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Integrating drivers influencing the detection of plant pests carried in the international cut flower trade

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Abstract

This paper analyses the cut flower market as an example of an invasion pathway along which species of non-indigenous plant pests can travel to reach new areas. The paper examines the probability of pest detection by assessing information on pest detection and detection effort associated with the import of cut flowers. We test the link between the probability of plant pest arrivals, as a precursor to potential invasion, and volume of traded flowers using count data regression models. The analysis is applied to the UK import of specific genera of cut flowers from Kenya between 1996 and 2004.

There is a link between pest detection and the Genus of cut flower imported. Hence, pest detection efforts should focus on identifying and targeting those imported plants with a high risk of carrying pest species. For most of the plants studied, efforts allocated to inspection have a significant influence on the probability of pest detection. However, by better targeting inspection efforts, it is shown that plant inspection effort could be reduced without increasing the risk of pest entry. Similarly, for most of the plants analysed, an increase in volume traded will not necessarily lead to an increase in the number of pests entering the UK. For some species, such as *Carthamus* and *Veronica*, the volume of flowers traded has a significant and positive impact on the likelihood of pest detection. We conclude that analysis at the rank of plant Genus is important both to understand the effectiveness of plant pest detection efforts and consequently to manage the risk of introduction of non-indigenous species.

Keywords: Alien invasive species; Cut flowers; Plant pest species; Count data models; Phytosanitary inspection

1. Introduction

It has been recognised that the growth and development of world markets has a significant impact on the risk of biological invasions (Perrings et al., 2000; McNeely, 2001). The development of trade routes has opened up new pathways for invasive and potentially invasive species, and increased the frequency of detections and introductions (Frank and McCoy, 1992; Ruiz and Carlton, 2003; Caton et al., 2006; McCullough et al., 2006). This paper examines the invasion risks associated with the development of the international cut flower trade in the United Kingdom (UK), focusing on UK imports of cut flowers from Kenya between 1996 and 2004. Invasion risks are influenced by both environmental and social factors including the invasive species' life cycle strategy,[1] its prevalence on the traded host (which can vary seasonally), its adaptability to new environments, the nature of the trade pathway; and

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[1] A pest's life cycle strategy can influence invasion risk, e.g., parthenogenic (asexual) reproduction enables an individual female to give rise to progeny without partner. Thus even if a single individual were introduced, it could potentially generate a pest population.

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the frequency and volume of trade. A more detailed description of the factors contributing to the risk of pest entry is provided in FAO (2004). Since we are concerned with the introductions of species associated with particular pathways (MacLeod and Baker, 2003) and the effectiveness of phytosanitary inspection contributes to likelihood of detection on those pathways (Perrings et al., 2005), we analyse detections not on cut flowers in general, but at the taxonomic rank[2] of plant Genus. More particularly, we analyse (a) the likelihood that pests will be detected as a function of the volume of cut flower imports, by Genus, and (b) the likelihood that an increase in inspection efforts will increase the pest detection rate, again by Genus.

The international cut flower trade has grown in volume and value as a proportion of world trade (AIPH, 2004). This has led to an increased risk of plant pest introductions in importing countries (Kiritani and Yamamura, 2003; Work et al., 2005). Although the problem is not new (Frey (1993) showed that 13% of cuttings and 25% of whole plants imported to Switzerland were carrying arthropod pest species), the increase in the volume of imported plant material has substantially influenced the movement of pests in trade.

At the beginning of the 21st century, the European Union (EU) had established itself as the world's leading importer of cut flowers, accounting for over 50% of the global consumption of cut flowers (CBI, 2002). Not only has the volume of the trade continued to grow rapidly, but so too has the number of countries exporting cut flowers to Europe. African countries are becoming a significant source, currently accounting for around 8% of world exports of cut flowers, at a value of almost US$ 300 million (World Bank, 2005). Kenya was already the largest African exporter with 55% of the African market in 2001 (World Bank, 2005), and continues to dominate the African cut flower trade. It is one of the biggest suppliers of cut flowers to the EU, with 25% market share. Within the EU, the UK is the second largest importer of Kenyan cut flowers, cut flower imports from Kenya into the UK having increased by 239% between 1996 and 2003.[3] The value of cut flowers imported by the UK from Kenya in 2004 was approximately US$82 million.[3]

The Plant Health and Seeds Inspectorate (PHSI) executes plant health policy in England and Wales, part of which is to oversee and enforce import controls by carrying out intelligence-led, targeted, import inspections to inhibit the entry of prohibited plants and plant pests, and to audit those commodities that require a phytosanitary certificate. Upon detection of a regulated pest, there are a number of options available including (a) destruction of the consignment in a prescribed manner, (b) removal of contaminated products within the consignment followed by the release of the remainder of the consignment, (c) quarantining of the consignment pending tests, (d) application of an appropriate pest treatment, e.g., application of chemical insecticides, restriction of the use of the consignment, e.g., fresh produce could be directed for industrial processing or (f) the consignment could be rejected and returned or re-exported.

This paper analyses the effectiveness of inspection regimes in controlling the invasion risks from the increased cut flower trade between Kenya and the UK. In principle, the economics of inspections as a mechanism for controlling invasive species are straightforward. Inspections for pests should optimally be set to the level at which the marginal cost of inspection is equal to the expected marginal damage costs avoided by pest detection, and the various interception and control strategies that inspection supports (Southey, 1979; Ebbels, 2003; Ashby et al., 2005). When the infestation of the imported material reaches a given level in which detection has no effect on damage avoided, there is also a threshold interception rate beyond which it is optimal to not inspect but to charge an import tariff equal to the expected damage of pest imports (McAusland and Costello, 2004). Actual practice however includes import bans or standards. Commodities which, without regulation, present an unacceptable phytosanitary risk, are required to comply with a phytosanitary import standard, e.g., be free from specific plant pests, as noted in the EC Council Directive (2000/29/EC).

Within the threshold described by McAusland and Costello (2004), it follows that if the risk associated with different cut flowers varies (i.e. the level of potential avoided damaged varies), so should the level of inspection effort. In this paper, we test the hypothesis that inspection effort varies with the rate of interceptions. Unlike previous work where cut flowers and cumulative imports were regarded as a single route for pest entry (Levine and D'Antonio, 2003; McCullough et al., 2006) we examined the invasion risks associated with the main imported cut flowers and their individual inspection regimes separately. A count data approach is applied to explore the relationship between the number of pest interceptions, the volume of cut flowers traded and the level of detection effort.

2. Methods

2.1. Data

There are no direct observations on the number of pest species that enter and establish as a result of their presence on imports of different cut flowers (Smith et al., 2005). However, we can obtain a measure of the risk by determining the number of pests intercepted per unit of inspection effort,[4] again by flower type. To test the

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[2] Taxonomists classify organisms using a hierarchy with levels such as Kingdom, Phylum, Order, Family, Genus and species. Each level is referred to as a rank.

[3] *Source*: Based on data prepared by Statistics (Commodities & Food) Division, Defra, provided by HM Revenue and Customs.

[4] In this study, effort is not a measure of time but the number of consignments of each type of cut flower inspected.

relationship between (a) the number of pest species intercepted per cut flower Genus, (b) the number of cut flower consignments inspected and (c) imported volume, we obtained monthly data for the period between January 1996 and March 2004. The dataset consisted of records of plants inspected and plant pests detected by the personnel of the PHSI of the Department for environment food and rural affairs (DEFRA) in the UK. Volumes of cut flowers imported to the UK from Kenya were obtained from the Eurostat Database. The Eurostat Dataset includes data on the volume of cut flowers imported from Kenya to the UK for the following categories: "roses", "carnations" and "other cut flowers". For those plants for which the volume of imports was not available, we used the data on the latter category as a proxy.

Data on pest interceptions do not specify whether the host is a cut flower, a cutting or a plant, while data on inspections distinguish between these types of hosts. Accordingly, in order to make sure that the host of the pest species intercepted was a cut flower, the date of inspection and date when pest was intercepted in both datasets were checked to ensure that they coincided. Only *Dendranthema* was removed from the dataset since it was not possible to say whether the pest intercepted was found in cut flowers or cuttings in every case.

2.2. Count data models

We use count data models to study the variability of monthly pest species interceptions in cut flowers. Count data describe the number of times a given event occurs. Count data models are appropriate when the dependent variable is a variable that takes on nonnegative integer values, $y = 0, 1, 2, \ldots$, where y is measured in natural units on a fixed scale. In our case, this is the number of pest species detected in cut flowers per month. The variable takes discrete values including 0. Count data distributions are characterised by being skewed to the left. Using the count data on interceptions in the study period, we estimated the following models: the Poisson Regression Model (PRM), the Negative Binomial Regression Model (NBRM), the Zero Inflated Poisson (ZIP) and the Zero Inflated Negative Binomial (ZINB). The last three were used to account for the presence of overdispersion and the frequency of zero pest species intercepted.

The number of pest species intercepted was firstly modelled using the Poisson Regression Model, which it is normally the first step for most count data analyses. This approach specifies that the count dependent variable (y) follows a Poisson distribution with expectation parameter λ (i.e. expected number of interceptions per month), $\Pr(Y|\lambda) = (e^{-\lambda}\lambda^{y}/y!)$, $y = 0, 1, 2, \ldots$. One of the main characteristics of the Poisson distribution is that the expectation parameter, λ is both the mean and the variance of the count data (y). This property is known as equidispersion. This Poisson distribution is extended to obtain a regression model by allowing each observation y_i to have a different value of λ. The most popular formulation is an exponential relationship between the expectation rate and a set of regressors, $\lambda_i = e^{x_i\beta}$ where x_i is the vector of regressors that includes the number of phytosanitary inspections and volume imported of cut flowers per month and β is the vector of unknown parameters to be estimated which captures the effect of the number of inspections, and volume of cut flowers imported on the number of interceptions. In practice, the variance of the data is often larger than the mean, i.e. the data are characterised by overdispersion. In this case, the standard errors estimated from the Poisson Regression Model are biased downward and the p-values are small and spurious; therefore, it is important to check for overdispersion (Cameron and Trivedi, 1986, 1990; Dean, 1992). A number of tests have been devised for overdispersion in the Poisson Regression Model. We use a Likelihood ratio (LR) test to determine whether overdispersion is present, i.e. whether the assumption behind the Poisson model, $\mathrm{Var}(y|x) = \alpha E(y|x)$, is satisfied. If overdispersion is found a solution is provided by the Negative Binomial model (i.e. NegBin II), which is usually applied to account for overdispersion. This model allows the variance to exceed the mean. It requires that the variance be equal to $\mathrm{Var}(y_i|x_i) = (1 + \alpha \exp(x_i'\beta)) \exp(x_i'\beta)$ for some $\alpha > 0$, where the amount of overdispersion increases with the conditional mean $E(y_i|x_i) = e^{x_i\beta}$ (Cameron and Trivedi, 1986).

Some cut flowers show a large number of zero interceptions. This may occur for two different reasons. It may be that no inspections were conducted or when inspections were conducted no pest was detected. Too high an incidence of zero counts in the data may cause problems if it is greater than expected for the Poisson distribution. Excess zeros or zero inflation in data result in heterogeneity leading to biased coefficient estimates. In addition, the PRM and NBRM do not account for the potential sources of zeros in the dependent variable. In order to account for excess zeros ZIP and ZINB models were estimated (Lambert, 1992). Following Long and Freese (2003) zero inflated models assume that there are two unobserved groups. In one group (G1), the outcome is always zero. In the other group (G2), the Poisson or negative binomial distribution produces the zero outcome or some other. Formally,

$$Y_i \begin{cases} \text{G1}: & 0 \text{ with probability } 1, \\ \text{G2}: & \text{Poisson } (\lambda_i) \text{ or Negative binomial } (\lambda_i, \varphi), \text{positive outcome with probability } p_i > 0, \end{cases}$$

where Y_i is the count dependent variable and $\varphi \geqslant 0$ is a scalar. When $\varphi = 0$, it reduces the ZINB to a ZIP model.

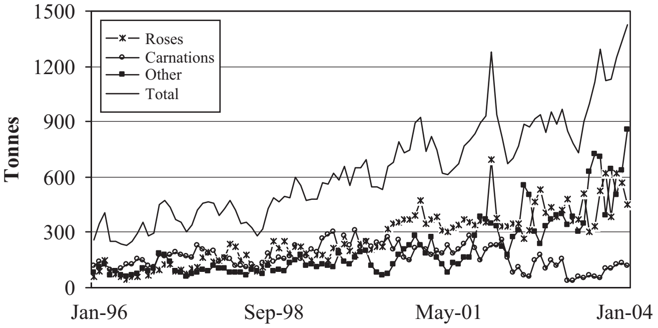

Fig. 1. Imported volume of roses, carnations and other cut flowers between January 1996 and March 2004 to the UK.

We conducted PRM, NBRM, ZIP and ZINB regressions on each individual cut flower to estimate the model parameters. Misspecification of the models was checked using a regression specification error test (RESET). This involved including the squares of the predicted values as an extra covariate in the models (Long and Freese, 2003). Overdispersion was tested by conducting a LR test. This helped to decide between PRM and NBRM. The Vuong's test provides a mechanism for testing hypotheses concerning model validity (Vuong, 1989). Greene (1994, 2003) proposed to use Vuong's test statistic to compare the ZIP model to PRM or the ZIBN to the NBRM. Vuong's test provides evidence of which of the two competing models fits the data best for a given dependent variable (Long and Freese, 2003).

3. Results

The cut flower trade between Kenya and the UK grew rapidly during the study period (Fig. 1), the volume and value (in 2004 US$) of cut flowers imported to the UK having increased by approximately 239% and 326%, respectively, during the period.

A total of 148 pest interceptions, representing approximately 33 species, were reported in 2080 phytosanitary inspections carried out on the set of cut flowers analysed in this study during the 8-year period. Insects were the most common plant pests detected in the inspections (93% of the interceptions) with Diptera (flies) (38%), Thysanoptera (Thrips) (32%) and Hemiptera (21%) as the most frequently detected insects.[5] Data analysis suggests that *Veronica*, *Carthamus*, *Lisianthus* and *Eryngium* are the plants that represent the greatest risk of pest introduction by representing the highest number of pest interceptions per inspection, with on average 30% or more of inspections identifying pest presence (Table 1).

The number of pest species found per interception varied significantly between cut flowers, as did the nature of the pest species associated with each plant type. *Veronica*, for example, yielded pest species in 43% of inspections, 93% of which were Thysanoptera (Thrips), which represents 87% of all the Thrips intercepted (Table 2).

Fig. 2 shows the number of inspections and interceptions of 12 pest hosts throughout the period studied. Significant differences were observed between cut flowers in terms of both the number of inspections and interceptions across the period analysed. The detection effort was distributed unevenly through time for most of the plants considered, with just a few of the flowers regularly inspected. Some flowers such as *Alstroemeria*, *Dianthus*, *Eustoma*, *Gypsophila*, *Limonium*, *Rosa* and *Solidago* were inspected regularly during the period, whereas others such as *Carthamus*, *Eryngium*, *Lisianthus*, *Solidaster* and especially *Veronica* show periods when inspections have not been conducted. It is worth noting that it is an obligation of contracting parties to the International Plant Protection Convention (IPPC) that information is shared about new pest finds and incursions. Protocols for the dissemination of such information, for example through the European and Mediterranean Plant Protection Organisation assists countries to gather intelligence and target inspections. In addition, analysis of past finds informs decision makers on which pathways to target (MacLeod et al., 2005). Local PHSI knowledge and experience also contribute to selecting consignments to inspect.

Table 3 shows the results of the PRM, NBRM, ZIP and ZINB regressions. They show that, in general, the volume of imports and the introduction of pests are not correlated. However, for the particular species *Carthamus* and *Veronica*, import volumes are positively related to the number of pest species intercepted (p-value<0.001). This means that an increase in trade in these cut flowers in particular does increase the risk of pest entry, holding the number of inspections constant. In one case, *Eustoma*, import volumes were found to be negatively related to the number of pest species intercepted. This is due to the fact that the data do not show any interceptions after February 2000 when import volumes of the flower increased. No volume effects were found for the other cut flowers studied.

There is evidence in some cases that the level of inspection efforts was sensitive to the perceived risk. The number of inspections was, for example, found to be positively related to the number of pest species intercepted, holding everything else constant, in the case of *Alstroemeria*, *Carthamus*, *Eryngium*, *Lisianthus*, *Solidago* and *Veronica* (p-value<0.001). This is consistent with recognition that the import of these cut flower genera carries a risk of introducing pest species more than other cut flower genera. However, import volumes and inspections were uncorrelated with the frequency of interceptions in the case of *Rosa* and *Solidaster*. Indeed, the most heavily inspected flowers typically had the lowest interception to inspection ratios (Table 1). The estimates for the expected number of interceptions (i.e. λ)

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[5] Hemiptera are insect bugs. Hemiptera that are plant pests damage plants by feeding on the plant's nutrients and can cause unsightly blemishes to ornamental flowers. Thysanoptera are small winged insects closely related to bugs (Hemiptera) with similar sucking mouthparts and can cause similar plant damage. Diptera are flies. Some juvenile stages (larvae) burrow within a host plant, excavating a mine, weakening the host plant.

Table 1
No. of pest detections and inspections per host

Host	No. of detections	No. of pest species	No. of inspections	Inspections (%)	Interception/inspection (%)
Geranium	1	1	1	0	100.0
Veronica	13	42	30	1.4	43.3
Carthamus	8	10	24	1.2	33.3
Eryngium	9	15	29	1.4	31.0
Lisianthus	20	21	69	3.3	29.0
Hypericum	4	4	25	1.2	16.0
Euphorbia	2	2	14	0.7	14.3
Eustoma	16	17	114	5.5	14.0
Solidago	22	26	184	8.8	12.0
Stachys	1	1	10	0.5	10.0
Gypsophila	13	13	156	7.5	8.3
Solidaster	4	4	64	3.1	6.3
Dianthus	15	17	298	14.3	5.0
Limonium	6	7	121	5.8	5.0
Alstroemeria	7	12	143	6.9	4.9
Bupleurum	2	2	52	2.5	3.8
Aster	2	2	65	3.1	3.1
Rosa	3	3	258	12.4	1.2
Dendranthema			198	9.5	
Other			225	10.8	
Total	148		2080		

Table 2
Number of *Veronica* consignments found to be contaminated with pests

Date	No. of contaminated consignments	Pest types present	No. of species found
June 2001	1	Insect/Hemiptera	1
October 2001	5	Insect/Thysanoptera	9
		Insect/Diptera	1
		Insect/Hemiptera	1
		Fungi/Erysiphales	1
November 2001	3	Insect/Thysanoptera	6
February 2002	2	Insect/Thysanoptera	2
October 2002	2	Insect/Thysanoptera	4
November 2003	2	Insect/Thysanoptera	2
		Insect/Hemiptera	1

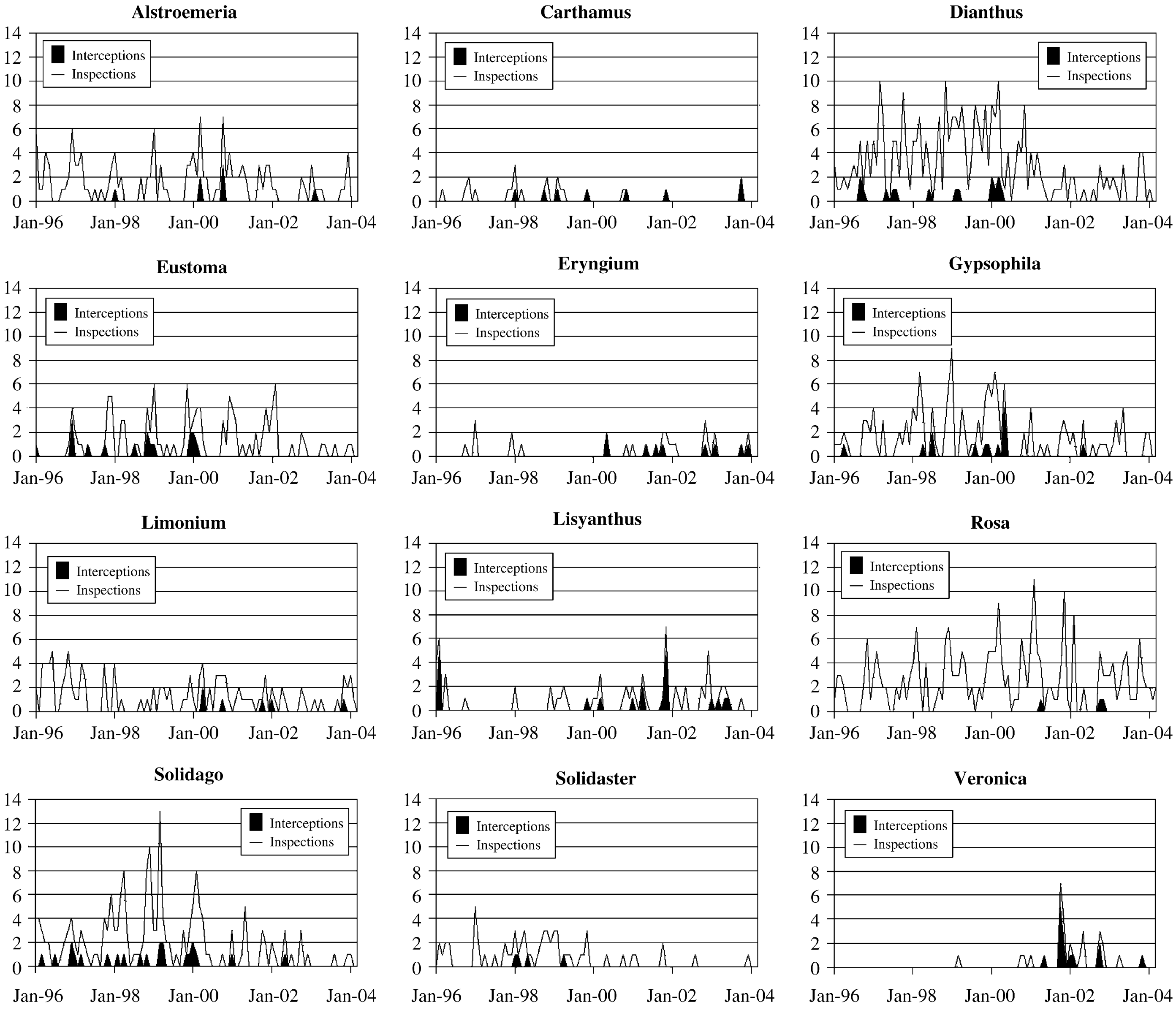
are shown in the last column of Table 3. This parameter has been estimated for the average of the total number of inspections and average import volume of cut flowers per month. Results show that cut flowers with the highest expected number of interceptions per month are *Eryngium*, *Carthamus*, *Lisianthus*, *Solidago and Veronica* whereas the cut flowers with the lowest estimates of λ are *Limonium*, *Solidaster*, *Alstroemeria* and *Rosa.*

4. Discussion and conclusions

This study contributes to an understanding of the invasion risks associated with the growth of the international cut flower trade. Using interceptions per inspection as a proxy for the risk of species entering the UK associated with different cut flower imports, we consider both the evidence of invasion risks from the record of inspections and interceptions, and the evidence for the efficiency of the inspection regime. The study shows that the likelihood of pest detection depends mainly on the Genus of cut flowers imported. Recalling that pest inspections should be set to the level where the marginal cost of inspection effort is the same as the expected marginal damage avoided by pest detection (McAusland and Costello, 2004), we find that if the potential economic impacts associated with distinct pests are independent of the specific host facilitating entry of the pest, then detection efforts should be higher for cut flowers with a greater risk of carrying pests known to be of concern, as MacLeod and Baker (1998) demonstrated when examining the threat posed by *Thrips palmi* to EU horticulture.

This analysis has found that the level of inspection effort for most cut flowers is not related to the likelihood of pest detection associated with those flowers.

Our results indicate that for most of the cut flowers analysed, the risk of pest entry did not increase with the volume of imports. That is, for most species, an increase in the volume of imports from Kenya did not lead to an increase in the number of pests intercepted in the UK, holding the number of inspections constant. For *Dianthus*, *Rosa*, *Solidago* and *Solidaster* the growth in import volumes had little discernible effect on entry of pest species. This partly reflects the quality of pest control in Kenya in respect to these genera (D. Grove, PHSI, pers.comm.). However, for *Carthamus* and *Veronica*, this was not the case. For these flowers, the growth in import volumes clearly increased the risk of pest species entering.


Alstroemeria

Carthamus

Dianthus

Eustoma

Eryngium

Gypsophila

Limonium

Lisyanthus

Rosa

Solidago

Solidaster

Veronica

Fig. 2. Number of inspections and interceptions per month of a set of cut flowers between January 1996 and March 2004.

Table 3
Model results

	Constant	Inspections	Log (volume)	Log^{-1}	N	Method	λ
Eryngium	−2.14 (3.33)	2.30** (0.58)	−0.42 (0.63)	−23.97	99	NegBin	1.37
Carthamus	−10.51** (2.30)	1.83** (0.32)	1.25** (0.37)	−16.98	99	Poisson	0.62
Lisianthus	−1.29 (2.32)	0.55** (0.09)	−0.15 (0.44)	−27.55	99	Poisson	0.38
Solidago	1.16 (1.97)	0.24** (0.05)	−0.65 (0.41)	−54.75	99	NegBin	0.19
Veronica	−21.62** (7.10)	0.97** (0.17)	3.52** (1.17)	−18.01	99	ZINB	0.18
Eustoma	6.96 (4.03)	0.57* (0.20)	−2.02*	−38.60	99	NegBin	0.11
Dianthus	2.46 (3.33)	0.24* (0.11)	−1.05 (0.70)	−42.83	99	NegBin	0.10
Gypsophila	4.95 (4.28)	0.47* (0.16)	−1.73 (0.92)	−30.10	99	ZIP	0.05
Limonium	−11.15 (5.71)	1.08* (0.45)	1.18 (0.93)	−19.67	99	Poisson	0.05
Solidaster	10.01 (8.22)	0.57 (0.43)	−2.96 (1.88)	−13.57	99	Poisson	0.02
Alstroemeria	−12.95* (4.89)	1.13** (0.21)	1.22 (0.82)	−14.50	99	Poisson	0.01
Rosa	−22.77* (10.90)	0.09 (0.21)	3.25 (1.81)	−10.57	99	Poisson	0.01

*Significant at 5% level.

**Significant at 0.1% level.

Without detailed data on the expected damage costs of pests or the cost of inspection we are unable to evaluate the optimal level of inspections. However, if we assume that the potential impact of a pest is independent of the species that acts as its host during shipment, we can at least evaluate the efficiency of the relative level of inspection effort for different hosts. We would expect the level of inspection effort for different cut flower hosts to be a function of the level of interceptions (our proxy for the level of expected pest entry associated with those species). We find no such relationship. For *Rosa* and *Solidaster*, we find that the level of inspection effort may be disproportionately high relative to the interception rate. Inspection effort for these species could be reduced without affecting pest entry. For *Alstroemeria*, *Carthamus*, *Eryngium*, *Lisianthus*, *Solidago* and *Veronica*, the level of inspection effort may be below the optimal level. If the potential impact of a pest is not independent of the host, then inspections of each host should increase up to the point where the marginal cost of inspections is equal to the marginal damage avoided by preventing introductions, where the marginal damage cost depends on both the likelihood that a shipment will introduce a pest, and the expected damage if a pest is introduced.

Increasing the level of inspection, and hence interceptions, may reduce the potential impact resulting from pest entry. There is some uncertainty, here, about the threshold interception rate beyond which inspections are no longer helpful. An interception rate above 30% implies a high proportion of infected shipments. If the marginal damage of pest infestation is relatively low in such cases, it can be better not to incur inspection costs, whilst providing exporters with an incentive to reduce the rate of infestation.

When undertaking pest risk analysis (FAO, 2001, 2004), a variety of techniques can be used to estimate pest impacts (Baker and MacLeod, 2005) and when integrated with an economic assessment of the pest management, options can be used to develop or support policy decisions, such as determining an appropriate level of inspection (Surkov et al., 2005). However, normally there is no detailed knowledge on expected damage costs and limited resources are used to inspect high-risk consignments. The European Commission has recently developed a system for better targeting phytosanitary inspections. In determining the minimum level of inspection required, the system takes biotic and abiotic factors into account, such as past pest detections and volume of trade (Anon., 2004). Nevertheless, the new system has been criticised on the basis that it is heuristic, based on value judgements and discriminatory risk classification (Broens and Willems, 2004).

One reason to be concerned about current inspection regimes is that recent regulatory changes may well have increased the likelihood that cut flower imports will be infested, and therefore that the expected marginal damage associated with invasions may be increasing. Since EU regulations on pesticide use were changed in 2000 many pesticides have been withdrawn from use. EU importers often require export partners to follow domestic EU legislation with respect to pesticide use (Chan and King, 2000). Thus, the withdrawal of dichlorvos, an insecticide previously commonly used on cut flowers, may increase pest problems at Kenyan sites.

Further research following the principles of pest risk analysis, using pest interception data on novel trade routes that includes cost data on both inspection effort and the value of potential pest damage could help identify an optimal inspection regime for specific trade routes and imported commodities. It could also be used to detect emerging trends in risk and provides an evidence base upon which management and legislative changes can be assessed (MacLeod and Baker, 1998; Touza et al., 2007; Knowler and Barbier, 2005). Subsequent analysis of pest interceptions that compares interceptions before and after legislative changes can provide a measure of how effective the legislative changes have been (MacLeod et al., 2005).

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