095	0.00366	Pyeongtaek	KOR	0	0
Apapa-Lagos	NGA	0.0000940	0.03625	Derince	TUR	0.0000085	0.00328	Donghae	KOR	0	0
Incheon	KOR	0.0000825	0.03181	Kolkata	IND	0.0000080	0.00308	Lattakia	SYR	0	0
Bandar Abbas	IRN	0.0000775	0.02988	Arzew	DZA	0.0000075	0.00289	Alang	IND	0	0
Mersin	TUR	0.0000630	0.02429	Palma	ESP	0.0000070	0.00270	Karwar	IND	0	0
Port Muhammad Bin Qasim	PAK	0.0000550	0.02121	Kochi	IND	0.0000055	0.00212	Sikka	IND	0	0
Haifa	ISR	0.0000530	0.02044	Sokhna	EGY	0.0000050	0.00193	Onne	NGA	0	0
El Dekheila	EGY	0.0000515	0.01986	Kandla	IND	0.0000040	0.00154	Dakar	SEN	0	0
Port Sudan	SDN	0.0000490	0.01889	Tarragona	ESP	0.0000040	0.00154	Casablanca	MAR	0	0
Ashdod	ISR	0.0000480	0.01851	Kakinada	IND	0.0000040	0.00154	Motril	ESP	0	0
Bilbao	ESP	0.0000445	0.01716	Jubail	SAU	0.0000020	0.00077	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-10. Ranking of all source ports for Khapra beetle introduction to the Australian port of Sydney Harbour.

Sydney Harbour											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.0084035	3.24043	Port Muhammad Bin Qasim	PAK	0.0000280	0.01080	Mai-Liao	TWN	0.0000010	0.00039
Kaohsiung	TWN	0.0076975	2.96820	Bilbao	ESP	0.0000280	0.01080	Haldia	IND	0.0000005	0.00019
Keelung	TWN	0.0025470	0.98214	Ambarli	TUR	0.0000275	0.01060	Pasajes	ESP	0.0000005	0.00019
Damietta	EGY	0.0017950	0.69216	Hodeidah	YEM	0.0000260	0.01003	Jubail	SAU	0.0000005	0.00019
Colombo	LKA	0.0008910	0.34357	Limassol	CYP	0.0000245	0.00945	Sokhna	EGY	0.0000005	0.00019
Jeddah	SAU	0.0006950	0.26800	Haifa	ISR	0.0000240	0.00925	Mongla	BGD	0.0000005	0.00019
Valencia	ESP	0.0006575	0.25354	Yarimca	TUR	0.0000210	0.00810	Nouakchott	MRT	0.0000005	0.00019
Port Said	EGY	0.0004950	0.19087	Istanbul	TUR	0.0000200	0.00771	Yanbu	SAU	0	0
Ulsan	KOR	0.0003795	0.14634	New Tuticorin	IND	0.0000185	0.00713	Malaga	ESP	0	0
Barcelona	ESP	0.0002920	0.11260	Izmir	TUR	0.0000150	0.00578	Bandirma	TUR	0	0
Gwangyang	KOR	0.0002500	0.09640	Montevideo	URY	0.0000140	0.00540	Mukalla	YEM	0	0
Algeciras	ESP	0.0001930	0.07442	Gemlik	TUR	0.0000130	0.00501	Eilat	ISR	0	0
Jawaharlal Nehru	IND	0.0001860	0.07172	Suez	EGY	0.0000125	0.00482	Mundra	IND	0	0
Apapa-Lagos	NGA	0.0001330	0.05129	Yosu	KOR	0.0000115	0.00443	Algiers	DZA	0	0
Aden	YEM	0.0001150	0.04434	Ashkelon	ISR	0.0000110	0.00424	Samho	KOR	0	0
Karachi	PAK	0.0000940	0.03625	Alexandria	EGY	0.0000110	0.00424	Santander	ESP	0	0
Dammam	SAU	0.0000830	0.03201	Cadiz	ESP	0.0000090	0.00347	Ceuta	ESP	0	0
Taichung	TWN	0.0000800	0.03085	Beirut	LBN	0.0000080	0.00308	Ras Lanuf	LBY	0	0
Mumbai	IND	0.0000785	0.03027	Chittagong	BGD	0.0000075	0.00289	Pyeongtaek	KOR	0	0
Masan	KOR	0.0000680	0.02622	Kolkata	IND	0.0000065	0.00251	Donghae	KOR	0	0
Chennai	IND	0.0000670	0.02584	Kandla	IND	0.0000060	0.00231	Lattakia	SYR	0	0
Port Sudan	SDN	0.0000535	0.02063	Kochi	IND	0.0000055	0.00212	Alang	IND	0	0
Bandar Abbas	IRN	0.0000520	0.02005	Visakhapatnam	IND	0.0000050	0.00193	Karwar	IND	0	0
Incheon	KOR	0.0000405	0.01562	Palma	ESP	0.0000035	0.00135	Sikka	IND	0	0
Mersin	TUR	0.0000395	0.01523	Tripoli	LBY	0.0000020	0.00077	Onne	NGA	0	0
Arzew	DZA	0.0000345	0.01330	Derince	TUR	0.0000015	0.00058	Dakar	SEN	0	0
El Dekheila	EGY	0.0000330	0.01272	Ain Sukhna Term.	EGY	0.0000015	0.00058	Casablanca	MAR	0	0
Ashdod	ISR	0.0000320	0.01234	Tuzla	TUR	0.0000015	0.00058	Motril	ESP	0	0
Tarragona	ESP	0.0000320	0.01234	Kakinada	IND	0.0000010	0.00039	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-11. Ranking of all source ports for Khapra beetle introduction to the Australian port of Hobart.

Hobart											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.0048670	1.87674	Ashdod	ISR	0.0000120	0.00463	Mongla	BGD	0.0000005	0.00019
Kaohsiung	TWN	0.0041040	1.58252	Bilbao	ESP	0.0000110	0.00424	Kakinada	IND	0	0
Keelung	TWN	0.0014075	0.54274	Ambarli	TUR	0.0000105	0.00405	Pasajes	ESP	0	0
Damietta	EGY	0.0006960	0.26838	Istanbul	TUR	0.0000105	0.00405	Jubail	SAU	0	0
Ulsan	KOR	0.0005480	0.21131	Port Muhammad Bin Qasim	PAK	0.0000100	0.00386	Mai-Liao	TWN	0	0
Colombo	LKA	0.0003945	0.15212	Montevideo	URY	0.0000090	0.00347	Malaga	ESP	0	0
Valencia	ESP	0.0003520	0.13573	Izmir	TUR	0.0000085	0.00328	Sokhna	EGY	0	0
Jeddah	SAU	0.0003500	0.13496	Suez	EGY	0.0000080	0.00308	Bandirma	TUR	0	0
Port Said	EGY	0.0002160	0.08329	Yosu	KOR	0.0000080	0.00308	Tuzla	TUR	0	0
Barcelona	ESP	0.0001265	0.04878	Gemlik	TUR	0.0000075	0.00289	Mukalla	YEM	0	0
Gwangyang	KOR	0.0001115	0.04299	Beirut	LBN	0.0000075	0.00289	Nouakchott	MRT	0	0
Algeciras	ESP	0.0000730	0.02815	New Tuticorin	IND	0.0000065	0.00251	Eilat	ISR	0	0
Jawaharlal Nehru	IND	0.0000565	0.02179	Ashkelon	ISR	0.0000060	0.00231	Mundra	IND	0	0
Aden	YEM	0.0000500	0.01928	Alexandria	EGY	0.0000060	0.00231	Algiers	DZA	0	0
Dammam	SAU	0.0000400	0.01542	Yarimca	TUR	0.0000045	0.00174	Samho	KOR	0	0
Taichung	TWN	0.0000400	0.01542	Cadiz	ESP	0.0000045	0.00174	Santander	ESP	0	0
Karachi	PAK	0.0000365	0.01407	Chittagong	BGD	0.0000035	0.00135	Ceuta	ESP	0	0
Chennai	IND	0.0000355	0.01369	Visakhapatnam	IND	0.0000025	0.00096	Ras Lanuf	LBY	0	0
Masan	KOR	0.0000340	0.01311	Kolkata	IND	0.0000025	0.00096	Pyeongtaek	KOR	0	0
Bandar Abbas	IRN	0.0000295	0.01138	Palma	ESP	0.0000020	0.00077	Donghae	KOR	0	0
Incheon	KOR	0.0000280	0.01080	Tripoli	LBY	0.0000020	0.00077	Lattakia	SYR	0	0
Apapa-Lagos	NGA	0.0000225	0.00868	Kochi	IND	0.0000015	0.00058	Alang	IND	0	0
Haifa	ISR	0.0000165	0.00636	Tarragona	ESP	0.0000015	0.00058	Karwar	IND	0	0
Mersin	TUR	0.0000160	0.00617	Haldia	IND	0.0000015	0.00058	Sikka	IND	0	0
Limassol	CYP	0.0000135	0.00521	Derince	TUR	0.0000010	0.00039	Onne	NGA	0	0
Mumbai	IND	0.0000135	0.00521	Arzew	DZA	0.0000010	0.00039	Dakar	SEN	0	0
Port Sudan	SDN	0.0000125	0.00482	Kandla	IND	0.0000005	0.00019	Casablanca	MAR	0	0
El Dekheila	EGY	0.0000125	0.00482	Ain Sukhna Term.	EGY	0.0000005	0.00019	Motril	ESP	0	0
Hodeidah	YEM	0.0000125	0.00482	Yanbu	SAU	0.0000005	0.00019	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-12. Ranking of all source ports for Khapra beetle introduction to the Australian port of Newcastle.

Newcastle											
Port of origin *i*	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***	**Port of origin *i***	**Country**	**φ_{ij}**	**relative φ_{ij} ***
Busan	KOR	0.0008935	0.34454	Yarimca	TUR	0.0000045	0.00174	Suez	EGY	0	0
Kaohsiung	TWN	0.0008225	0.31716	Port Sudan	SDN	0.0000030	0.00116	Derince	TUR	0	0
Keelung	TWN	0.0002775	0.10701	Port Muhammad Bin Qasim	PAK	0.0000030	0.00116	Tarragona	ESP	0	0
Damietta	EGY	0.0001785	0.06883	El Dekheila	EGY	0.0000025	0.00096	Ain Sukhna Term.	EGY	0	0
Colombo	LKA	0.0000935	0.03605	Hodeidah	YEM	0.0000025	0.00096	Pasajes	ESP	0	0
Valencia	ESP	0.0000865	0.03335	Ashdod	ISR	0.0000025	0.00096	Jubail	SAU	0	0
Jeddah	SAU	0.0000665	0.02564	Limassol	CYP	0.0000025	0.00096	Yanbu	SAU	0	0
Barcelona	ESP	0.0000505	0.01947	Mumbai	IND	0.0000020	0.00077	Malaga	ESP	0	0
Port Said	EGY	0.0000390	0.01504	New Tuticorin	IND	0.0000020	0.00077	Mukalla	YEM	0	0
Karachi	PAK	0.0000365	0.01407	Ashkelon	ISR	0.0000020	0.00077	Mongla	BGD	0	0
Ulsan	KOR	0.0000345	0.01330	Beirut	LBN	0.0000020	0.00077	Nouakchott	MRT	0	0
Arzew	DZA	0.0000340	0.01311	Montevideo	URY	0.0000015	0.00058	Eilat	ISR	0	0
Ambarli	TUR	0.0000330	0.01272	Bilbao	ESP	0.0000010	0.00039	Mundra	IND	0	0
Bandirma	TUR	0.0000320	0.01234	Alexandria	EGY	0.0000010	0.00039	Algiers	DZA	0	0
Chittagong	BGD	0.0000280	0.01080	Cadiz	ESP	0.0000010	0.00039	Samho	KOR	0	0
Kakinada	IND	0.0000260	0.01003	Visakhapatnam	IND	0.0000010	0.00039	Santander	ESP	0	0
Gwangyang	KOR	0.0000240	0.00925	Kolkata	IND	0.0000010	0.00039	Ceuta	ESP	0	0
Jawaharlal Nehru	IND	0.0000185	0.00713	Kochi	IND	0.0000010	0.00039	Ras Lanuf	LBY	0	0
Algeciras	ESP	0.0000180	0.00694	Tripoli	LBY	0.0000010	0.00039	Pyeongtaek	KOR	0	0
Aden	YEM	0.0000165	0.00636	Istanbul	TUR	0.0000005	0.00019	Donghae	KOR	0	0
Taichung	TWN	0.0000105	0.00405	Gemlik	TUR	0.0000005	0.00019	Lattakia	SYR	0	0
Chennai	IND	0.0000105	0.00405	Yosu	KOR	0.0000005	0.00019	Alang	IND	0	0
Dammam	SAU	0.0000095	0.00366	Kandla	IND	0.0000005	0.00019	Karwar	IND	0	0
Masan	KOR	0.0000070	0.00270	Palma	ESP	0.0000005	0.00019	Sikka	IND	0	0
Haifa	ISR	0.0000055	0.00212	Haldia	IND	0.0000005	0.00019	Onne	NGA	0	0
Bandar Abbas	IRN	0.0000050	0.00193	Mai-Liao	TWN	0.0000005	0.00019	Dakar	SEN	0	0
Incheon	KOR	0.0000050	0.00193	Sokhna	EGY	0.0000005	0.00019	Casablanca	MAR	0	0
Mersin	TUR	0.0000045	0.00174	Tuzla	TUR	0.0000005	0.00019	Motril	ESP	0	0
Apapa-Lagos	NGA	0.0000045	0.00174	Izmir	TUR	0	0	Seville	ESP	0	0

***** denotes the relative pest's arrival rate versus the avergae φ_{ij} values for all network locations (i.e. the mean of all φ_{ij} values in Tables A3-A12) ($\overline{\varphi}_{ij}$ = 0.00259)

Table A8-13. Top 100 ranked species by invasion likelihood for the port of Adelaide.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.001133	51	*Mamestra brassicae*	0.000188
2	*Philaenus spumarius*	0.000951	52	*Schistocerca gregaria*	0.000186
3	*Hadula trifolii*	0.000852	53	*Dasineura mali*	0.000185
4	*Pieris brassicae*	0.000717	54	*Delia radicum*	0.000178
5	*Trichoplusia ni*	0.000607	55	*Metopolophium festucae*	0.000177
6	*Lymantria dispar*	0.000583	56	*Opogona sacchari*	0.000176
7	*Sitobion avenae*	0.000548	57	*Dasineura pyri*	0.000173
8	*Aphis fabae*	0.000507	58	*Epidiaspis leperii*	0.000173
9	*Oulema melanopus*	0.000455	59	*Lixus juncii*	0.000173
10	*Ceroplastes rusci*	0.000443	60	*Anthonomus pomorum*	0.000170
11	*Mayetiola destructor*	0.000434	61	*Megastigmus spermotrophus*	0.000166
12	*Acronicta rumicis*	0.000421	62	*Bactrocera oleae*	0.000165
13	*Scolytus rugulosus*	0.000366	63	*Dialeurodes citri*	0.000162
14	*Meligethes aeneus*	0.000360	64	*Paranthrene tabaniformis*	0.000154
15	*Cryptoblabes gnidiella*	0.000356	65	*Rhagoletis cerasi*	0.000144
16	*Aphis pomi*	0.000352	66	*Orthosia cerasi*	0.000141
17	*Orthezia insignis*	0.000351	67	*Delia antiqua*	0.000140
18	*Liriomyza trifolii*	0.000335	68	*Aulacophora foveicollis*	0.000131
19	*Chromatomyia horticola*	0.000320	69	*Acrolepiopsis assectella*	0.000130
20	*Euproctis chrysorrhoea*	0.000316	70	*Phyllotreta cruciferae*	0.000130
21	*Brachycaudus helichrysi*	0.000316	71	*Aproaerema modicella*	0.000125
22	*Spodoptera littoralis*	0.000303	72	*Sitona lepidus*	0.000119
23	*Deilephila elpenor*	0.000296	73	*Thrips angusticeps*	0.000118
24	*Aleurothrixus floccosus*	0.000294	74	*Eulecanium tiliae*	0.000116
25	*Laodelphax striatellus*	0.000292	75	*Megachile rotundata*	0.000114
26	*Cacoecimorpha pronubana*	0.000273	76	*Thaumetopoea pityocampa*	0.000114
27	*Henosepilachna elaterii*	0.000272	77	*Pseudococcus comstocki*	0.000112
28	*Psila rosae*	0.000272	78	*Acanthiophilus helianthi*	0.000111
29	*Operophtera brumata*	0.000272	79	*Sesamia cretica*	0.000108
30	*Leptinotarsa decemlineata*	0.000263	80	*Haplothrips tritici*	0.000108
31	*Lobesia botrana*	0.000256	81	*Neoaliturus tenellus*	0.000106
32	*Pissodes castaneus*	0.000251	82	*Rhyacionia buoliana*	0.000105
33	*Anarsia lineatella*	0.000248	83	*Nipaecoccus nipae*	0.000105
34	*Liriomyza huidobrensis*	0.000244	84	*Cephus pygmeus*	0.000101
35	*Xylosandrus compactus*	0.000243	85	*Sitona cylindricollis*	0.000099
36	*Contarinia tritici*	0.000236	86	*Sitona humeralis*	0.000097
37	*Peridroma saucia*	0.000233	87	*Lymantria monacha*	0.000097
38	*Mythimna unipuncta*	0.000233	88	*Zeuzera pyrina*	0.000085
39	*Malacosoma neustria*	0.000232	89	*Tipula paludosa*	0.000084
40	*Liriomyza bryoniae*	0.000229	90	*Prays oleae*	0.000080
41	*Trialeurodes vaporariorum*	0.000225	91	*Scolytus scolytus*	0.000079
42	*Grapholita funebrana*	0.000220	92	*Dioryctria abietella*	0.000078
43	*Ostrinia nubilalis*	0.000212	93	*Jacobiasca lybica*	0.000077
44	*Dysaphis plantaginea*	0.000205	94	*Taeniothrips inconsequens*	0.000076
45	*Parlatoria oleae*	0.000200	95	*Saturnia pyri*	0.000076
46	*Diuraphis noxia*	0.000200	96	*Byturus tomentosus*	0.000073
47	*Phorodon humuli*	0.000197	97	*Empoasca vitis*	0.000073
48	*Eupoecilia ambiguella*	0.000197	98	*Sitona hispidulus*	0.000072
49	*Scrobipalpa ocellatella*	0.000194	99	*Frankliniella intonsa*	0.000070
50	*Autographa gamma*	0.000191	100	*Psylliodes chrysocephala*	0.000069

Table A8-14. Top 100 ranked species by invasion likelihood for the port of Botany Bay.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Xylosandrus compactus*	0.510496	51	*Omphisa anastomosalis*	0.132613
2	*Pinnaspis strachani*	0.411172	52	*Zeuzera coffeae*	0.128716
3	*Liriomyza trifolii*	0.394227	53	*Helopeltis theivora*	0.125890
4	*Agrotis segetum*	0.386366	54	*Omiodes indicata*	0.125571
5	*Sesamia inferens*	0.379196	55	*Liriomyza sativae*	0.123634
6	*Orthezia insignis*	0.377598	56	*Pyrilla perpusilla*	0.122033
7	*Trichoplusia ni*	0.328127	57	*Fulmekiola serrata*	0.117080
8	*Diaphorina citri*	0.326541	58	*Bombyx mori*	0.116638
9	*Oryctes rhinoceros*	0.322967	59	*Henosepilachna pusillanima*	0.115976
10	*Leucinodes orbonalis*	0.307911	60	*Planococcus lilacinus*	0.112612
11	*Toxoptera odinae*	0.282440	61	*Lopholeucaspis japonica*	0.110285
12	*Dialeurodes citri*	0.277944	62	*Papilio polytes*	0.108078
13	*Aleurocanthus woglumi*	0.271629	63	*Hieroglyphus banian*	0.106259
14	*Acherontia styx*	0.237222	64	*Atherigona pulla*	0.096458
15	*Sinoxylon conigerum*	0.225420	65	*Statherotis discana*	0.096062
16	*Stephanitis typica*	0.224906	66	*Prostephanus truncatus*	0.094668
17	*Pelopidas mathias*	0.217915	67	*Idioscopus clypealis*	0.090764
18	*Nephotettix virescens*	0.216361	68	*Chaetocnema confinis*	0.089390
19	*Aphis fabae*	0.215552	69	*Opogona sacchari*	0.088958
20	*Aproaerema modicella*	0.210138	70	*Sesamia cretica*	0.088812
21	*Aulacophora lewisii*	0.206478	71	*Minthea rugicollis*	0.088691
22	*Chilo infuscatellus*	0.199356	72	*Naranga diffusa*	0.087909
23	*Liriomyza huidobrensis*	0.196211	73	*Heterobostrychus aequalis*	0.085397
24	*Atherigona soccata*	0.196078	74	*Aleurothrixus floccosus*	0.083796
25	*Hydrellia philippina*	0.194573	75	*Amsacta moorei*	0.083401
26	*Bactrocera dorsalis*	0.191855	76	*Medythia suturalis*	0.083070
27	*Chromatomyia horticola*	0.191062	77	*Deilephila elpenor*	0.082887
28	*Chilo auricilius*	0.189084	78	*Tetramoera schistaceana*	0.082599
29	*Dicladispa armigera*	0.179611	79	*Frankliniella intonsa*	0.077237
30	*Erionota thrax*	0.170323	80	*Bactrocera tau*	0.076965
31	*Phyllotreta striolata*	0.168279	81	*Hyblaea puera*	0.074543
32	*Brachycaudus helichrysi*	0.168026	82	*Pseudodendrothrips mori*	0.071994
33	*Orseolia oryzae*	0.166978	83	*Pieris brassicae*	0.068789
34	*Odoiporus longicollis*	0.164683	84	*Acanthocoris scabrator*	0.068467
35	*Bactrocera latifrons*	0.161335	85	*Chondracris rosea*	0.068158
36	*Batocera rubus*	0.157526	86	*Parlatoria oleae*	0.067895
37	*Parasa lepida*	0.148908	87	*Parabemisia myricae*	0.066331
38	*Orgyia postica*	0.145633	88	*Hypothenemus hampei*	0.065483
39	*Ceratovacuna lanigera*	0.144898	89	*Cryptoblabes gnidiella*	0.063910
40	*Xylotrechus quadripes*	0.144392	90	*Adoretus sinicus*	0.062773
41	*Rhipiphorothrips cruentatus*	0.144282	91	*Unaspis yanonensis*	0.060798
42	*Sitobion avenae*	0.142632	92	*Diuraphis noxia*	0.060271
43	*Nipaecoccus nipae*	0.142327	93	*Laodelphax striatellus*	0.059891
44	*Rastrococcus invadens*	0.141144	94	*Clanis bilineata*	0.059094
45	*Hypomeces squamosus*	0.141039	95	*Ceroplastes rusci*	0.057327
46	*Attacus atlas*	0.139923	96	*Pseudococcus comstocki*	0.056661
47	*Chilo sacchariphagus*	0.138642	97	*Cossus cossus*	0.056426
48	*Xyleborus ferrugineus*	0.133896	98	*Aonidomytilus albus*	0.056153
49	*Batocera rufomaculata*	0.132874	99	*Acanthiophilus helianthi*	0.055116
50	*Plocaederus obesus*	0.132829	100	*Euscepes postfasciatus*	0.053964

Table A8-15. Top 100 ranked species by invasion likelihood for the port of Brisbane.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Xylosandrus compactus*	0.414387	51	*Parasa lepida*	0.053683
2	*Aproaerema modicella*	0.202048	52	*Orgyia postica*	0.053039
3	*Sesamia inferens*	0.192184	53	*Ceratovacuna lanigera*	0.052434
4	*Pinnaspis strachani*	0.190205	54	*Helopeltis bradyi*	0.050260
5	*Oryctes rhinoceros*	0.188678	55	*Bactrocera tau*	0.048941
6	*Aleurocanthus woglumi*	0.187458	56	*Atherigona soccata*	0.048710
7	*Leucinodes orbonalis*	0.176473	57	*Adoretus versutus*	0.048607
8	*Diaphorina citri*	0.160936	58	*Chilo infuscatellus*	0.046499
9	*Toxoptera odinae*	0.148601	59	*Aulacophora foveicollis*	0.046047
10	*Agrotis segetum*	0.125983	60	*Phyllotreta chotanica*	0.045592
11	*Stephanitis typica*	0.120654	61	*Dialeurodes citri*	0.045432
12	*Sinoxylon conigerum*	0.115316	62	*Omiodes indicata*	0.044936
13	*Rastrococcus invadens*	0.114149	63	*Pseudococcus jackbeardsleyi*	0.043951
14	*Helopeltis theivora*	0.101215	64	*Papilio polytes*	0.043541
15	*Liriomyza huidobrensis*	0.095473	65	*Aphis fabae*	0.043225
16	*Pelopidas mathias*	0.094018	66	*Prays endocarpa*	0.040587
17	*Erionota thrax*	0.093935	67	*Rhynchophorus vulneratus*	0.040510
18	*Trichoplusia ni*	0.093423	68	*Aleurothrixus floccosus*	0.039954
19	*Brachycaudus helichrysi*	0.091454	69	*Megymenum brevicorne*	0.039472
20	*Odoiporus longicollis*	0.090755	70	*Trialeurodes ricini*	0.039272
21	*Rastrococcus iceryoides*	0.089324	71	*Bombyx mori*	0.039089
22	*Urentius hystricellus*	0.088377	72	*Fulmekiola serrata*	0.038476
23	*Bactrocera latifrons*	0.087323	73	*Heterobostrychus aequalis*	0.036907
24	*Chilo auricilius*	0.086899	74	*Bactrocera dorsalis*	0.035303
25	*Chilo sacchariphagus*	0.084474	75	*Oryzaephilus mercator*	0.033700
26	*Dicladispa armigera*	0.082301	76	*Statherotis discana*	0.032286
27	*Orthezia insignis*	0.081889	77	*Tetramoera schistaceana*	0.032271
28	*Hypothenemus hampei*	0.080515	78	*Minthea rugicollis*	0.032135
29	*Bactrocera umbrosa*	0.079748	79	*Xylotrechus quadripes*	0.031791
30	*Batocera rubus*	0.079340	80	*Bactrocera papayae*	0.031563
31	*Hypomeces squamosus*	0.077270	81	*Acanthocoris scabrator*	0.030944
32	*Xyleborus ferrugineus*	0.077248	82	*Adoretus sinicus*	0.030176
33	*Liriomyza trifolii*	0.077090	83	*Lepidiota stigma*	0.029915
34	*Acherontia styx*	0.076760	84	*Hysteroneura setariae*	0.029531
35	*Aulacaspis tegalensis*	0.075779	85	*Rhynchocoris poseidon*	0.029446
36	*Nephotettix virescens*	0.075223	86	*Artona catoxantha*	0.028994
37	*Aulacophora lewisii*	0.071342	87	*Ahasverus advena*	0.028933
38	*Orseolia oryzae*	0.070643	88	*Nipaecoccus nipae*	0.028467
39	*Tarophagus colocasiae*	0.065552	89	*Deporaus marginatus*	0.027800
40	*Planococcus lilacinus*	0.063714	90	*Batocera rufomaculata*	0.026885
41	*Idioscopus clypealis*	0.063343	91	*Perkinsiella vastatrix*	0.026508
42	*Hydrellia philippina*	0.063156	92	*Pyrilla perpusilla*	0.025951
43	*Omphisa anastomosalis*	0.062982	93	*Trialeurodes vaporariorum*	0.025792
44	*Sternochetus frigidus*	0.062935	94	*Liriomyza sativae*	0.025783
45	*Cryptoblabes gnidiella*	0.060730	95	*Rhipiphorothrips cruentatus*	0.025540
46	*Zeuzera coffeae*	0.057825	96	*Promecotheca cumingii*	0.025425
47	*Henosepilachna pusillanima*	0.057553	97	*Sitobion avenae*	0.024757
48	*Phyllotreta striolata*	0.056700	98	*Cricula trifenestrata*	0.024565
49	*Attacus atlas*	0.056531	99	*Chlumetia transversa*	0.023105
50	*Chromatomyia horticola*	0.056423	100	*Plocaederus obesus*	0.023037

Table A8-16. Top 100 ranked species by invasion likelihood for the port of Burnie.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Philaenus spumarius*	0.00084654	51	*Diaphorina citri*	0.00001443
2	*Cryptoblabes gnidiella*	0.00048224	52	*Xyleborus ferrugineus*	0.00001381
3	*Mayetiola destructor*	0.00038553	53	*Autographa gamma*	0.00001373
4	*Brachycaudus helichrysi*	0.00033231	54	*Mamestra brassicae*	0.00001330
5	*Xylosandrus compactus*	0.00030834	55	*Acherontia styx*	0.00001312
6	*Psila rosae*	0.00024156	56	*Anthonomus pomorum*	0.00001306
7	*Contarinia tritici*	0.00023913	57	*Atherigona pulla*	0.00001238
8	*Trialeurodes vaporariorum*	0.00020664	58	*Minthea rugicollis*	0.00001233
9	*Aproaerema modicella*	0.00019980	59	*Paranthrene tabaniformis*	0.00001056
10	*Metopolophium festucae*	0.00019866	60	*Pelopidas mathias*	0.00001003
11	*Dasineura mali*	0.00018773	61	*Popillia japonica*	0.00000958
12	*Phorodon humuli*	0.00018527	62	*Bothynoderes punctiventris*	0.00000956
13	*Dasineura pyri*	0.00017543	63	*Leucinodes orbonalis*	0.00000896
14	*Sitona lepidus*	0.00017243	64	*Nipaecoccus nipae*	0.00000860
15	*Megastigmus spermotrophus*	0.00017134	65	*Atherigona soccata*	0.00000847
16	*Megachile rotundata*	0.00016997	66	*Delia antiqua*	0.00000840
17	*Agrotis segetum*	0.00006835	67	*Sitona cylindricollis*	0.00000831
18	*Hadula trifolii*	0.00005290	68	*Sphaerolecanium prunastri*	0.00000829
19	*Trichoplusia ni*	0.00003984	69	*Ips sexdentatus*	0.00000752
20	*Lymantria dispar*	0.00003541	70	*Sesamia inferens*	0.00000746
21	*Aphis fabae*	0.00003424	71	*Liriomyza sativae*	0.00000719
22	*Sesamia cretica*	0.00003279	72	*Lymantria monacha*	0.00000696
23	*Oulema melanopus*	0.00003174	73	*Cossus cossus*	0.00000693
24	*Sitobion avenae*	0.00003107	74	*Aulacophora lewisii*	0.00000680
25	*Acronicta rumicis*	0.00002981	75	*Aleurocanthus woglumi*	0.00000670
26	*Pinnaspis strachani*	0.00002801	76	*Dioryctria abietella*	0.00000668
27	*Euproctis chrysorrhoea*	0.00002517	77	*Empoasca vitis*	0.00000668
28	*Parlatoria oleae*	0.00002447	78	*Toxoptera odinae*	0.00000662
29	*Laodelphax striatellus*	0.00002408	79	*Batocera rufomaculata*	0.00000616
30	*Dialeurodes citri*	0.00002401	80	*Ips typographus*	0.00000594
31	*Orthezia insignis*	0.00002359	81	*Loxostege sticticalis*	0.00000572
32	*Acanthiophilus helianthi*	0.00002348	82	*Dicladispa armigera*	0.00000559
33	*Liriomyza trifolii*	0.00002339	83	*Pyrilla perpusilla*	0.00000526
34	*Anarsia lineatella*	0.00002307	84	*Rhipiphorothrips cruentatus*	0.00000519
35	*Aphis pomi*	0.00002230	85	*Chilo auricilius*	0.00000508
36	*Chromatomyia horticola*	0.00002145	86	*Lopholeucaspis japonica*	0.00000494
37	*Opogona sacchari*	0.00002132	87	*Frankliniella intonsa*	0.00000483
38	*Deilephila elpenor*	0.00002125	88	*Prostephanus truncatus*	0.00000472
39	*Diuraphis noxia*	0.00002068	89	*Adoxophyes orana*	0.00000466
40	*Pseudococcus comstocki*	0.00001923	90	*Dendroctonus micans*	0.00000466
41	*Chilo infuscatellus*	0.00001903	91	*Delia floralis*	0.00000436
42	*Liriomyza bryoniae*	0.00001666	92	*Autographa nigrisigna*	0.00000433
43	*Malacosoma neustria*	0.00001663	93	*Melolontha melolontha*	0.00000406
44	*Liriomyza huidobrensis*	0.00001628	94	*Ampelophaga rubiginosa*	0.00000382
45	*Delia radicum*	0.00001600	95	*Carposina sasakii*	0.00000369
46	*Grapholita funebrana*	0.00001583	96	*Phyllotreta striolata*	0.00000369
47	*Haplothrips tritici*	0.00001563	97	*Ips cembrae*	0.00000344
48	*Eupoecilia ambiguella*	0.00001556	98	*Cacopsylla pyri*	0.00000336
49	*Peridroma saucia*	0.00001459	99	*Orgyia antiqua*	0.00000331
50	*Parabemisia myricae*	0.00001452	100	*Pseudodendrothrips mori*	0.00000326

Table A8-17. Top 100 ranked species by invasion likelihood for the port of Dampier.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.0013205	51	*Bactrocera oleae*	0.0001976
2	*Hadula trifolii*	0.0009218	52	*Ampelophaga rubiginosa*	0.0001968
3	*Diaphorina citri*	0.0007912	53	*Bactrocera dorsalis*	0.0001961
4	*Trichoplusia ni*	0.0007851	54	*Papilio polytes*	0.0001955
5	*Sitobion avenae*	0.0007051	55	*Chilo partellus*	0.0001940
6	*Lymantria dispar*	0.0006875	56	*Spodoptera littoralis*	0.0001905
7	*Toxoptera odinae*	0.0005665	57	*Dacus ciliatus*	0.0001875
8	*Pieris brassicae*	0.0005603	58	*Mythimna unipuncta*	0.0001873
9	*Brachycaudus helichrysi*	0.0005280	59	*Aproaerema modicella*	0.0001866
10	*Laodelphax striatellus*	0.0004796	60	*Diuraphis noxia*	0.0001863
11	*Aphis fabae*	0.0004672	61	*Chilo auricilius*	0.0001827
12	*Ceroplastes rusci*	0.0004574	62	*Parasa lepida*	0.0001821
13	*Henosepilachna elaterii*	0.0004513	63	*Paranthrene tabaniformis*	0.0001814
14	*Deilephila elpenor*	0.0004427	64	*Trogoderma granarium*	0.0001762
15	*Xylosandrus compactus*	0.0004420	65	*Rastrococcus iceryoides*	0.0001732
16	*Aleurothrixus floccosus*	0.0004067	66	*Oedaleus senegalensis*	0.0001732
17	*Philaenus spumarius*	0.0003971	67	*Pelopidas mathias*	0.0001654
18	*Leucinodes orbonalis*	0.0003952	68	*Frankliniella intonsa*	0.0001647
19	*Dialeurodes citri*	0.0003854	69	*Pinnaspis strachani*	0.0001597
20	*Aulacophora foveicollis*	0.0003753	70	*Opogona sacchari*	0.0001572
21	*Parlatoria oleae*	0.0003731	71	*Pyrilla perpusilla*	0.0001569
22	*Liriomyza huidobrensis*	0.0003574	72	*Lopholeucaspis japonica*	0.0001560
23	*Chromatomyia horticola*	0.0003572	73	*Scolytus rugulosus*	0.0001557
24	*Sesamia cretica*	0.0003413	74	*Jacobiasca lybica*	0.0001542
25	*Sesamia inferens*	0.0003375	75	*Batocera rufomaculata*	0.0001526
26	*Acherontia styx*	0.0003324	76	*Autographa nigrisigna*	0.0001478
27	*Phyllotreta striolata*	0.0003308	77	*Oryctes rhinoceros*	0.0001462
28	*Liriomyza trifolii*	0.0003171	78	*Trialeurodes ricini*	0.0001453
29	*Orthezia insignis*	0.0003120	79	*Neoaliturus tenellus*	0.0001449
30	*Acanthiophilus helianthi*	0.0002969	80	*Eulecanium tiliae*	0.0001384
31	*Mamestra brassicae*	0.0002943	81	*Cryptoblabes gnidiella*	0.0001374
32	*Urentius hystricellus*	0.0002943	82	*Oryzaephilus mercator*	0.0001363
33	*Aleurocanthus woglumi*	0.0002743	83	*Pseudococcus comstocki*	0.0001330
34	*Chilo infuscatellus*	0.0002685	84	*Mayetiola destructor*	0.0001308
35	*Schistocerca gregaria*	0.0002672	85	*Lymantria monacha*	0.0001291
36	*Pterochloroides persicae*	0.0002610	86	*Bactrocera zonata*	0.0001259
37	*Aphis pomi*	0.0002566	87	*Psila rosae*	0.0001216
38	*Liriomyza bryoniae*	0.0002534	88	*Malacosoma neustria*	0.0001214
39	*Acronicta rumicis*	0.0002523	89	*Operophtera brumata*	0.0001207
40	*Dioryctria abietella*	0.0002347	90	*Leptinotarsa decemlineata*	0.0001201
41	*Autographa gamma*	0.0002323	91	*Rhipiphorothrips cruentatus*	0.0001199
42	*Oulema melanopus*	0.0002211	92	*Cossus cossus*	0.0001175
43	*Pseudodendrothrips mori*	0.0002211	93	*Hieroglyphus banian*	0.0001171
44	*Delia antiqua*	0.0002195	94	*Sipha maydis*	0.0001154
45	*Euproctis chrysorrhoea*	0.0002145	95	*Cicadulina mbila*	0.0001144
46	*Atherigona soccata*	0.0002134	96	*Scolytus scolytus*	0.0001132
47	*Dicladispa armigera*	0.0002085	97	*Trialeurodes vaporariorum*	0.0001127
48	*Anarsia lineatella*	0.0002059	98	*Minthea rugicollis*	0.0001084
49	*Aulacophora lewisii*	0.0002031	99	*Adoretus versutus*	0.0001041
50	*Meligethes aeneus*	0.0001991	100	*Phyllotreta cruciferae*	0.0001036

Table A8-18. Top 100 ranked species by invasion likelihood for the port of Darwin.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Aleurocanthus woglumi*	0.004871	51	*Dialeurodes citri*	0.000456
2	*Xylosandrus compactus*	0.004304	52	*Henosepilachna pusillanima*	0.000445
3	*Sesamia inferens*	0.003532	53	*Minthea rugicollis*	0.000438
4	*Oryctes rhinoceros*	0.003433	54	*Sesamia cretica*	0.000424
5	*Pinnaspis strachani*	0.003233	55	*Cossus cossus*	0.000397
6	*Diaphorina citri*	0.003085	56	*Ceroplastes rusci*	0.000393
7	*Chilo auricilius*	0.003065	57	*Hieroglyphus banian*	0.000384
8	*Toxoptera odinae*	0.002826	58	*Batocera rufomaculata*	0.000375
9	*Chilo infuscatellus*	0.002747	59	*Spodoptera littoralis*	0.000374
10	*Dicladispa armigera*	0.002720	60	*Henosepilachna elaterii*	0.000364
11	*Pelopidas mathias*	0.002685	61	*Dacus ciliatus*	0.000362
12	*Leucinodes orbonalis*	0.002685	62	*Oryzaephilus mercator*	0.000360
13	*Planococcus lilacinus*	0.002201	63	*Rhipiphorothrips cruentatus*	0.000356
14	*Agrotis segetum*	0.001939	64	*Bactrocera zonata*	0.000341
15	*Rastrococcus iceryoides*	0.001861	65	*Aphis fabae*	0.000321
16	*Rastrococcus invadens*	0.001816	66	*Opisina arenosella*	0.000313
17	*Urentius hystricellus*	0.001625	67	*Xylotrechus quadripes*	0.000306
18	*Aulacaspis tegalensis*	0.001492	68	*Omiodes indicata*	0.000305
19	*Xyleborus ferrugineus*	0.001454	69	*Zeuzera coffeae*	0.000303
20	*Stephanitis typica*	0.001393	70	*Phyllotreta striolata*	0.000302
21	*Aproaerema modicella*	0.001366	71	*Brachycaudus helichrysi*	0.000296
22	*Atherigona soccata*	0.001324	72	*Chromatomyia horticola*	0.000288
23	*Acherontia styx*	0.001284	73	*Bactrocera tau*	0.000283
24	*Chilo partellus*	0.001167	74	*Sternochetus frigidus*	0.000283
25	*Trichoplusia ni*	0.001149	75	*Prays endocarpa*	0.000274
26	*Odoiporus longicollis*	0.001022	76	*Amsacta moorei*	0.000273
27	*Orseolia oryzae*	0.000969	77	*Bactrocera latifrons*	0.000271
28	*Liriomyza huidobrensis*	0.000968	78	*Acrocercops syngramma*	0.000271
29	*Pyrilla perpusilla*	0.000913	79	*Schistocerca gregaria*	0.000270
30	*Phyllotreta chotanica*	0.000887	80	*Hypomeces squamosus*	0.000262
31	*Adoretus versutus*	0.000820	81	*Hadula trifolii*	0.000250
32	*Bactrocera dorsalis*	0.000790	82	*Sitobion avenae*	0.000230
33	*Aleurothrixus floccosus*	0.000772	83	*Hydrellia philippina*	0.000212
34	*Aulacophora foveicollis*	0.000768	84	*Bactrocera umbrosa*	0.000208
35	*Sinoxylon conigerum*	0.000761	85	*Helopeltis bradyi*	0.000205
36	*Parasa lepida*	0.000744	86	*Acanthocoris scabrator*	0.000205
37	*Nephotettix virescens*	0.000717	87	*Hysteroneura setariae*	0.000192
38	*Hypothenemus hampei*	0.000704	88	*Parlatoria oleae*	0.000191
39	*Melanagromyza obtusa*	0.000683	89	*Idioscopus clypealis*	0.000190
40	*Erionota thrax*	0.000680	90	*Cricula trifenestrata*	0.000188
41	*Liriomyza trifolii*	0.000671	91	*Papilio polytes*	0.000182
42	*Orthezia insignis*	0.000660	92	*Pterochloroides persicae*	0.000177
43	*Aulacophora lewisii*	0.000605	93	*Characoma stictigrapta*	0.000175
44	*Helopeltis theivora*	0.000602	94	*Plocaederus obesus*	0.000174
45	*Batocera rubus*	0.000545	95	*Tetramoera schistaceana*	0.000173
46	*Chilo sacchariphagus*	0.000500	96	*Pieris brassicae*	0.000171
47	*Elaeidobius kamerunicus*	0.000478	97	*Cryptoblabes gnidiella*	0.000160
48	*Attacus atlas*	0.000478	98	*Ceratovacuna lanigera*	0.000159
49	*Trialeurodes ricini*	0.000475	99	*Acanthiophilus helianthi*	0.000158
50	*Orgyia postica*	0.000458	100	*Oedaleus senegalensis*	0.000151

Table A8-19. Top 100 ranked species by invasion likelihood for the port of Esperance.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Trichoplusia ni*	0.00022235	51	*Phyllotreta striolata*	0.00001299
2	*Sitobion avenae*	0.00019648	52	*Delia antiqua*	0.00001291
3	*Ceroplastes rusci*	0.00015367	53	*Aleurocanthus woglumi*	0.00001275
4	*Aphis fabae*	0.00014769	54	*Megalurothrips sjostedti*	0.00001216
5	*Liriomyza trifolii*	0.00010600	55	*Eupoecilia ambiguella*	0.00001207
6	*Brachycaudus helichrysi*	0.00008925	56	*Neoaliturus tenellus*	0.00001177
7	*Aleurothrixus floccosus*	0.00008864	57	*Sesamia calamistis*	0.00001154
8	*Orthezia insignis*	0.00008820	58	*Nipaecoccus nipae*	0.00001096
9	*Parlatoria oleae*	0.00008336	59	*Atherigona pulla*	0.00001033
10	*Dialeurodes citri*	0.00008198	60	*Cacoecimorpha pronubana*	0.00001001
11	*Pieris brassicae*	0.00007838	61	*Clavigralla elongata*	0.00000982
12	*Diuraphis noxia*	0.00007499	62	*Hypothenemus hampei*	0.00000959
13	*Agrotis segetum*	0.00007476	63	*Minthea rugicollis*	0.00000946
14	*Liriomyza huidobrensis*	0.00007311	64	*Erosomyia mangiferae*	0.00000929
15	*Scolytus rugulosus*	0.00006860	65	*Sipha maydis*	0.00000879
16	*Pseudococcus comstocki*	0.00005380	66	*Dysdercus fasciatus*	0.00000847
17	*Mythimna unipuncta*	0.00005215	67	*Rhyacionia buoliana*	0.00000810
18	*Jacobiasca lybica*	0.00005062	68	*Taeniothrips inconsequens*	0.00000755
19	*Opogona sacchari*	0.00004156	69	*Apate monachus*	0.00000742
20	*Xylosandrus compactus*	0.00004114	70	*Earias biplaga*	0.00000729
21	*Henosepilachna elaterii*	0.00003964	71	*Prostephanus truncatus*	0.00000709
22	*Spodoptera littoralis*	0.00003960	72	*Phenacoccus madeirensis*	0.00000706
23	*Diaphorina citri*	0.00003874	73	*Clavigralla tomentosicollis*	0.00000673
24	*Xyleborus ferrugineus*	0.00003696	74	*Nomadacris septemfasciata*	0.00000616
25	*Liriomyza sativae*	0.00003595	75	*Cacyreus marshalli*	0.00000590
26	*Toxoptera odinae*	0.00003249	76	*Pissodes nemorensis*	0.00000584
27	*Aulacophora foveicollis*	0.00003122	77	*Scirtothrips aurantii*	0.00000576
28	*Peridroma saucia*	0.00002959	78	*Busseola fusca*	0.00000519
29	*Schistocerca gregaria*	0.00002899	79	*Metopolophium festucae*	0.00000492
30	*Dacus ciliatus*	0.00002886	80	*Ceratitis cosyra*	0.00000359
31	*Epidiaspis leperii*	0.00002640	81	*Spodoptera frugiperda*	0.00000342
32	*Chromatomyia horticola*	0.00002246	82	*Helicoverpa zea*	0.00000336
33	*Leucinodes orbonalis*	0.00002154	83	*Heteronychus licas*	0.00000327
34	*Chilo partellus*	0.00002147	84	*Ceratitis rosa*	0.00000325
35	*Phenacoccus manihoti*	0.00002037	85	*Perileucoptera coffeella*	0.00000288
36	*Oryctes monoceros*	0.00001988	86	*Spodoptera eridania*	0.00000288
37	*Bactrocera oleae*	0.00001986	87	*Leucoptera caffeina*	0.00000287
38	*Oryctes boas*	0.00001960	88	*Omiodes indicata*	0.00000283
39	*Trialeurodes vaporariorum*	0.00001931	89	*Metamasius hemipterus*	0.00000281
40	*Cryptophlebia leucotreta*	0.00001865	90	*Trichispa sericea*	0.00000277
41	*Atherigona soccata*	0.00001837	91	*Diatraea saccharalis*	0.00000271
42	*Urentius hystricellus*	0.00001835	92	*Erinnyis alope*	0.00000266
43	*Eldana saccharina*	0.00001779	93	*Erinnyis ello*	0.00000266
44	*Cicadulina mbila*	0.00001761	94	*Sinoxylon conigerum*	0.00000260
45	*Trioza erytreae*	0.00001759	95	*Anastrepha fraterculus*	0.00000252
46	*Oryzaephilus mercator*	0.00001617	96	*Anastrepha grandis*	0.00000237
47	*Aproaerema modicella*	0.00001567	97	*Diabrotica speciosa*	0.00000227
48	*Pinnaspis strachani*	0.00001414	98	*Heliothis virescens*	0.00000222
49	*Megachile rotundata*	0.00001406	99	*Piezodorus guildinii*	0.00000213
50	*Chaetocnema confinis*	0.00001310	100	*Elasmopalpus lignosellus*	0.00000210

Table A8-20. Top 100 ranked species by invasion likelihood for the port of Fremantle.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.21362	51	*Adoretus versutus*	0.02564
2	*Diaphorina citri*	0.13879	52	*Liriomyza bryoniae*	0.02560
3	*Trichoplusia ni*	0.12463	53	*Chilo infuscatellus*	0.02518
4	*Toxoptera odinae*	0.11062	54	*Schistocerca gregaria*	0.02432
5	*Xylosandrus compactus*	0.08271	55	*Euproctis chrysorrhoea*	0.02409
6	*Hadula trifolii*	0.07846	56	*Acanthiophilus helianthi*	0.02400
7	*Leucinodes orbonalis*	0.07588	57	*Dioryctria abietella*	0.02397
8	*Sitobion avenae*	0.07390	58	*Acronicta rumicis*	0.02396
9	*Liriomyza huidobrensis*	0.07122	59	*Autographa gamma*	0.02349
10	*Pieris brassicae*	0.06852	60	*Trialeurodes ricini*	0.02337
11	*Aleurothrixus floccosus*	0.06494	61	*Scolytus rugulosus*	0.02285
12	*Laodelphax striatellus*	0.06182	62	*Aulacophora lewisii*	0.02251
13	*Lymantria dispar*	0.05926	63	*Chilo partellus*	0.02189
14	*Ceroplastes rusci*	0.05855	64	*Aphis pomi*	0.02135
15	*Chromatomyia horticola*	0.05777	65	*Delia antiqua*	0.02025
16	*Aulacophora foveicollis*	0.05441	66	*Lymantria monacha*	0.01954
17	*Sesamia inferens*	0.05425	67	*Oryzaephilus mercator*	0.01916
18	*Spodoptera littoralis*	0.05391	68	*Malacosoma neustria*	0.01863
19	*Urentius hystricellus*	0.05301	69	*Trialeurodes vaporariorum*	0.01858
20	*Orthezia insignis*	0.05002	70	*Minthea rugicollis*	0.01774
21	*Acherontia styx*	0.04999	71	*Leptinotarsa decemlineata*	0.01723
22	*Aphis fabae*	0.04952	72	*Planococcus lilacinus*	0.01710
23	*Philaenus spumarius*	0.04603	73	*Odoiporus longicollis*	0.01708
24	*Aleurocanthus woglumi*	0.04590	74	*Erionota thrax*	0.01683
25	*Phyllotreta striolata*	0.04578	75	*Mayetiola destructor*	0.01663
26	*Liriomyza trifolii*	0.04493	76	*Anarsia lineatella*	0.01663
27	*Henosepilachna elaterii*	0.04409	77	*Operophtera brumata*	0.01652
28	*Deilephila elpenor*	0.04154	78	*Aulacaspis tegalensis*	0.01636
29	*Brachycaudus helichrysi*	0.04141	79	*Eupoecilia ambiguella*	0.01626
30	*Atherigona soccata*	0.03715	80	*Psila rosae*	0.01624
31	*Rastrococcus iceryoides*	0.03458	81	*Jacobiasca lybica*	0.01618
32	*Dialeurodes citri*	0.03186	82	*Cacoecimorpha pronubana*	0.01602
33	*Dicladispa armigera*	0.03098	83	*Lobesia botrana*	0.01598
34	*Oryctes rhinoceros*	0.03018	84	*Oryctes monoceros*	0.01595
35	*Aproaerema modicella*	0.03016	85	*Hypothenemus hampei*	0.01575
36	*Opogona sacchari*	0.02996	86	*Anthonomus pomorum*	0.01559
37	*Parlatoria oleae*	0.02976	87	*Rastrococcus invadens*	0.01549
38	*Papilio polytes*	0.02851	88	*Hypomeces squamosus*	0.01522
39	*Chilo auricilius*	0.02851	89	*Bactrocera dorsalis*	0.01507
40	*Mamestra brassicae*	0.02799	90	*Haplothrips tritici*	0.01507
41	*Parasa lepida*	0.02735	91	*Byturus tomentosus*	0.01506
42	*Sesamia cretica*	0.02708	92	*Bactrocera zonata*	0.01499
43	*Oulema melanopus*	0.02665	93	*Cossus cossus*	0.01451
44	*Pterochloroides persicae*	0.02631	94	*Mythimna unipuncta*	0.01442
45	*Diuraphis noxia*	0.02625	95	*Paranthrene tabaniformis*	0.01430
46	*Meligethes aeneus*	0.02625	96	*Trioza erytreae*	0.01426
47	*Bactrocera oleae*	0.02623	97	*Cryptophlebia leucotreta*	0.01411
48	*Dacus ciliatus*	0.02618	98	*Pissodes castaneus*	0.01410
49	*Pelopidas mathias*	0.02586	99	*Frankliniella intonsa*	0.01389
50	*Pinnaspis strachani*	0.02565	100	*Phyllotreta cruciferae*	0.01357

Table A8-21. Top 100 ranked species by invasion likelihood for the port of Geelong.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.0010835	51	*Autographa gamma*	0.0001813
2	*Hadula trifolii*	0.0009768	52	*Eupoecilia ambiguella*	0.0001804
3	*Pieris brassicae*	0.0006560	53	*Mamestra brassicae*	0.0001701
4	*Trichoplusia ni*	0.0006210	54	*Paranthrene tabaniformis*	0.0001653
5	*Aphis fabae*	0.0006087	55	*Phyllotreta cruciferae*	0.0001652
6	*Sitobion avenae*	0.0005728	56	*Eulecanium tiliae*	0.0001648
7	*Philaenus spumarius*	0.0005467	57	*Psila rosae*	0.0001627
8	*Lymantria dispar*	0.0005255	58	*Orthosia cerasi*	0.0001626
9	*Ceroplastes rusci*	0.0005045	59	*Anthonomus pomorum*	0.0001585
10	*Oulema melanopus*	0.0004965	60	*Cryptoblabes gnidiella*	0.0001536
11	*Meligethes aeneus*	0.0004911	61	*Delia antiqua*	0.0001457
12	*Scolytus rugulosus*	0.0004237	62	*Rhagoletis cerasi*	0.0001426
13	*Aleurothrixus floccosus*	0.0004104	63	*Acrolepiopsis assectella*	0.0001423
14	*Acronicta rumicis*	0.0003703	64	*Schistocerca gregaria*	0.0001377
15	*Aphis pomi*	0.0003634	65	*Trialeurodes vaporariorum*	0.0001304
16	*Parlatoria oleae*	0.0003468	66	*Thrips angusticeps*	0.0001293
17	*Mythimna unipuncta*	0.0003407	67	*Tipula paludosa*	0.0001224
18	*Euproctis chrysorrhoea*	0.0003108	68	*Opogona sacchari*	0.0001195
19	*Operophtera brumata*	0.0003096	69	*Acanthiophilus helianthi*	0.0001162
20	*Chromatomyia horticola*	0.0002997	70	*Cephus pygmeus*	0.0001138
21	*Diuraphis noxia*	0.0002819	71	*Rhyacionia buoliana*	0.0001137
22	*Henosepilachna elaterii*	0.0002783	72	*Phorodon humuli*	0.0001135
23	*Leptinotarsa decemlineata*	0.0002766	73	*Dasineura pyri*	0.0001121
24	*Orthezia insignis*	0.0002727	74	*Pseudococcus comstocki*	0.0001113
25	*Laodelphax striatellus*	0.0002664	75	*Contarinia tritici*	0.0001097
26	*Pissodes castaneus*	0.0002632	76	*Dasineura mali*	0.0001061
27	*Peridroma saucia*	0.0002589	77	*Nipaecoccus nipae*	0.0001054
28	*Deilephila elpenor*	0.0002578	78	*Diaphorina citri*	0.0001036
29	*Ostrinia nubilalis*	0.0002540	79	*Sitona cylindricollis*	0.0001025
30	*Liriomyza trifolii*	0.0002477	80	*Byturus tomentosus*	0.0000979
31	*Mayetiola destructor*	0.0002464	81	*Aulacophora foveicollis*	0.0000946
32	*Lobesia botrana*	0.0002360	82	*Scolytus scolytus*	0.0000914
33	*Cacoecimorpha pronubana*	0.0002351	83	*Haplothrips tritici*	0.0000902
34	*Liriomyza huidobrensis*	0.0002336	84	*Pterochloroides persicae*	0.0000889
35	*Dialeurodes citri*	0.0002323	85	*Zeuzera pyrina*	0.0000878
36	*Anarsia lineatella*	0.0002290	86	*Prays oleae*	0.0000841
37	*Dysaphis plantaginea*	0.0002201	87	*Megastigmus spermotrophus*	0.0000836
38	*Scrobipalpa ocellatella*	0.0002143	88	*Thaumetopoea pityocampa*	0.0000834
39	*Brachycaudus helichrysi*	0.0002128	89	*Dioryctria abietella*	0.0000828
40	*Delia radicum*	0.0002104	90	*Ips sexdentatus*	0.0000821
41	*Spodoptera littoralis*	0.0002097	91	*Pinnaspis strachani*	0.0000814
42	*Sesamia cretica*	0.0002056	92	*Lymantria monacha*	0.0000801
43	*Neoaliturus tenellus*	0.0002028	93	*Phenacoccus madeirensis*	0.0000783
44	*Malacosoma neustria*	0.0002019	94	*Sphaerolecanium prunastri*	0.0000769
45	*Bactrocera oleae*	0.0001986	95	*Xyleborus dispar*	0.0000742
46	*Epidiaspis leperii*	0.0001957	96	*Taeniothrips inconsequens*	0.0000741
47	*Grapholita funebrana*	0.0001922	97	*Xylosandrus compactus*	0.0000733
48	*Liriomyza bryoniae*	0.0001888	98	*Psylliodes chrysocephala*	0.0000731
49	*Lixus juncii*	0.0001885	99	*Sesamia nonagrioides*	0.0000727
50	*Sitona humeralis*	0.0001876	100	*Sitona hispidulus*	0.0000716

Table A8-22. Top 100 ranked species by invasion likelihood for the port of Geraldton.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.0003197	51	*Delia antiqua*	0.0000538
2	*Hadula trifolii*	0.0002455	52	*Aulacophora lewisii*	0.0000517
3	*Trichoplusia ni*	0.0001789	53	*Carposina sasakii*	0.0000508
4	*Diaphorina citri*	0.0001702	54	*Eupoecilia ambiguella*	0.0000503
5	*Lymantria dispar*	0.0001687	55	*Bactrocera dorsalis*	0.0000499
6	*Sitobion avenae*	0.0001581	56	*Papilio polytes*	0.0000498
7	*Toxoptera odinae*	0.0001465	57	*Autographa nigrisigna*	0.0000494
8	*Laodelphax striatellus*	0.0001331	58	*Dicladispa armigera*	0.0000492
9	*Philaenus spumarius*	0.0001328	59	*Loxostege sticticalis*	0.0000470
10	*Deilephila elpenor*	0.0001256	60	*Anthonomus pomorum*	0.0000463
11	*Aphis fabae*	0.0001189	61	*Anoplophora glabripennis*	0.0000462
12	*Brachycaudus helichrysi*	0.0001161	62	*Monochamus alternatus*	0.0000456
13	*Dialeurodes citri*	0.0001066	63	*Chilo auricilius*	0.0000454
14	*Sesamia cretica*	0.0001030	64	*Paranthrene tabaniformis*	0.0000445
15	*Parlatoria oleae*	0.0001025	65	*Parasa lepida*	0.0000429
16	*Leucinodes orbonalis*	0.0000971	66	*Sphaerolecanium prunastri*	0.0000412
17	*Chromatomyia horticola*	0.0000961	67	*Batocera rufomaculata*	0.0000405
18	*Acanthiophilus helianthi*	0.0000949	68	*Ips typographus*	0.0000404
19	*Acherontia styx*	0.0000922	69	*Grapholita funebrana*	0.0000402
20	*Xylosandrus compactus*	0.0000915	70	*Aproaerema modicella*	0.0000401
21	*Liriomyza huidobrensis*	0.0000857	71	*Frankliniella intonsa*	0.0000400
22	*Liriomyza trifolii*	0.0000853	72	*Bothynoderes punctiventris*	0.0000399
23	*Orthezia insignis*	0.0000842	73	*Pyrilla perpusilla*	0.0000394
24	*Mamestra brassicae*	0.0000835	74	*Delia radicum*	0.0000393
25	*Euproctis chrysorrhoea*	0.0000828	75	*Ips cembrae*	0.0000393
26	*Phyllotreta striolata*	0.0000809	76	*Pelopidas mathias*	0.0000390
27	*Ceroplastes rusci*	0.0000808	77	*Aulacophora foveicollis*	0.0000388
28	*Oulema melanopus*	0.0000791	78	*Cossus cossus*	0.0000386
29	*Opogona sacchari*	0.0000780	79	*Unaspis yanonensis*	0.0000384
30	*Aleurothrixus floccosus*	0.0000754	80	*Adoxophyes orana*	0.0000378
31	*Diuraphis noxia*	0.0000748	81	*Lopholeucaspis japonica*	0.0000373
32	*Spodoptera littoralis*	0.0000744	82	*Delia floralis*	0.0000370
33	*Pieris brassicae*	0.0000734	83	*Trialeurodes vaporariorum*	0.0000365
34	*Sesamia inferens*	0.0000730	84	*Dendroctonus micans*	0.0000365
35	*Liriomyza bryoniae*	0.0000719	85	*Popillia japonica*	0.0000364
36	*Chilo infuscatellus*	0.0000712	86	*Rhipiphorothrips cruentatus*	0.0000361
37	*Acronicta rumicis*	0.0000706	87	*Sitona cylindricollis*	0.0000361
38	*Henosepilachna elaterii*	0.0000681	88	*Oryctes rhinoceros*	0.0000359
39	*Pseudodendrothrips mori*	0.0000666	89	*Urentius hystricellus*	0.0000358
40	*Autographa gamma*	0.0000659	90	*Grapholita inopinata*	0.0000355
41	*Dioryctria abietella*	0.0000659	91	*Dendrolimus spectabilis*	0.0000353
42	*Aleurocanthus woglumi*	0.0000656	92	*Pinnaspis strachani*	0.0000353
43	*Aphis pomi*	0.0000629	93	*Acrobasis pyrivorella*	0.0000349
44	*Atherigona soccata*	0.0000626	94	*Meligethes aeneus*	0.0000342
45	*Ampelophaga rubiginosa*	0.0000593	95	*Bactrocera oleae*	0.0000341
46	*Lymantria monacha*	0.0000568	96	*Ips sexdentatus*	0.0000336
47	*Anarsia lineatella*	0.0000567	97	*Atherigona biseta*	0.0000331
48	*Pseudococcus comstocki*	0.0000561	98	*Hieroglyphus banian*	0.0000319
49	*Malacosoma neustria*	0.0000554	99	*Contarinia tritici*	0.0000316
50	*Haplothrips tritici*	0.0000552	100	*Bombyx mori*	0.0000307

Table A8-23. Top 100 ranked species by invasion likelihood for the port of Gladstone.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.00025569	51	*Dasineura mali*	0.00003891
2	*Trichoplusia ni*	0.00023857	52	*Epidiaspis leperii*	0.00003797
3	*Philaenus spumarius*	0.00016824	53	*Phorodon humuli*	0.00003681
4	*Sitobion avenae*	0.00015539	54	*Dasineura pyri*	0.00003636
5	*Aleurothrixus floccosus*	0.00015214	55	*Schistocerca gregaria*	0.00003625
6	*Aphis fabae*	0.00015179	56	*Toxoptera odinae*	0.00003565
7	*Xylosandrus compactus*	0.00012772	57	*Megastigmus spermotrophus*	0.00003551
8	*Hadula trifolii*	0.00012116	58	*Xyleborus ferrugineus*	0.00003531
9	*Pieris brassicae*	0.00012076	59	*Euproctis chrysorrhoea*	0.00003492
10	*Liriomyza huidobrensis*	0.00012024	60	*Metopolophium festucae*	0.00003449
11	*Liriomyza trifolii*	0.00011073	61	*Acherontia styx*	0.00003332
12	*Ceroplastes rusci*	0.00010216	62	*Phyllotreta cruciferae*	0.00003261
13	*Chromatomyia horticola*	0.00009991	63	*Deilephila elpenor*	0.00003207
14	*Cryptoblabes gnidiella*	0.00009960	64	*Ostrinia nubilalis*	0.00003171
15	*Brachycaudus helichrysi*	0.00008256	65	*Sitona lepidus*	0.00003123
16	*Lymantria dispar*	0.00008110	66	*Oryzaephilus mercator*	0.00002997
17	*Mayetiola destructor*	0.00007991	67	*Delia antiqua*	0.00002970
18	*Meligethes aeneus*	0.00007897	68	*Trialeurodes ricini*	0.00002847
19	*Diaphorina citri*	0.00007601	69	*Pissodes castaneus*	0.00002838
20	*Aulacophora foveicollis*	0.00007484	70	*Acanthiophilus helianthi*	0.00002829
21	*Dialeurodes citri*	0.00006922	71	*Dysaphis plantaginea*	0.00002705
22	*Orthezia insignis*	0.00006751	72	*Megachile rotundata*	0.00002628
23	*Laodelphax striatellus*	0.00006684	73	*Aleurocanthus woglumi*	0.00002517
24	*Diuraphis noxia*	0.00006598	74	*Liriomyza bryoniae*	0.00002514
25	*Mythimna unipuncta*	0.00006408	75	*Anarsia lineatella*	0.00002465
26	*Oulema melanopus*	0.00006357	76	*Paranthrene tabaniformis*	0.00002420
27	*Parlatoria oleae*	0.00006315	77	*Eulecanium tiliae*	0.00002374
28	*Trialeurodes vaporariorum*	0.00006013	78	*Phyllotreta striolata*	0.00002235
29	*Urentius hystricellus*	0.00005862	79	*Delia radicum*	0.00002219
30	*Henosepilachna elaterii*	0.00005590	80	*Phenacoccus madeirensis*	0.00002201
31	*Leptinotarsa decemlineata*	0.00005552	81	*Jacobiasca lybica*	0.00002175
32	*Cacoecimorpha pronubana*	0.00005445	82	*Dacus ciliatus*	0.00002158
33	*Neoaliturus tenellus*	0.00005428	83	*Atherigona soccata*	0.00002076
34	*Scolytus rugulosus*	0.00005250	84	*Autographa gamma*	0.00002072
35	*Aproaerema modicella*	0.00005152	85	*Liriomyza sativae*	0.00002072
36	*Aphis pomi*	0.00005108	86	*Minthea rugicollis*	0.00002071
37	*Psila rosae*	0.00005006	87	*Malacosoma neustria*	0.00002033
38	*Pseudococcus comstocki*	0.00004992	88	*Mamestra brassicae*	0.00002008
39	*Opogona sacchari*	0.00004869	89	*Prostephanus truncatus*	0.00001948
40	*Hypothenemus hampei*	0.00004856	90	*Grapholita funebrana*	0.00001935
41	*Leucinodes orbonalis*	0.00004825	91	*Acrolepiopsis assectella*	0.00001920
42	*Acronicta rumicis*	0.00004499	92	*Empoasca vitis*	0.00001869
43	*Pinnaspis strachani*	0.00004486	93	*Adoretus versutus*	0.00001819
44	*Nipaecoccus nipae*	0.00004301	94	*Aulacophora lewisii*	0.00001727
45	*Peridroma saucia*	0.00004230	95	*Lobesia botrana*	0.00001638
46	*Spodoptera littoralis*	0.00004091	96	*Orthosia cerasi*	0.00001637
47	*Contarinia tritici*	0.00003981	97	*Dioryctria abietella*	0.00001622
48	*Operophtera brumata*	0.00003963	98	*Anthonomus pomorum*	0.00001596
49	*Sesamia cretica*	0.00003951	99	*Chilo infuscatellus*	0.00001574
50	*Bactrocera oleae*	0.00003924	100	*Tipula paludosa*	0.00001567

Table A8-24. Top 100 ranked species by invasion likelihood for the port of Gove.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Diaphorina citri*	0.0021552	51	*Attacus atlas*	0.0004613
2	*Toxoptera odinae*	0.0020324	52	*Prostephanus truncatus*	0.0004441
3	*Aleurocanthus woglumi*	0.0019997	53	*Oryzaephilus mercator*	0.0004350
4	*Leucinodes orbonalis*	0.0019212	54	*Plocaederus obesus*	0.0004329
5	*Xylosandrus compactus*	0.0016741	55	*Henosepilachna pusillanima*	0.0004309
6	*Urentius hystricellus*	0.0015515	56	*Chromatomyia horticola*	0.0004277
7	*Aulacophora foveicollis*	0.0014629	57	*Helopeltis theivora*	0.0004149
8	*Sesamia inferens*	0.0013952	58	*Henosepilachna elaterii*	0.0004026
9	*Atherigona soccata*	0.0013891	59	*Acrocercops syngramma*	0.0003593
10	*Liriomyza trifolii*	0.0013556	60	*Acanthiophilus helianthi*	0.0003590
11	*Oryctes rhinoceros*	0.0013501	61	*Brachycaudus helichrysi*	0.0003424
12	*Chilo partellus*	0.0012611	62	*Chilo sacchariphagus*	0.0003422
13	*Rastrococcus invadens*	0.0012538	63	*Schistocerca gregaria*	0.0003265
14	*Trichoplusia ni*	0.0010300	64	*Chaetocnema confinis*	0.0002951
15	*Chilo auricilius*	0.0010034	65	*Xylotrechus quadripes*	0.0002909
16	*Acherontia styx*	0.0010009	66	*Phyllotreta striolata*	0.0002908
17	*Phyllotreta chotanica*	0.0009455	67	*Pieris brassicae*	0.0002870
18	*Agrotis segetum*	0.0009304	68	*Adoretus versutus*	0.0002855
19	*Bactrocera zonata*	0.0009192	69	*Cryptoblabes gnidiella*	0.0002854
20	*Chilo infuscatellus*	0.0009115	70	*Erionota thrax*	0.0002684
21	*Pelopidas mathias*	0.0009029	71	*Aphis fabae*	0.0002509
22	*Rastrococcus iceryoides*	0.0008848	72	*Omiodes indicata*	0.0002470
23	*Dicladispa armigera*	0.0008818	73	*Ceroplastes rusci*	0.0002394
24	*Aproaerema modicella*	0.0008692	74	*Liriomyza sativae*	0.0002283
25	*Dialeurodes citri*	0.0008464	75	*Oryctes monoceros*	0.0002054
26	*Pyrilla perpusilla*	0.0008272	76	*Orthezia insignis*	0.0002050
27	*Planococcus lilacinus*	0.0007980	77	*Aonidomytilus albus*	0.0002020
28	*Sesamia cretica*	0.0007918	78	*Oryctes boas*	0.0001991
29	*Rhipiphorothrips cruentatus*	0.0007339	79	*Bactrocera tau*	0.0001970
30	*Hieroglyphus banian*	0.0007334	80	*Melanagromyza obtusa*	0.0001890
31	*Aulacophora lewisii*	0.0007315	81	*Eldana saccharina*	0.0001859
32	*Orseolia oryzae*	0.0007314	82	*Cicadulina mbila*	0.0001856
33	*Bactrocera dorsalis*	0.0007246	83	*Bombyx mori*	0.0001839
34	*Liriomyza huidobrensis*	0.0007194	84	*Hadula trifolii*	0.0001828
35	*Batocera rufomaculata*	0.0007156	85	*Bactrocera latifrons*	0.0001824
36	*Odoiporus longicollis*	0.0006715	86	*Nipaecoccus nipae*	0.0001815
37	*Aulacaspis tegalensis*	0.0006399	87	*Jacobiasca lybica*	0.0001812
38	*Hypothenemus hampei*	0.0006394	88	*Hyblaea puera*	0.0001800
39	*Erosomyia mangiferae*	0.0005852	89	*Hypomeces squamosus*	0.0001756
40	*Sitobion avenae*	0.0005773	90	*Parlatoria oleae*	0.0001711
41	*Parasa lepida*	0.0005706	91	*Cricula trifenestrata*	0.0001681
42	*Nephotettix virescens*	0.0005549	92	*Elaeidobius kamerunicus*	0.0001674
43	*Stephanitis typica*	0.0005545	93	*Trogoderma granarium*	0.0001507
44	*Sinoxylon conigerum*	0.0005277	94	*Orgyia postica*	0.0001502
45	*Aleurothrixus floccosus*	0.0005182	95	*Xyleborus ferrugineus*	0.0001500
46	*Batocera rubus*	0.0005000	96	*Naranga diffusa*	0.0001491
47	*Pinnaspis strachani*	0.0004752	97	*Minthea rugicollis*	0.0001429
48	*Spodoptera littoralis*	0.0004729	98	*Laodelphax striatellus*	0.0001335
49	*Dacus ciliatus*	0.0004636	99	*Melanaspis glomerata*	0.0001333
50	*Trialeurodes ricini*	0.0004629	100	*Papilio polytes*	0.0001312

Table A8-25. Top 100 ranked species by invasion likelihood for the port of Hastings.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Philaenus spumarius*	0.00026090	51	*Eulecanium tiliae*	0.00001983
2	*Cryptoblabes gnidiella*	0.00015500	52	*Phyllotreta cruciferae*	0.00001905
3	*Mayetiola destructor*	0.00012391	53	*Acrolepiopsis assectella*	0.00001835
4	*Brachycaudus helichrysi*	0.00010240	54	*Popillia japonica*	0.00001833
5	*Hadula trifolii*	0.00010124	55	*Pinnaspis strachani*	0.00001817
6	*Ceroplastes rusci*	0.00009948	56	*Nipaecoccus nipae*	0.00001646
7	*Xylosandrus compactus*	0.00009169	57	*Delia antiqua*	0.00001607
8	*Psila rosae*	0.00007763	58	*Sitona cylindricollis*	0.00001589
9	*Trichoplusia ni*	0.00007625	59	*Sphaerolecanium prunastri*	0.00001587
10	*Lymantria dispar*	0.00006776	60	*Tipula paludosa*	0.00001497
11	*Aphis fabae*	0.00006553	61	*Parabemisia myricae*	0.00001479
12	*Trialeurodes vaporariorum*	0.00006367	62	*Cephus pygmeus*	0.00001468
13	*Oulema melanopus*	0.00006074	63	*Rhyacionia buoliana*	0.00001391
14	*Dasineura mali*	0.00006033	64	*Liriomyza sativae*	0.00001376
15	*Aleurothrixus floccosus*	0.00005972	65	*Xyleborus ferrugineus*	0.00001355
16	*Sitobion avenae*	0.00005945	66	*Zeuzera pyrina*	0.00001240
17	*Phorodon humuli*	0.00005708	67	*Amphimallon majalis*	0.00001225
18	*Dasineura pyri*	0.00005638	68	*Taeniothrips inconsequens*	0.00001148
19	*Sitona lepidus*	0.00005542	69	*Oryzaephilus mercator*	0.00001054
20	*Megastigmus spermotrophus*	0.00005507	70	*Xyleborus dispar*	0.00000957
21	*Contarinia tritici*	0.00005480	71	*Lopholeucaspis japonica*	0.00000946
22	*Megachile rotundata*	0.00005463	72	*Frankliniella intonsa*	0.00000925
23	*Meligethes aeneus*	0.00005212	73	*Sitona hispidulus*	0.00000923
24	*Scolytus rugulosus*	0.00005016	74	*Prostephanus truncatus*	0.00000903
25	*Euproctis chrysorrhoea*	0.00004818	75	*Agromyza frontella*	0.00000894
26	*Metopolophium festucae*	0.00004748	76	*Caulophilus oryzae*	0.00000855
27	*Parlatoria oleae*	0.00004683	77	*Delia floralis*	0.00000835
28	*Leptinotarsa decemlineata*	0.00004651	78	*Cnephasia longana*	0.00000815
29	*Dialeurodes citri*	0.00004595	79	*Spodoptera frugiperda*	0.00000727
30	*Aproaerema modicella*	0.00004578	80	*Helicoverpa zea*	0.00000716
31	*Orthezia insignis*	0.00004514	81	*Phyllotreta striolata*	0.00000707
32	*Liriomyza trifolii*	0.00004475	82	*Diatraea saccharalis*	0.00000698
33	*Anarsia lineatella*	0.00004415	83	*Aleurocanthus woglumi*	0.00000682
34	*Aphis pomi*	0.00004268	84	*Erinnyis alope*	0.00000682
35	*Opogona sacchari*	0.00004079	85	*Erinnyis ello*	0.00000657
36	*Diuraphis noxia*	0.00003958	86	*Orgyia antiqua*	0.00000633
37	*Mythimna unipuncta*	0.00003847	87	*Anastrepha fraterculus*	0.00000630
38	*Operophtera brumata*	0.00003787	88	*Pseudodendrothrips mori*	0.00000624
39	*Pseudococcus comstocki*	0.00003681	89	*Chaetocnema confinis*	0.00000615
40	*Neoaliturus tenellus*	0.00003629	90	*Archips podana*	0.00000610
41	*Cacoecimorpha pronubana*	0.00003593	91	*Ceresa alta*	0.00000574
42	*Epidiaspis leperii*	0.00003181	92	*Spodoptera eridania*	0.00000556
43	*Liriomyza huidobrensis*	0.00003116	93	*Heliothis virescens*	0.00000543
44	*Delia radicum*	0.00003062	94	*Stenoma catenifer*	0.00000520
45	*Ostrinia nubilalis*	0.00003030	95	*Delia coarctata*	0.00000513
46	*Peridroma saucia*	0.00002792	96	*Elasmopalpus lignosellus*	0.00000498
47	*Diaphorina citri*	0.00002762	97	*Metamasius hemipterus*	0.00000484
48	*Dysaphis plantaginea*	0.00002584	98	*Sesamia inferens*	0.00000484
49	*Phenacoccus madeirensis*	0.00002510	99	*Bactrocera dorsalis*	0.00000482
50	*Paranthrene tabaniformis*	0.00002022	100	*Cacopsylla pyricola*	0.00000482

Table A8-26. Top 100 ranked species by invasion likelihood for the port of Launceston.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Aleurothrixus floccosus*	0.0005206	51	*Henosepilachna elaterii*	0.0000518
2	*Sitobion avenae*	0.0003670	52	*Mayetiola destructor*	0.0000510
3	*Trichoplusia ni*	0.0003248	53	*Spodoptera littoralis*	0.0000501
4	*Liriomyza huidobrensis*	0.0003166	54	*Delia radicum*	0.0000491
5	*Aphis fabae*	0.0002793	55	*Ostrinia nubilalis*	0.0000486
6	*Liriomyza trifolii*	0.0002763	56	*Prostephanus truncatus*	0.0000425
7	*Agrotis segetum*	0.0002392	57	*Brachycaudus helichrysi*	0.0000421
8	*Ceroplastes rusci*	0.0002166	58	*Dysaphis plantaginea*	0.0000415
9	*Orthezia insignis*	0.0002020	59	*Spodoptera frugiperda*	0.0000407
10	*Dialeurodes citri*	0.0001897	60	*Helicoverpa zea*	0.0000401
11	*Scolytus rugulosus*	0.0001656	61	*Diatraea saccharalis*	0.0000391
12	*Diaphorina citri*	0.0001651	62	*Delia antiqua*	0.0000391
13	*Hadula trifolii*	0.0001624	63	*Erinnyis alope*	0.0000382
14	*Opogona sacchari*	0.0001581	64	*Phyllotreta striolata*	0.0000374
15	*Xylosandrus compactus*	0.0001540	65	*Erinnyis ello*	0.0000368
16	*Phenacoccus madeirensis*	0.0001406	66	*Bactrocera oleae*	0.0000364
17	*Peridroma saucia*	0.0001153	67	*Anastrepha fraterculus*	0.0000353
18	*Urentius hystricellus*	0.0001103	68	*Schistocerca gregaria*	0.0000336
19	*Lymantria dispar*	0.0001087	69	*Paranthrene tabaniformis*	0.0000324
20	*Philaenus spumarius*	0.0001073	70	*Psila rosae*	0.0000319
21	*Meligethes aeneus*	0.0001037	71	*Eulecanium tiliae*	0.0000318
22	*Nipaecoccus nipae*	0.0001016	72	*Acherontia styx*	0.0000315
23	*Diuraphis noxia*	0.0001015	73	*Heliothis virescens*	0.0000304
24	*Hypothenemus hampei*	0.0001004	74	*Perileucoptera coffeella*	0.0000299
25	*Oulema melanopus*	0.0000974	75	*Acrolepiopsis assectella*	0.0000294
26	*Mythimna unipuncta*	0.0000935	76	*Popillia japonica*	0.0000294
27	*Parlatoria oleae*	0.0000932	77	*Stenoma catenifer*	0.0000291
28	*Neoaliturus tenellus*	0.0000930	78	*Sesamia inferens*	0.0000289
29	*Leptinotarsa decemlineata*	0.0000926	79	*Aproaerema modicella*	0.0000289
30	*Trialeurodes vaporariorum*	0.0000906	80	*Spodoptera eridania*	0.0000287
31	*Leucinodes orbonalis*	0.0000849	81	*Metopolophium festucae*	0.0000278
32	*Aulacophora foveicollis*	0.0000848	82	*Metamasius hemipterus*	0.0000271
33	*Cacoecimorpha pronubana*	0.0000782	83	*Leucoptera caffeina*	0.0000262
34	*Euproctis chrysorrhoea*	0.0000773	84	*Manduca sexta*	0.0000261
35	*Chromatomyia horticola*	0.0000751	85	*Sitona cylindricollis*	0.0000255
36	*Oryzaephilus mercator*	0.0000737	86	*Sphaerolecanium prunastri*	0.0000255
37	*Pseudococcus comstocki*	0.0000733	87	*Dasineura mali*	0.0000248
38	*Xyleborus ferrugineus*	0.0000717	88	*Tipula paludosa*	0.0000240
39	*Anarsia lineatella*	0.0000708	89	*Parabemisia myricae*	0.0000237
40	*Aphis pomi*	0.0000685	90	*Cephus pygmeus*	0.0000235
41	*Pinnaspis strachani*	0.0000670	91	*Phorodon humuli*	0.0000235
42	*Cryptoblabes gnidiella*	0.0000637	92	*Dasineura pyri*	0.0000232
43	*Epidiaspis leperii*	0.0000633	93	*Sitona lepidus*	0.0000228
44	*Toxoptera odinae*	0.0000627	94	*Megastigmus spermotrophus*	0.0000226
45	*Operophtera brumata*	0.0000607	95	*Megachile rotundata*	0.0000225
46	*Aleurocanthus woglumi*	0.0000604	96	*Rhyacionia buoliana*	0.0000223
47	*Trialeurodes ricini*	0.0000576	97	*Minthea rugicollis*	0.0000213
48	*Liriomyza sativae*	0.0000568	98	*Elasmopalpus lignosellus*	0.0000205
49	*Pieris brassicae*	0.0000551	99	*Anastrepha grandis*	0.0000204
50	*Phyllotreta cruciferae*	0.0000545	100	*Jacobiasca lybica*	0.0000202

Table A8-27. Top 100 ranked species by invasion likelihood for the port of Melbourne.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.4015	51	*Cacoecimorpha pronubana*	0.0682
2	*Trichoplusia ni*	0.2939	52	*Phorodon humuli*	0.0667
3	*Hadula trifolii*	0.2938	53	*Delia antiqua*	0.0659
4	*Lymantria dispar*	0.2582	54	*Leptinotarsa decemlineata*	0.0645
5	*Philaenus spumarius*	0.2555	55	*Psila rosae*	0.0645
6	*Aphis fabae*	0.2342	56	*Pinnaspis strachani*	0.0623
7	*Sitobion avenae*	0.2069	57	*Haplothrips tritici*	0.0614
8	*Liriomyza trifolii*	0.1856	58	*Mythimna unipuncta*	0.0606
9	*Dialeurodes citri*	0.1780	59	*Lobesia botrana*	0.0546
10	*Oulema melanopus*	0.1685	60	*Nipaecoccus nipae*	0.0541
11	*Acronicta rumicis*	0.1670	61	*Parabemisia myricae*	0.0540
12	*Orthezia insignis*	0.1613	62	*Popillia japonica*	0.0528
13	*Laodelphax striatellus*	0.1543	63	*Leucinodes orbonalis*	0.0507
14	*Chromatomyia horticola*	0.1469	64	*Sphaerolecanium prunastri*	0.0505
15	*Aphis pomi*	0.1433	65	*Chilo infuscatellus*	0.0498
16	*Deilephila elpenor*	0.1390	66	*Aproaerema modicella*	0.0492
17	*Pseudococcus comstocki*	0.1354	67	*Liriomyza sativae*	0.0463
18	*Euproctis chrysorrhoea*	0.1310	68	*Sitona cylindricollis*	0.0451
19	*Parlatoria oleae*	0.1292	69	*Epidiaspis leperii*	0.0446
20	*Brachycaudus helichrysi*	0.1275	70	*Ostrinia nubilalis*	0.0430
21	*Aleurothrixus floccosus*	0.1267	71	*Neoaliturus tenellus*	0.0427
22	*Pieris brassicae*	0.1210	72	*Dasineura mali*	0.0418
23	*Anarsia lineatella*	0.1187	73	*Lymantria monacha*	0.0417
24	*Xylosandrus compactus*	0.1184	74	*Toxoptera odinae*	0.0413
25	*Liriomyza huidobrensis*	0.1161	75	*Atherigona pulla*	0.0407
26	*Sesamia cretica*	0.1156	76	*Frankliniella intonsa*	0.0395
27	*Peridroma saucia*	0.1141	77	*Dioryctria abietella*	0.0391
28	*Liriomyza bryoniae*	0.1129	78	*Dasineura pyri*	0.0390
29	*Diuraphis noxia*	0.1105	79	*Aulacophora lewisii*	0.0363
30	*Opogona sacchari*	0.1049	80	*Minthea rugicollis*	0.0361
31	*Eupoecilia ambiguella*	0.1005	81	*Megastigmus spermotrophus*	0.0361
32	*Diaphorina citri*	0.1000	82	*Bothynoderes punctiventris*	0.0354
33	*Ceroplastes rusci*	0.0985	83	*Acrolepiopsis assectella*	0.0352
34	*Malacosoma neustria*	0.0969	84	*Lopholeucaspis japonica*	0.0349
35	*Cryptoblabes gnidiella*	0.0905	85	*Ips typographus*	0.0342
36	*Mamestra brassicae*	0.0897	86	*Ips sexdentatus*	0.0341
37	*Trialeurodes vaporariorum*	0.0873	87	*Empoasca vitis*	0.0328
38	*Delia radicum*	0.0849	88	*Atherigona soccata*	0.0325
39	*Mayetiola destructor*	0.0843	89	*Metopolophium festucae*	0.0321
40	*Grapholita funebrana*	0.0836	90	*Trogoderma granarium*	0.0318
41	*Acanthiophilus helianthi*	0.0828	91	*Sitona lepidus*	0.0313
42	*Meligethes aeneus*	0.0780	92	*Delia floralis*	0.0304
43	*Contarinia tritici*	0.0774	93	*Megachile rotundata*	0.0297
44	*Acherontia styx*	0.0769	94	*Phenacoccus madeirensis*	0.0293
45	*Anthonomus pomorum*	0.0767	95	*Zeuzera pyrina*	0.0293
46	*Autographa gamma*	0.0749	96	*Pissodes castaneus*	0.0288
47	*Operophtera brumata*	0.0720	97	*Phyllotreta cruciferae*	0.0281
48	*Scolytus rugulosus*	0.0716	98	*Adoxophyes orana*	0.0280
49	*Dysaphis plantaginea*	0.0703	99	*Phyllotreta striolata*	0.0278
50	*Paranthrene tabaniformis*	0.0700	100	*Henosepilachna elaterii*	0.0277

Table A8-28. Top 100 ranked species by invasion likelihood for the port of Newcastle.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Xylosandrus compactus*	0.0008044	51	*Orgyia postica*	0.0000482
2	*Pinnaspis strachani*	0.0003430	52	*Ceratovacuna lanigera*	0.0000476
3	*Aproaerema modicella*	0.0003341	53	*Aleurothrixus floccosus*	0.0000467
4	*Sesamia inferens*	0.0003181	54	*Rastrococcus iceryoides*	0.0000453
5	*Xyleborus ferrugineus*	0.0002441	55	*Statherotis discana*	0.0000448
6	*Orthezia insignis*	0.0002270	56	*Rhynchophorus vulneratus*	0.0000448
7	*Aleurocanthus woglumi*	0.0001999	57	*Urentius hystricellus*	0.0000440
8	*Liriomyza trifolii*	0.0001858	58	*Rastrococcus invadens*	0.0000438
9	*Brachycaudus helichrysi*	0.0001817	59	*Perkinsiella vastatrix*	0.0000434
10	*Oryctes rhinoceros*	0.0001784	60	*Batocera rubus*	0.0000421
11	*Trichoplusia ni*	0.0001587	61	*Chromatomyia horticola*	0.0000417
12	*Bactrocera umbrosa*	0.0001560	62	*Nipaecoccus nipae*	0.0000402
13	*Liriomyza huidobrensis*	0.0001534	63	*Helopeltis theivora*	0.0000388
14	*Cryptoblabes gnidiella*	0.0001440	64	*Jacobiasca lybica*	0.0000379
15	*Agrotis segetum*	0.0001356	65	*Bactrocera papayae*	0.0000377
16	*Tarophagus colocasiae*	0.0001307	66	*Liriomyza sativae*	0.0000373
17	*Hydrellia philippina*	0.0001294	67	*Phyllotreta chotanica*	0.0000372
18	*Elaeidobius kamerunicus*	0.0001179	68	*Ceroplastes rusci*	0.0000365
19	*Aphis fabae*	0.0001145	69	*Frankliniella intonsa*	0.0000354
20	*Planococcus lilacinus*	0.0001127	70	*Diuraphis noxia*	0.0000354
21	*Stephanitis typica*	0.0001087	71	*Henosepilachna elaterii*	0.0000353
22	*Phyllotreta striolata*	0.0001070	72	*Odoiporus longicollis*	0.0000335
23	*Ahasverus advena*	0.0000905	73	*Bactrocera latifrons*	0.0000325
24	*Promecotheca caerulipennis*	0.0000880	74	*Sesamia cretica*	0.0000318
25	*Pelopidas mathias*	0.0000877	75	*Heterobostrychus aequalis*	0.0000318
26	*Aulacaspis tegalensis*	0.0000864	76	*Chilo sacchariphagus*	0.0000314
27	*Pseudococcus jackbeardsleyi*	0.0000828	77	*Henosepilachna pusillanima*	0.0000303
28	*Chilo auricilius*	0.0000825	78	*Parabemisia myricae*	0.0000302
29	*Erionota thrax*	0.0000816	79	*Attacus atlas*	0.0000292
30	*Chilo infuscatellus*	0.0000787	80	*Hypomeces squamosus*	0.0000285
31	*Dicladispa armigera*	0.0000780	81	*Minthea rugicollis*	0.0000277
32	*Dialeurodes citri*	0.0000767	82	*Schistocerca gregaria*	0.0000275
33	*Sitobion avenae*	0.0000763	83	*Acherontia styx*	0.0000274
34	*Sternochetus frigidus*	0.0000713	84	*Trialeurodes ricini*	0.0000273
35	*Sinoxylon conigerum*	0.0000677	85	*Deilephila elpenor*	0.0000254
36	*Leucinodes orbonalis*	0.0000676	86	*Helopeltis bradyi*	0.0000250
37	*Aulacophora foveicollis*	0.0000642	87	*Delia antiqua*	0.0000243
38	*Oryzaephilus mercator*	0.0000625	88	*Contarinia tritici*	0.0000237
39	*Selenaspidus articulatus*	0.0000589	89	*Neoaliturus tenellus*	0.0000236
40	*Pieris brassicae*	0.0000585	90	*Hadula trifolii*	0.0000223
41	*Hyblaea puera*	0.0000583	91	*Papilio polytes*	0.0000219
42	*Diaphorina citri*	0.0000580	92	*Phorodon humuli*	0.0000219
43	*Chaetocnema confinis*	0.0000579	93	*Omphisa anastomosalis*	0.0000217
44	*Idioscopus clypealis*	0.0000572	94	*Acanthiophilus helianthi*	0.0000198
45	*Hypothenemus hampei*	0.0000568	95	*Dysaphis plantaginea*	0.0000197
46	*Toxoptera odinae*	0.0000554	96	*Atherigona pulla*	0.0000193
47	*Zeuzera coffeae*	0.0000543	97	*Bactrocera tau*	0.0000191
48	*Atherigona soccata*	0.0000536	98	*Prays endocarpa*	0.0000189
49	*Trialeurodes vaporariorum*	0.0000513	99	*Lymantria dispar*	0.0000184
50	*Spodoptera littoralis*	0.0000483	100	*Phyllotreta cruciferae*	0.0000181

Table A8-29. Top 100 ranked species by invasion likelihood for the port of Port Alma.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Xylosandrus compactus*	0.0012788	51	*Sitobion avenae*	0.0002688
2	*Pinnaspis strachani*	0.0011204	52	*Ceratovacuna lanigera*	0.0002658
3	*Aleurocanthus woglumi*	0.0010296	53	*Henosepilachna pusillanima*	0.0002626
4	*Agrotis segetum*	0.0009606	54	*Omiodes indicata*	0.0002606
5	*Sesamia inferens*	0.0009144	55	*Omphisa anastomosalis*	0.0002590
6	*Oryctes rhinoceros*	0.0008837	56	*Attacus atlas*	0.0002541
7	*Liriomyza trifolii*	0.0008352	57	*Tarophagus colocasiae*	0.0002486
8	*Diaphorina citri*	0.0008301	58	*Xylotrechus quadripes*	0.0002472
9	*Leucinodes orbonalis*	0.0007893	59	*Parasa lepida*	0.0002454
10	*Orthezia insignis*	0.0007619	60	*Sternochetus frigidus*	0.0002376
11	*Trichoplusia ni*	0.0006734	61	*Bactrocera dorsalis*	0.0002307
12	*Toxoptera odinae*	0.0006132	62	*Pseudococcus jackbeardsleyi*	0.0002198
13	*Sinoxylon conigerum*	0.0006042	63	*Fulmekiola serrata*	0.0002154
14	*Stephanitis typica*	0.0005528	64	*Brachycaudus helichrysi*	0.0002140
15	*Liriomyza huidobrensis*	0.0005323	65	*Papilio polytes*	0.0002140
16	*Pelopidas mathias*	0.0005035	66	*Pyrilla perpusilla*	0.0002036
17	*Rastrococcus invadens*	0.0004901	67	*Batocera rufomaculata*	0.0001992
18	*Hypothenemus hampei*	0.0004791	68	*Minthea rugicollis*	0.0001990
19	*Xyleborus ferrugineus*	0.0004768	69	*Aulacophora foveicollis*	0.0001914
20	*Chilo auricilius*	0.0004635	70	*Pieris brassicae*	0.0001876
21	*Aphis fabae*	0.0004598	71	*Oryzaephilus mercator*	0.0001849
22	*Dicladispa armigera*	0.0004378	72	*Bactrocera tau*	0.0001820
23	*Helopeltis theivora*	0.0004248	73	*Phyllotreta chotanica*	0.0001798
24	*Atherigona soccata*	0.0004186	74	*Liriomyza sativae*	0.0001747
25	*Erionota thrax*	0.0004124	75	*Heterobostrychus aequalis*	0.0001723
26	*Acherontia styx*	0.0004020	76	*Helopeltis bradyi*	0.0001721
27	*Aproaerema modicella*	0.0004005	77	*Ceroplastes rusci*	0.0001709
28	*Odoiporus longicollis*	0.0003818	78	*Opogona sacchari*	0.0001592
29	*Chilo infuscatellus*	0.0003768	79	*Tetramoera schistaceana*	0.0001555
30	*Batocera rubus*	0.0003749	80	*Bombyx mori*	0.0001529
31	*Dialeurodes citri*	0.0003708	81	*Hieroglyphus banian*	0.0001519
32	*Nephotettix virescens*	0.0003636	82	*Megymenum brevicorne*	0.0001493
33	*Hydrellia philippina*	0.0003630	83	*Statherotis discana*	0.0001484
34	*Chilo sacchariphagus*	0.0003568	84	*Rhynchophorus vulneratus*	0.0001484
35	*Orseolia oryzae*	0.0003525	85	*Adoretus versutus*	0.0001453
36	*Planococcus lilacinus*	0.0003509	86	*Plocaederus obesus*	0.0001445
37	*Bactrocera latifrons*	0.0003478	87	*Chilo partellus*	0.0001407
38	*Chromatomyia horticola*	0.0003410	88	*Rhipiphorothrips cruentatus*	0.0001381
39	*Phyllotreta striolata*	0.0003340	89	*Prays endocarpa*	0.0001379
40	*Aulacophora lewisii*	0.0003263	90	*Prostephanus truncatus*	0.0001343
41	*Hypomeces squamosus*	0.0003200	91	*Ahasverus advena*	0.0001306
42	*Nipaecoccus nipae*	0.0003074	92	*Selenaspidus articulatus*	0.0001295
43	*Zeuzera coffeae*	0.0002966	93	*Sesamia cretica*	0.0001284
44	*Aulacaspis tegalensis*	0.0002801	94	*Elaeidobius kamerunicus*	0.0001194
45	*Idioscopus clypealis*	0.0002761	95	*Acanthocoris scabrator*	0.0001182
46	*Rastrococcus iceryoides*	0.0002738	96	*Adoretus sinicus*	0.0001169
47	*Aleurothrixus floccosus*	0.0002730	97	*Cricula trifenestrata*	0.0001165
48	*Urentius hystricellus*	0.0002696	98	*Perkinsiella vastatrix*	0.0001164
49	*Bactrocera umbrosa*	0.0002695	99	*Trialeurodes ricini*	0.0001146
50	*Orgyia postica*	0.0002693	100	*Naranga diffusa*	0.0001141

Table A8-30. Top 100 ranked species by invasion likelihood for the port of Port Headland.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.0004693	51	*Papilio polytes*	0.0000457
2	*Hadula trifolii*	0.0002440	52	*Mythimna unipuncta*	0.0000455
3	*Trichoplusia ni*	0.0002160	53	*Lymantria monacha*	0.0000447
4	*Pieris brassicae*	0.0002085	54	*Malacosoma neustria*	0.0000437
5	*Lymantria dispar*	0.0001926	55	*Pissodes castaneus*	0.0000436
6	*Sitobion avenae*	0.0001805	56	*Acanthiophilus helianthi*	0.0000436
7	*Laodelphax striatellus*	0.0001660	57	*Schistocerca gregaria*	0.0000430
8	*Diaphorina citri*	0.0001562	58	*Chilo auricilius*	0.0000429
9	*Aphis fabae*	0.0001357	59	*Scolytus scolytus*	0.0000421
10	*Toxoptera odinae*	0.0001344	60	*Byturus tomentosus*	0.0000420
11	*Ceroplastes rusci*	0.0001321	61	*Operophtera brumata*	0.0000415
12	*Deilephila elpenor*	0.0001291	62	*Leptinotarsa decemlineata*	0.0000410
13	*Philaenus spumarius*	0.0001198	63	*Anarsia lineatella*	0.0000408
14	*Liriomyza huidobrensis*	0.0001032	64	*Parasa lepida*	0.0000406
15	*Aleurothrixus floccosus*	0.0000902	65	*Mayetiola destructor*	0.0000406
16	*Brachycaudus helichrysi*	0.0000899	66	*Psila rosae*	0.0000401
17	*Leucinodes orbonalis*	0.0000891	67	*Paranthrene tabaniformis*	0.0000392
18	*Chromatomyia horticola*	0.0000884	68	*Aproaerema modicella*	0.0000379
19	*Mamestra brassicae*	0.0000858	69	*Bactrocera dorsalis*	0.0000378
20	*Xylosandrus compactus*	0.0000840	70	*Pyrilla perpusilla*	0.0000373
21	*Acherontia styx*	0.0000830	71	*Spodoptera littoralis*	0.0000372
22	*Liriomyza bryoniae*	0.0000821	72	*Pelopidas mathias*	0.0000369
23	*Acronicta rumicis*	0.0000806	73	*Diuraphis noxia*	0.0000368
24	*Henosepilachna elaterii*	0.0000779	74	*Anthonomus pomorum*	0.0000365
25	*Pterochloroides persicae*	0.0000776	75	*Dendroctonus micans*	0.0000362
26	*Meligethes aeneus*	0.0000767	76	*Adoretus versutus*	0.0000352
27	*Aulacophora foveicollis*	0.0000767	77	*Frankliniella intonsa*	0.0000347
28	*Parlatoria oleae*	0.0000751	78	*Cacoecimorpha pronubana*	0.0000341
29	*Liriomyza trifolii*	0.0000741	79	*Eulecanium tiliae*	0.0000336
30	*Phyllotreta striolata*	0.0000734	80	*Pinnaspis strachani*	0.0000334
31	*Orthezia insignis*	0.0000695	81	*Minthea rugicollis*	0.0000331
32	*Dioryctria abietella*	0.0000682	82	*Oryctes rhinoceros*	0.0000330
33	*Autographa gamma*	0.0000677	83	*Sipha maydis*	0.0000318
34	*Chilo infuscatellus*	0.0000674	84	*Grapholita funebrana*	0.0000317
35	*Sesamia inferens*	0.0000670	85	*Oryzaephilus mercator*	0.0000312
36	*Aphis pomi*	0.0000647	86	*Lobesia botrana*	0.0000303
37	*Oulema melanopus*	0.0000623	87	*Dacus ciliatus*	0.0000296
38	*Atherigona soccata*	0.0000617	88	*Pseudodendrothrips mori*	0.0000295
39	*Sesamia cretica*	0.0000591	89	*Jacobiasca lybica*	0.0000288
40	*Delia antiqua*	0.0000553	90	*Trogoderma granarium*	0.0000283
41	*Scolytus rugulosus*	0.0000535	91	*Phyllotreta cruciferae*	0.0000282
42	*Aleurocanthus woglumi*	0.0000528	92	*Ips cembrae*	0.0000281
43	*Euproctis chrysorrhoea*	0.0000521	93	*Ips typographus*	0.0000280
44	*Chilo partellus*	0.0000520	94	*Oedaleus senegalensis*	0.0000274
45	*Urentius hystricellus*	0.0000503	95	*Eupoecilia ambiguella*	0.0000268
46	*Dialeurodes citri*	0.0000490	96	*Dysaphis plantaginea*	0.0000267
47	*Rastrococcus iceryoides*	0.0000489	97	*Melanagromyza obtusa*	0.0000265
48	*Bactrocera oleae*	0.0000488	98	*Adoxophyes orana*	0.0000257
49	*Dicladispa armigera*	0.0000465	99	*Orthosia cerasi*	0.0000243
50	*Cossus cossus*	0.0000459	100	*Ampelophaga rubiginosa*	0.0000238

Table A8-31. Top 100 ranked species by invasion likelihood for the port of Port Kembla.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Xylosandrus compactus*	0.0009052	51	*Omiodes indicata*	0.0002033
2	*Pinnaspis strachani*	0.0006848	52	*Bombyx mori*	0.0002007
3	*Agrotis segetum*	0.0005735	53	*Aulacophora foveicollis*	0.0001989
4	*Leucinodes orbonalis*	0.0005672	54	*Attacus atlas*	0.0001987
5	*Aleurocanthus woglumi*	0.0005655	55	*Hieroglyphus banian*	0.0001972
6	*Sesamia inferens*	0.0005437	56	*Hypothenemus hampei*	0.0001965
7	*Oryctes rhinoceros*	0.0005417	57	*Sesamia cretica*	0.0001858
8	*Diaphorina citri*	0.0005117	58	*Sitobion avenae*	0.0001847
9	*Orthezia insignis*	0.0005083	59	*Nipaecoccus nipae*	0.0001832
10	*Liriomyza trifolii*	0.0005054	60	*Omphisa anastomosalis*	0.0001775
11	*Trichoplusia ni*	0.0004907	61	*Idioscopus clypealis*	0.0001737
12	*Atherigona soccata*	0.0004572	62	*Papilio polytes*	0.0001492
13	*Toxoptera odinae*	0.0004286	63	*Urentius hystricellus*	0.0001476
14	*Aproaerema modicella*	0.0004146	64	*Bactrocera tau*	0.0001475
15	*Chilo auricilius*	0.0003631	65	*Liriomyza sativae*	0.0001459
16	*Sinoxylon conigerum*	0.0003626	66	*Atherigona pulla*	0.0001459
17	*Acherontia styx*	0.0003521	67	*Fulmekiola serrata*	0.0001454
18	*Dialeurodes citri*	0.0003518	68	*Prostephanus truncatus*	0.0001384
19	*Pelopidas mathias*	0.0003499	69	*Hyblaea puera*	0.0001373
20	*Dicladispa armigera*	0.0003429	70	*Statherotis discana*	0.0001368
21	*Stephanitis typica*	0.0003299	71	*Heterobostrychus aequalis*	0.0001356
22	*Nephotettix virescens*	0.0003285	72	*Planococcus lilacinus*	0.0001316
23	*Liriomyza huidobrensis*	0.0003259	73	*Minthea rugicollis*	0.0001291
24	*Orseolia oryzae*	0.0003167	74	*Amsacta moorei*	0.0001281
25	*Aulacophora lewisii*	0.0003131	75	*Tetramoera schistaceana*	0.0001259
26	*Rastrococcus invadens*	0.0003112	76	*Naranga diffusa*	0.0001246
27	*Chilo infuscatellus*	0.0002993	77	*Opogona sacchari*	0.0001232
28	*Batocera rubus*	0.0002868	78	*Xyleborus ferrugineus*	0.0001205
29	*Hydrellia philippina*	0.0002779	79	*Acanthocoris scabrator*	0.0001197
30	*Helopeltis theivora*	0.0002755	80	*Megymenum brevicorne*	0.0001094
31	*Bactrocera latifrons*	0.0002654	81	*Acanthiophilus helianthi*	0.0001056
32	*Chromatomyia horticola*	0.0002602	82	*Cryptoblabes gnidiella*	0.0000976
33	*Odoiporus longicollis*	0.0002596	83	*Idioscopus niveosparsus*	0.0000961
34	*Bactrocera dorsalis*	0.0002589	84	*Lopholeucaspis japonica*	0.0000959
35	*Rhipiphorothrips cruentatus*	0.0002436	85	*Parlatoria oleae*	0.0000941
36	*Aphis fabae*	0.0002427	86	*Cossus cossus*	0.0000931
37	*Xylotrechus quadripes*	0.0002413	87	*Aulacaspis tegalensis*	0.0000919
38	*Erionota thrax*	0.0002412	88	*Tarophagus colocasiae*	0.0000914
39	*Zeuzera coffeae*	0.0002387	89	*Chilo polychrysus*	0.0000888
40	*Batocera rufomaculata*	0.0002368	90	*Adoretus sinicus*	0.0000885
41	*Parasa lepida*	0.0002326	91	*Bactrocera umbrosa*	0.0000884
42	*Brachycaudus helichrysi*	0.0002319	92	*Deilephila elpenor*	0.0000867
43	*Phyllotreta striolata*	0.0002291	93	*Chondracris rosea*	0.0000858
44	*Pyrilla perpusilla*	0.0002266	94	*Pseudococcus jackbeardsleyi*	0.0000847
45	*Plocaederus obesus*	0.0002232	95	*Aleurothrixus floccosus*	0.0000845
46	*Chilo sacchariphagus*	0.0002228	96	*Tessaratoma papillosa*	0.0000843
47	*Hypomeces squamosus*	0.0002206	97	*Rastrococcus iceryoides*	0.0000839
48	*Orgyia postica*	0.0002120	98	*Deporaus marginatus*	0.0000831
49	*Ceratovacuna lanigera*	0.0002092	99	*Rhynchocoris poseidon*	0.0000819
50	*Henosepilachna pusillanima*	0.0002063	100	*Diuraphis noxia*	0.0000817

Table A8-32. Top 100 ranked species by invasion likelihood for the port of Portland.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Agrotis segetum*	0.0004222	51	*Rhagoletis cerasi*	0.0000792
2	*Hadula trifolii*	0.0003518	52	*Peridroma saucia*	0.0000787
3	*Pieris brassicae*	0.0003100	53	*Sitona humeralis*	0.0000783
4	*Ceroplastes rusci*	0.0002585	54	*Thaumetopoea pityocampa*	0.0000770
5	*Henosepilachna elaterii*	0.0002124	55	*Cacoecimorpha pronubana*	0.0000743
6	*Trichoplusia ni*	0.0001989	56	*Neoaliturus tenellus*	0.0000727
7	*Sitobion avenae*	0.0001919	57	*Orthosia cerasi*	0.0000723
8	*Aphis fabae*	0.0001914	58	*Mamestra brassicae*	0.0000718
9	*Lymantria dispar*	0.0001911	59	*Epidiaspis leperii*	0.0000716
10	*Philaenus spumarius*	0.0001886	60	*Eupoecilia ambiguella*	0.0000709
11	*Oulema melanopus*	0.0001863	61	*Haplothrips tritici*	0.0000691
12	*Spodoptera littoralis*	0.0001807	62	*Thrips angusticeps*	0.0000681
13	*Acronicta rumicis*	0.0001750	63	*Delia radicum*	0.0000678
14	*Scolytus rugulosus*	0.0001619	64	*Sesamia nonagrioides*	0.0000674
15	*Meligethes aeneus*	0.0001598	65	*Paranthrene tabaniformis*	0.0000653
16	*Bactrocera oleae*	0.0001491	66	*Brachycaudus helichrysi*	0.0000640
17	*Lixus juncii*	0.0001488	67	*Anthonomus pomorum*	0.0000618
18	*Lobesia botrana*	0.0001484	68	*Phyllotreta cruciferae*	0.0000615
19	*Aleurothrixus floccosus*	0.0001404	69	*Jacobiasca lybica*	0.0000605
20	*Scrobipalpa ocellatella*	0.0001363	70	*Eulecanium tiliae*	0.0000559
21	*Sesamia cretica*	0.0001257	71	*Saturnia pyri*	0.0000554
22	*Pissodes castaneus*	0.0001253	72	*Delia antiqua*	0.0000519
23	*Euproctis chrysorrhoea*	0.0001235	73	*Opogona sacchari*	0.0000498
24	*Parlatoria oleae*	0.0001222	74	*Psila rosae*	0.0000492
25	*Aphis pomi*	0.0001204	75	*Acrolepiopsis assectella*	0.0000437
26	*Anarsia lineatella*	0.0001174	76	*Cephus pygmeus*	0.0000414
27	*Deilephila elpenor*	0.0001147	77	*Sitona cylindricollis*	0.0000407
28	*Chromatomyia horticola*	0.0001144	78	*Scolytus scolytus*	0.0000406
29	*Orthezia insignis*	0.0001142	79	*Trogoderma granarium*	0.0000398
30	*Mythimna unipuncta*	0.0001085	80	*Rhyacionia buoliana*	0.0000392
31	*Acanthiophilus helianthi*	0.0001057	81	*Byturus tomentosus*	0.0000382
32	*Liriomyza trifolii*	0.0001053	82	*Empoasca vitis*	0.0000380
33	*Leptinotarsa decemlineata*	0.0001047	83	*Lymantria monacha*	0.0000376
34	*Diuraphis noxia*	0.0001032	84	*Zeuzera pyrina*	0.0000362
35	*Liriomyza bryoniae*	0.0001029	85	*Trialeurodes vaporariorum*	0.0000361
36	*Ostrinia nubilalis*	0.0000978	86	*Ips sexdentatus*	0.0000361
37	*Aulacophora foveicollis*	0.0000960	87	*Bothynoderes punctiventris*	0.0000348
38	*Laodelphax striatellus*	0.0000955	88	*Phorodon humuli*	0.0000348
39	*Prays oleae*	0.0000939	89	*Psylliodes chrysocephala*	0.0000335
40	*Operophtera brumata*	0.0000936	90	*Contarinia tritici*	0.0000332
41	*Cryptoblabes gnidiella*	0.0000935	91	*Dyspessa ulula*	0.0000323
42	*Dialeurodes citri*	0.0000921	92	*Parabemisia myricae*	0.0000306
43	*Malacosoma neustria*	0.0000898	93	*Dioryctria abietella*	0.0000304
44	*Mayetiola destructor*	0.0000896	94	*Tipula paludosa*	0.0000304
45	*Pterochloroides persicae*	0.0000864	95	*Sphaerolecanium prunastri*	0.0000302
46	*Schistocerca gregaria*	0.0000860	96	*Taeniothrips inconsequens*	0.0000294
47	*Grapholita funebrana*	0.0000855	97	*Dasineura pyri*	0.0000294
48	*Autographa gamma*	0.0000848	98	*Metopolophium festucae*	0.0000288
49	*Liriomyza huidobrensis*	0.0000838	99	*Neoaliturus haematoceps*	0.0000276
50	*Dysaphis plantaginea*	0.0000834	100	*Brachycerus muricatus*	0.0000272

Table A8-33. Top 100 ranked species by invasion likelihood for the port of Sydney.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Xylosandrus compactus*	0.077220	51	*Hyblaea puera*	0.002284
2	*Pinnaspis strachani*	0.034110	52	*Contarinia tritici*	0.002142
3	*Aproaerema modicella*	0.032706	53	*Atherigona soccata*	0.002121
4	*Sesamia inferens*	0.022582	54	*Liriomyza sativae*	0.002109
5	*Xyleborus ferrugineus*	0.018344	55	*Phorodon humuli*	0.002009
6	*Oryctes rhinoceros*	0.018109	56	*Bactrocera latifrons*	0.002009
7	*Aleurocanthus woglumi*	0.017637	57	*Statherotis discana*	0.001984
8	*Brachycaudus helichrysi*	0.016662	58	*Chromatomyia horticola*	0.001968
9	*Pelopidas mathias*	0.013489	59	*Ahasverus advena*	0.001920
10	*Chilo auricilius*	0.012602	60	*Adoretus versutus*	0.001911
11	*Cryptoblabes gnidiella*	0.012386	61	*Nipaecoccus nipae*	0.001887
12	*Planococcus lilacinus*	0.012133	62	*Acherontia styx*	0.001877
13	*Chilo infuscatellus*	0.011952	63	*Sitobion avenae*	0.001810
14	*Dicladispa armigera*	0.011906	64	*Nephotettix virescens*	0.001621
15	*Hydrellia philippina*	0.010851	65	*Rastrococcus invadens*	0.001600
16	*Stephanitis typica*	0.010753	66	*Euscepes postfasciatus*	0.001526
17	*Bactrocera umbrosa*	0.010525	67	*Aulacophora lewisii*	0.001514
18	*Elaeidobius kamerunicus*	0.008618	68	*Batocera rubus*	0.001457
19	*Tarophagus colocasiae*	0.008612	69	*Odoiporus longicollis*	0.001423
20	*Erionota thrax*	0.008590	70	*Orseolia oryzae*	0.001419
21	*Zeuzera coffeae*	0.008304	71	*Omphisa anastomosalis*	0.001411
22	*Ceratovacuna lanigera*	0.007608	72	*Ceroplastes rusci*	0.001397
23	*Aulacaspis tegalensis*	0.007557	73	*Aleurothrixus floccosus*	0.001395
24	*Orgyia postica*	0.007473	74	*Helopeltis theivora*	0.001388
25	*Promecotheca caerulipennis*	0.007141	75	*Chilo sacchariphagus*	0.001273
26	*Orthezia insignis*	0.006672	76	*Hypomeces squamosus*	0.001179
27	*Sternochetus frigidus*	0.006190	77	*Prostephanus truncatus*	0.001177
28	*Idioscopus clypealis*	0.005523	78	*Xylotrechus quadripes*	0.001156
29	*Liriomyza trifolii*	0.005338	79	*Parasa lepida*	0.001132
30	*Heterobostrychus aequalis*	0.005256	80	*Opogona sacchari*	0.001099
31	*Agrotis segetum*	0.004680	81	*Batocera rufomaculata*	0.001082
32	*Minthea rugicollis*	0.004410	82	*Attacus atlas*	0.001068
33	*Trichoplusia ni*	0.004384	83	*Rhipiphorothrips cruentatus*	0.001068
34	*Pseudococcus jackbeardsleyi*	0.004376	84	*Chaetocnema confinis*	0.001059
35	*Diaphorina citri*	0.003984	85	*Henosepilachna pusillanima*	0.001048
36	*Rhynchophorus vulneratus*	0.003926	86	*Omiodes indicata*	0.001044
37	*Perkinsiella vastatrix*	0.003797	87	*Philaenus spumarius*	0.001035
38	*Trialeurodes vaporariorum*	0.003639	88	*Bombyx mori*	0.001021
39	*Bactrocera papayae*	0.003260	89	*Pieris brassicae*	0.000993
40	*Dialeurodes citri*	0.003166	90	*Aulacophora foveicollis*	0.000992
41	*Leucinodes orbonalis*	0.003060	91	*Pyrilla perpusilla*	0.000991
42	*Liriomyza huidobrensis*	0.002965	92	*Oryzaephilus mercator*	0.000982
43	*Sinoxylon conigerum*	0.002955	93	*Plocaederus obesus*	0.000979
44	*Aphis fabae*	0.002931	94	*Sesamia cretica*	0.000978
45	*Parabemisia myricae*	0.002857	95	*Lopholeucaspis japonica*	0.000953
46	*Hypothenemus hampei*	0.002852	96	*Psila rosae*	0.000930
47	*Selenaspidus articulatus*	0.002711	97	*Parlatoria oleae*	0.000908
48	*Toxoptera odinae*	0.002649	98	*Metopolophium festucae*	0.000894
49	*Phyllotreta striolata*	0.002289	99	*Aonidomytilus albus*	0.000893
50	*Bactrocera dorsalis*	0.002286	100	*Urentius hystricellus*	0.000880

Table A8-34. Top 100 ranked species by invasion likelihood for the port of Townsville.

Rank	Species names	Invasion likelihood	Rank	Species names	Invasion likelihood
1	*Pinnaspis strachani*	0.0015756	51	*Adoretus versutus*	0.0001077
2	*Sesamia inferens*	0.0012999	52	*Helopeltis bradyi*	0.0001037
3	*Xylosandrus compactus*	0.0011452	53	*Aulacophora foveicollis*	0.0001003
4	*Oryctes rhinoceros*	0.0010067	54	*Trichoplusia ni*	0.0000957
5	*Xyleborus ferrugineus*	0.0009856	55	*Nephotettix virescens*	0.0000953
6	*Aleurocanthus woglumi*	0.0009363	56	*Acherontia styx*	0.0000933
7	*Pelopidas mathias*	0.0006919	57	*Orseolia oryzae*	0.0000918
8	*Planococcus lilacinus*	0.0006645	58	*Batocera rubus*	0.0000913
9	*Chilo auricilius*	0.0006509	59	*Aulacophora lewisii*	0.0000908
10	*Bactrocera umbrosa*	0.0006378	60	*Omphisa anastomosalis*	0.0000900
11	*Dicladispa armigera*	0.0006148	61	*Aproaerema modicella*	0.0000874
12	*Stephanitis typica*	0.0006132	62	*Phyllotreta chotanica*	0.0000808
13	*Hydrellia philippina*	0.0005530	63	*Trialeurodes ricini*	0.0000807
14	*Tarophagus colocasiae*	0.0005341	64	*Bactrocera tau*	0.0000790
15	*Chilo infuscatellus*	0.0005204	65	*Prays endocarpa*	0.0000784
16	*Aulacaspis tegalensis*	0.0004878	66	*Parasa lepida*	0.0000744
17	*Elaeidobius kamerunicus*	0.0004802	67	*Henosepilachna pusillanima*	0.0000657
18	*Erionota thrax*	0.0004604	68	*Megymenum brevicorne*	0.0000638
19	*Zeuzera coffeae*	0.0004281	69	*Attacus atlas*	0.0000633
20	*Sternochetus frigidus*	0.0004024	70	*Chromatomyia horticola*	0.0000620
21	*Orgyia postica*	0.0003801	71	*Phyllotreta striolata*	0.0000569
22	*Ceratovacuna lanigera*	0.0003752	72	*Artona catoxantha*	0.0000561
23	*Promecotheca caerulipennis*	0.0003584	73	*Omiodes indicata*	0.0000558
24	*Idioscopus clypealis*	0.0003229	74	*Cydia leucostoma*	0.0000523
25	*Leucinodes orbonalis*	0.0002804	75	*Bombyx mori*	0.0000517
26	*Rhynchophorus vulneratus*	0.0002526	76	*Cricula trifenestrata*	0.0000499
27	*Heterobostrychus aequalis*	0.0002505	77	*Oryzaephilus mercator*	0.0000494
28	*Pseudococcus jackbeardsleyi*	0.0002474	78	*Promecotheca cumingii*	0.0000488
29	*Diaphorina citri*	0.0002405	79	*Fulmekiola serrata*	0.0000482
30	*Toxoptera odinae*	0.0002296	80	*Rhynchocoris poseidon*	0.0000478
31	*Minthea rugicollis*	0.0002187	81	*Hysteroneura setariae*	0.0000477
32	*Bactrocera papayae*	0.0002126	82	*Lepidiota stigma*	0.0000477
33	*Perkinsiella vastatrix*	0.0002112	83	*Papilio polytes*	0.0000475
34	*Rastrococcus iceryoides*	0.0001880	84	*Aleurothrixus floccosus*	0.0000459
35	*Urentius hystricellus*	0.0001823	85	*Adoretus sinicus*	0.0000449
36	*Rastrococcus invadens*	0.0001816	86	*Chlumetia transversa*	0.0000446
37	*Sinoxylon conigerum*	0.0001666	87	*Deporaus marginatus*	0.0000445
38	*Helopeltis theivora*	0.0001608	88	*Acanthocoris scabrator*	0.0000445
39	*Statherotis discana*	0.0001434	89	*Bactrocera carambolae*	0.0000438
40	*Agrotis segetum*	0.0001401	90	*Setora nitens*	0.0000428
41	*Odoiporus longicollis*	0.0001391	91	*Tetramoera schistaceana*	0.0000418
42	*Selenaspidus articulatus*	0.0001363	92	*Citripestis sagittiferella*	0.0000399
43	*Hyblaea puera*	0.0001349	93	*Scotinophara coarctata*	0.0000396
44	*Bactrocera latifrons*	0.0001346	94	*Chilo polychrysus*	0.0000284
45	*Ahasverus advena*	0.0001332	95	*Idioscopus niveosparsus*	0.0000279
46	*Chilo sacchariphagus*	0.0001300	96	*Oxya chinensis*	0.0000257
47	*Liriomyza huidobrensis*	0.0001294	97	*Chondracris rosea*	0.0000249
48	*Hypothenemus hampei*	0.0001219	98	*Tessaratoma papillosa*	0.0000244
49	*Hypomeces squamosus*	0.0001181	99	*Stauropus alternus*	0.0000220
50	*Parabemisia myricae*	0.0001099	100	*Acherontia lachesis*	0.0000212

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