Experiences and limitations with pest risk analysis in the Galapagos Islands

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Abstract

More than 1 000 plant and invertebrate species have been introduced into the Galapagos Archipelago since the arrival of human settlers 200 years ago. In 1991, the Charles Darwin Foundation (CDF) proposed the implementation of an inspection and quarantine system for the Galapagos Islands (Sistema de Inspección y Cuarentena para las Islas Galápagos, SICGAL) to prevent further introductions. A pilot system was initiated in 1999, and in 2001, the Ecuadorian Service of Plant and Animal Health assumed responsibility for the SICGAL quarantine system with inspection points in the airports and ports of mainland Ecuador and Galapagos. Unfortunately, the success of the quarantine system has been limited by financial restraints, a lack of trained and qualified inspectors, and deficiencies in the execution of existing quarantine laws and regulations. In order to make SICGAL more efficient and effective, the CDF, together with other stakeholders, compiled a list of permitted import products based on criteria that addressed the dilemma of conserving the unique biodiversity of Galapagos while satisfying the demands of the growing human population and tourism industry. Recently, the CDF has been improving the methods for assessing the risks of introducing alien invertebrate or plant species. Together with Paul Pheloung, the CDF has adapted the Australian weed risk assessment system to evaluate the risk of species not yet introduced becoming weeds in Galapagos. The system was extended to evaluate the actual and potential weediness of introduced species already present in Galapagos. At the same time, the CDF has identified potential quarantine invertebrate pests and evaluated their risks of introduction using a simple scoring model. Based on the Australian weed risk assessment model, a pest risk assessment system is being adapted to rank the 500 known introduced invertebrates.

Introduction to Galapagos

The Galapagos Archipelago is the largest, most complex tropical oceanic island ecosystem that still remains in near pristine condition. It is estimated that 95 percent of the original, pre-human diversity of species is still recoverable (Bensted-Smith, Powell and Dinerstein, 2002). Galapagos is a UNESCO World Heritage site whose exceptional value derives from its high rate of flora and fauna endemism. The archipelago is considered one of the earth's most biologically outstanding terrestrial, freshwater and marine habitats as defined by World Wildlife Fund (World Wide Fund for Nature, WWF) in its Global 200 analysis (refer panda.org). This "ecoregion" of high biological endemism has been the subject of intensive conservation planning effort (Charles Darwin Foundation and WWF, 2002).

The archipelago is situated on the Galapagos Submarine Platform and contains 128 islands. It lies on the equator approximately 1 000 km due west of the Ecuadorian Pacific coastline, and spans 304 km from east to west and 341 km northwest to southeast. The total land area is roughly 7 856 km^2. The islands range in altitude from 2 m to almost 1 700 m.

Because of their late human colonization, the Galapagos Islands constitute a unique example of how ecological, evolutionary and biogeographic processes shape the flora and fauna of single islands and an entire archipelago.

Although the islands' harsh conditions have prevented large numbers of species from becoming established, the estimated 7 000 to 9 000 hardy species that do live in the Galapagos are among the most distinctive on Earth. Endemic species are common throughout the terrestrial, or land-based, parts of the islands. Approximately 80 percent of all land birds in the islands, 97 percent of reptiles and land mammals, and more than 30 percent of plants and approximately 50 percent of insects are endemic.

The problem of alien species

The preservation of these species, however, is threatened by the introduction and dispersal of alien organisms by human beings. The growth of tourism and associated migrations to the islands in the past 20 years has brought about a dramatic rise in the number of introductions of alien species (Peck *et al.*, 1998; Tye *et al.*, 2002). Approximately, 90 000 tourists visit each year, and more than 25 000 people inhabit the five populated islands. The annual growth rate for the archipelago is estimated at over 6 percent. To supply the islands, 1 100 flights and over 100 cargo shipments bring more than 30 000 tonnes of materials to the islands each year. The transport of such large volumes of materials opens up major pathways for new incursions and is a threat to the survival of 117 endemic terrestrial vertebrates, 560 endemic plants and an estimated 5 000 terrestrial invertebrates. Positively related with the increase in population is the number of introduced plant and invertebrate species (Peck, 2001; Snell *et al*., 2002). More than 17 vertebrate, 550 plant and 500 invertebrate species have been introduced into the Galapagos Archipelago since colonization by human settlers almost 200 years ago. Alien species are responsible for 11 of the 13 full species extinctions and 39 extinctions of subspecies, races, varieties and populations in the archipelago.

Until recently, the main focus of eradication programmes has been on mammals, particularly goats and pigs. On the island of Isabela, the impact of goats endangers the existence of the endemic flora and of the giant land tortoises. In 2002, a massive eradication programme was started to eliminate approximately 500 000 goats from Isabela.

Eradication programmes now include invasive plant and invertebrate species. More than 50 percent of the Galapagos flora has been introduced in the last 500 years since the discovery of the archipelago by the Spanish. This is about 10 000 times the rate at which species arrived in Galapagos prior to human settlement. Invasive plant species are generally introduced intentionally by people for food, forage, fibre and ornamental purposes. More than 40 of the 550 introduced plant species have become invasive. More species, which are already present but have not yet naturalized and spread on a large scale, will add to these problems in the future (see table 1).

Currently 432 species of introduced insects are registered in the Galapagos (Causton, 2004 subm.). These species, in the absence of their natural enemies and other factors that regulate their numbers in their native range, have multiplied and invaded a wide range of habitats. Alien species are a serious threat to the conservation of the biodiversity of the Galapagos. Fire ants are voracious predators of native invertebrates. The Australian mealybug, or cottony cushion scale (*Icerya purchasi*), first recorded in 1982, attacks almost 62 endemic and native plant species, of which several are in danger of extinction. Certain alien species also pose a threat to human and animal health. The biting black fly (*Simulium ochraceum*) is a known vector for onchocercosis and various avian diseases. The recent introduction of the *Aedes aegypti* mosquito is associated with the first recorded outbreaks of dengue fever in the archipelago. In addition, introduced crop pests have reduced agricultural production in the islands and have increased the use of pesticides.

Development of regulations and control systems

In 1991, the rapidly growing threat of invasive species led the Charles Darwin Foundation (CDF) to seek support and funding for the development of an inspection and quarantine system for the

Table 1: The most aggressive invasive plant species in Galapagos.

Invasive plant species	**Family**	**Type**
Bryophyllum pinnatum	Crassulaceae	ornamental
Cedrela odorata	Meliaceae	wood
Cestrum auriculatum	Solanaceae	medicinal
Cinchona pubescens	Rubiaceae	medicinal
Citrus x *limon*	Rutaceae	fruit
Cleome viscosa	Capparaceae	weed
Cordia alliodora	Boraginaceae	wood
Cucumis dipsaceus	Cucurbitaceae	weed
Datura stramonium	Solanaceae	ornamental/medicinal
Digitaria decumbens	Poaceae	pasture
Furcraea hexapetala	Agavaceae	fibre/ornamental
Lantana camara	Verbenaceae	ornamental
Leersia sp. 1	Poaceae	weed
Melinis minutiflora	Poaceae	pasture
Ochroma pyramidale	Bombacaceae	wood
Panicum maximum	Poaceae	pasture
Passiflora edulis	Passifloraceae	fruit
Passiflora ligularis	Passifloraceae	fruit
Passiflora quadrangularis	Passifloraceae	fruit
Pennisetum purpureum	Poaceae	pasture
Persea americana	Lauraceae	fruit
Psidium guajava	Myrtaceae	fruit
Rubus glaucus	Rosaceae	fruit
Rubus niveus	Rosaceae	fruit
Senna obtusifolia	Caesalpiniaceae	weed
Solanum pimpinellifolium	Solanaceae	weed
Syzygium jambos	Myrtaceae	fruit

Syzygium malaccense	Myrtaceae	fruit
Tradescantia fluminensis	Commelinaceae	ornamental
Urochloa decumbens	Poaceae	pasture
Urochloa mutica	Poaceae	weed

Galapagos Islands (Sistema de Inspección y Cuarentena para las Islas Galápagos, SICGAL). The enactment of a Special Regulation for Plant and Animal Health and Quarantine and Natural Areas of the Galapagos in 1994 and the passing of the Law of the Special Regimen for the Conservation and Sustainable Development of the Province of the Galapagos in 1998 have given the islands the legislative support required for a much-needed quarantine and inspection system for the archipelago. In 2003, the Ecuadorian President approved the Regulation of the Total Control of Invasive Species for Galapagos. These laws and regulations provide great opportunities for strengthening the conservation of the archipelago. The regulations, if enforced, should control the transport of food products and animals from the continent and between islands, thereby reducing the number of intentional and accidental alien introductions.

Since 2001, the Ecuadorian Plant and Animal Health Service (Servicio Ecuatoriano de Sanidad Agropecuaria, SESA) has assumed responsibility for the SICGAL quarantine system. There are now 32 SICGAL quarantine officers inspecting passengers and cargo at inspection points in the airports and maritime ports in mainland Ecuador and in the Galapagos. Unfortunately, the efficiency and success of the quarantine system is severely limited by SESA's financial difficulties, lack of trained and qualified inspectors and deficiencies in the execution of existing quarantine laws and regulations.

The pest risk analysis of all commodities imported to the Galapagos Islands is crucial for the protection of the unique biodiversity. Fortunately, because of the special circumstances of the Galapagos Islands, the final decision about whether a product is allowed to be imported can be very conservative. In contrast to countries such as Australia or New Zealand, Galapagos can, if needed, apply a zero-risk policy. As a province of Ecuador, Galapagos does not have to follow international trade rules. In addition, Galapagos is protected under special laws giving SESA and the Galapagos National Park Service authority to restrict any products deemed high risk.

In 1999, the CDF, together with all other stakeholders (wholesalers, conservation and tourism sectors, and farmers), elaborated a list of permitted, restricted and prohibited products for importation into the Galapagos Islands. This list currently de fines what foodstuffs, fresh products and some inorganic material can be transported from the continent to the islands and between islands. It also sets health standards for all import products. This list was developed using a simple questionnaire (table 2), because of the urgency to restrict the number of risk goods entering Galapagos. This methodology scored import products according to their risk of introducing into the Galapagos Islands new alien species that are a threat to biodiversity, agriculture and health, or species that are already established but have been identified as a threat and are under control. At the same time, these risks were weighed against the importance of the import product to the consumer. Interestingly, most stakeholders were in agreement with the majority of the classifications because of their interest in minimizing the damage caused by alien species.

Some of the limitations of this 1999 product list are that the invasiveness and the potential behaviour of a plant or invertebrate in the Galapagos Islands are not adequately addressed. We also found that data sheets of many of the import products and their associated pests were not readily available in other countries, which prevented us from being able to assess the risk of importing some import products. In particular, we found that most countries address the threats of alien species to the economy, agriculture and health, but do not address the threats to the conservation of biodiversity. For example, it is common to find information about known agricultural pests, but very hard to find out whether a species is invasive or not.

Adapting the weed risk assessment model

Another model was necessary to address the new requirements for conservation of biodiversity. An internationally renowned weed risk assessment system from Australia and New Zealand, described in Pheloung, Williams and Halloy (1999), was adapted with the help of one of its key developers, Paul Pheloung from the Department of Agriculture, Fisheries and Forestry Australia.

The WRA system is the best relative measure of invasiveness of species in the Galapagos Islands. However, it does not analyse the risk of the importation pathways of a plant species. Thus, the WRA used in New Zealand and Australia has been altered to include several new concepts. This adapted WRA model (see table 3) will help to develop the following prioritization tools:

- to evaluate the potential invasiveness of plant species, thereby preventing introduction at the border or, if already present in Galapagos, determining priority for control management
- to select and prioritize species for eradication based on their invasiveness and the feasibility of eradication (with the feasibility being assessed separately).

Not only does this adapted system allow us to determine which plants are likely to become invasive if introduced, but it has been modified to consider the behaviour of species already present in Galapagos. Sometimes, the predicted invasiveness and the actual invasiveness can differ, because our predictions are based on the behaviour of the species overseas. For example, a species that is not a known invader overseas could have a low score, but when we look at its behaviour in the Galapagos it is seen as highly invasive.

Table 2: Questionnaire evaluating status of a product for import into the Galapagos Islands.

Variables	Description	Options	Scoring
t	**Importance of the product to consumer**	High demand	10
		Regular demand	5
		Low demand	0
		Occasional demand	-5
		No demand	-10
u	**Invasiveness**	Very invasive in Galapagos	-6
		Potentially invasive in Galapagos	-4
		Low invasive potential anywhere	0
		Not invasive anywhere	6
v	**Known to carry pests**	Associated with important pests that are generalist feeders	-6
		Associated with important pests that are specialist feeders	-4
		Associated with pests of little importance	0
		No pests	2
w	**Exists in Galapagos**	Not present, potentially invasive	-20
		Not present, not adaptive to Galapagos	0
		Present	1
x	**Internal demand satisfied**	No market	-2
		Temporary market	0
		Dissatisfied	2
y	**Control programme**	Control programme implemented	-15
		No control programme	0
z	**Practical and economical method available for treating import product if required**	Yes	6
		No	0

Basic formula: St = t+u+v+w+x+y+z
Scoring results: not permitted <-5; restricted =5; permitted >5.

The model can still be operated as a tool to decide which species should or should not be permitted entry. As in the original, the adapted model produces one of three outcomes for species: (1) they are considered low risk (arguably safe to introduce), (2) they are considered high risk (not safe to introduce) or (3) more information is required. If a large number of questions are unanswered, a score is arrived at where the use of the system produces a recommendation that the species be further assessed (3 above).

Table 3: Galapagos weed risk assessment model using* Hedychium coronarium *as as example.

Q no.	Section	Question	Response
Biogeographic history			
1.01	***Domestication and cultivation***	Species/variety is highly domesticated (weakened by selective breeding).	N
1.02		Has become naturalized where grown.	Y
1.03		Biotypes within the species have been problem weeds.	Y
2.01	***Climate similarity***	Suited to Galapagos climates.	high
2.02		Quality of climate match information.	high
2.03		Native or naturalized across a broad climate range.	y
2.04		Evidence of naturalization/native in tropical volcanic oceanic islands (other than Galapagos)	y
2.05		History of repeated introductions outside its natural range.	y
3.01	***Weed elsewhere***	Evidence of naturalization beyond native range.	y
3.02		Impacts garden/amenity/disturbance sites.	y
3.03		Impacts agricultural/forestry/horticultural sites.	y

3.04		Evidence that it is environmental weed (transformer) in natural areas.	y
3.05		Other species in the same genus are serious invaders elsewhere or are native or naturalized in Galapagos.	y
Undesirable characters			
4.01	***Undesirable attributes***	Spines, thorns, burrs, cutting edges or other features impede or injure people or animals.	n
4.02		Evidence of changes to soil chemistry: e.g. allelopathic, alters pH, fixes nitrogen.	
4.03		Parasitic.	n
4.04		Unpalatable to native or introduced grazing animals present where the plant is likely to invade.	
4.05		Toxic to humans or to native or economically important domesticated animals.	
4.06		Evidence that it is host/vector for recognized pests and pathogens that affect other native or valued species.	
4.07		Causes allergies in humans.	
5.01	***Life form and competition for resources in natural environments***	Evidence that it modifies physical ecosystem processes; e.g. increases fire hazard, alters natural erosion processes, affects soil hydrology.	y
5.02		Is a shade-tolerant plant at some stage of its life cycle.	y
5.03		Tolerates coarse, acidic and nutritionally poor soils.	y
5.04		Climbing or smothering growth habit.	y
5.05		Forms dense thickets, particularly woody perennials.	
5.06		Is a tree, woody perennial shrub, grass or geophyte.	geophyte
Biological and ecological characters			
6.01	***Reproductive mechanisms***	Evidence of biotic factors, not present in Galapagos, that reduce its reproductive capacity in its native habitat.	
6.02		Produces viable seed.	
6.03		Evidence that it is capable of interspecific hybridization.	
6.04		Endemic congeneric species present in Galapagos.	n
6.05		Self-compatible, apomictic.	
6.06		Requires specialist pollinators.	
6.07		Reproduction by vegetative fragmentation other than by apomictic or geophytic mechanisms.	y
6.08		Minimum generative time (years).	1 year
7.01	***Propagule dispersal mechanisms***	Propagules likely to be dispersed unintentionally (plants growing in heavily trafficked areas) e.g. machinery, people.	y
7.02		Propagules frequently dispersed or cultivated intentionally by people.	y
7.03		Propagules likely to disperse as a produce contaminant.	n
7.04		Propagules adapted to wind dispersal.	
7.05		Propagules adapted to water dispersal.	y
7.06		Propagules bird dispersed.	
7.07		Propagules dispersed by other animals (externally).	
7.08		Propagules survive passage through the gut (animals other than birds).	
8.01	***Persistence traits***	Prolific viable seed production (>5 000/m2/year).	
8.02		Propagule bank persistence (years).	
8.03		Easy to find and control at moderate cost with a known and effective method.	Y
8.04		Clearly benefits from mutilation, cultivation or fire (increased vegetative spread).	
8.05		Known natural enemies are present in Galapagos.	

Galapagos invasiveness			
9.01	***Naturalization in Galapagos***	Viable seed production.	
9.02		Evidence of seedlings produced without human assistance.	y
9.03		Evidence of two or more generations of adult plants.	y
9.04		Invasiveness - Evidence of long-distance propagule dispersal and establishment.	n
9.05		Invasiveness - Evidence of establishment in disturbed areas.	y
9.06		Invasiveness - Evidence of establishment in undisturbed areas (natural ecosystems).	n
9.07		Invasiveness - Current status.	Imminent transformer
9.08	***Distribution in Galapagos***	Already growing wild in the National Park in the arid zone.	n
9.09		Already growing wild in the National Park in the humid zone.	n
9.10		Already growing on 2 or more islands.	y
9.11		Already growing wild on uninhabited islands.	n
Scoring		Total score	30
		Outcome	High risk
		Biogeographic characters	16
		Undesirable characters	4
		Biological and ecological characters	4
		Galapagos invasiveness	6
(Some characters are scored in both sectors)		Agricultural	20
		Environmental	20

Adapted from Pheloung, Williams and Halloy (1999). To be published.
Scores usually 1 for traits contributing to weediness; some have been given extra weight if important.

The threshold for scores that produce the three outcomes is determined by running a large number of species through the model and comparing the score with expert opinions and the known behaviour of species in Galapagos. The thresholds for the different outcomes have not yet been recalculated for the Galapagos WRA. Thus, the model can help users to make decisions about the relative safety of importation of species or whether a species will become a problem. (However, it may also arrive in Galapagos accidentally or be smuggled in illegally.)

The user responds to a series of questions; the original had 49 questions and the new one has 58. Sixteen of these relate to species behaviour in Galapagos. A number of questions in the original were not considered relevant as they focused overly on themes unrelated to protection of biodiversity, or led to double dipping on scores (the same or a similar issue considered twice). The benefit of the model is that even where information about a species is incomplete, the answered questions can lead one to a score that allows a recommendation to be made as to the risk of its becoming a weed.

The inclusion of a series of questions about species behaviour in Galapagos is the main obvious change to the model. This means that the model can be used to produce a classification of invasiveness, or separate lists, for example a list of species that are considered highly invasive elsewhere but have not yet shown that potential in Galapagos, or species that are highly invasive in Galapagos and are not known invaders elsewhere. In addition, scores of the relative level of invasiveness displayed in Galapagos can be derived.

Therefore, the model should have the same level of functionality as the WRA for Australia, but some added uses that relate to the prioritization of species for management and classification of species.

Measures for invertebrate species

The growing volume and frequency of imported agricultural products from mainland Ecuador to Galapagos significantly increase the risk of introduction of alien species, in particular, invertebrates associated with the commodities. In 2002, the CDF analysed each agricultural product legally imported to the Galapagos according to which invertebrate pests are commonly associated with the product. A list of more than 500 potential quarantine pests was assembled. Using a simple scoring model, these pests were tested for their potential risk of introduction (see table 4). These species were selected by comparing a list of species already present in the Galapagos with species lists from the Andean region and with lists of known tramp and invasive species. Emphasis was put on three criteria: (1) probability of introduction, (2) probability of establishment and (3) potential impact of the introduced species. The analysed quarantine invertebrates were classified as high-, medium- and low-risk species. The results of this model are useful in the development of the pest risk assessments to identify products that carry a high risk of introduction of quarantine pests and for monitoring new introductions at ports of entry. Once completed, this information will be used to reassess the current product importation list.

Because no prioritization model for insects exists, the CDF is developing a model based on the Australian WRA system to prioritize the almost 500 already-introduced invertebrates and define their risk of invasiveness. The prioritization model will also be applied to assess the 500-plus quarantine species not yet introduced to Galapagos to determine the suspected pathways by which they may arrive. This is important to identify weaknesses in the inspection and quarantine system as well as to identify which pathways and import goods are high risk. Currently, the CDF is developing the criteria to use in the prioritization methodology and also compiling dossiers on each alien and quarantine species with information that is needed to respond to the criteria. The model will allow identifying future eradication or management projects.

Table 4: Scoring model for potential quarantine invertebrate species.

Scoring		**Probability of introduction**		**Probability of establishment**				**Potential impact**				**Total risk**
		Number of pathways, frequency of importation, volume of product (low-median-high)	Probability of detection by inspectors	Host range	Distribution range (area/country)	Presence of same genus in Glps; official control programme; pest is in priority list	Distribution potential; fecundity, no. of generations, dispersal capacity (low-median-high), life cycle, phoresis	Impact on agriculture (yield, affected crops)	Impact on biodiversity (endemic or native species of importance)	Impact on public and animal health	Control feasibility	
Low	**1**	1 pathway, low volume, low frequency	High; big size and/or obvious damage	1 genus or 1 species	Present in Ecuador	Nothing of above	Low reproduction, high mortality, 2 generation, does not fly	Yield little affected, minimal control costs	Minimal impact on endemic species	No effect on humans	High	1-10
Median	**3**	2-3 pathways, low volume, low frequency	Median; small size and/or damage difficult to detect	1 family	Present in Andean countries	One or two of above	k-Strategist: low reproduction, high survival rate, flies	Yield reduced, quality reduced, increased production costs	Attacks endemic plants and animals	Nuisance pest and vector of not lethal disease	Median	11-30
High	**6**	>3 pathways high volume, high frequency hitchhiker	Low; small size and/or invisible damage	> 1 family	Cosmopolitan	All of above	r-Strategist: high reproduction, low survival; phoresis, multiple generations, strong fliers	Attacks various crops and is important vector; requires continuous control	Direct impact on endemic species	Vector of lethal disease	Low	31-60

The Galapagos Islands constitute the world's last nearly intact ecosystem, allowing the study of the evolutionary and ecological processes that exist before invasive species are added to the species mix. Nevertheless, despite the fact that almost 97 percent of the Galapagos land area is protected by law as Galapagos National Park, the impression that terrestrial habitats are well protected is misleading (Snell *et al.*, 2002) The assumption that the current rate of species extinctions in Galapagos is relatively low compared with other oceanic archipelagos or continental countries is not correct. When compared with other countries and island groups, Galapagos scores relatively highly for species extinction within the period of recorded biological history over the past 400 years (Snell *et al.*, 2002). Invasive species are the biggest single threat to endemic flora and fauna of the archipelago. Preservation of the unique biodiversity found in the Galapagos Islands depends on the efficacy of the inspection and quarantine system, SICGAL. The development, implementation and efficient use of an appropriate pest risk assessment model to analyse the threat of quarantine pests and already introduced species is essential for the future protection of the Galapagos Islands.

References

Bensted-Smith, R., Powell, G. & Dinerstein, E. 2002. Planning for the ecoregion. *In* R. Bensted-Smith, ed. *A biodiversity vision for the Galapagos Islands*, pp. 1-5. Charles Darwin Foundation and World Wildlife Fund. Puerto Ayora, Galapagos, Ecuador, CDF (available at www.darwinfoundation.org). 147 pp.

Causton, C. 2004 (subm.). Alien insects: Threats and implications for the conservation of the Galápagos Islands. Submitted to *Annals of the Entomological Society of America*.

Charles Darwin Foundation and WWF. 2002. *A biodiversity vision for the Galapagos Islands*. R. Bensted-Smith, ed. Puerto Ayora, Galapagos, Ecuador, CDF (available at www.darwinfoundation.org). 147 pp.

Peck, S. B. 2001. *Smaller orders of insects of the Galápagos islands, Ecuador: Evolution, ecology and diversity*. Ottawa, Canada, National Research Council Canada, NRC Research Press. 278 pp.

Peck, S., Heraty, J., Landry, B. & Sinclair, B.J. 1998. Introduced insect fauna of an oceanic archipelago: the Galápagos islands, Ecuador. *American Entomologist*, 44: 218-237.

Pheloung, P.C., Williams, P.A. & Halloy, S.R. 1999. A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. *Journal of Environmental Management*, 57: 239-251.

Snell, H.L., Powell, G., Tye, A., Bensted-Smith, R., Bustamante, R.H. & Branch, G.M. 2002. Approach to projecting the future of Galapagos biodiversity. *In* R. Bensted-Smith, ed. *A biodiversity vision for the Galapagos Islands*, pp. 6-11. Charles Darwin Foundation and World Wildlife Fund. Puerto Ayora, Galapagos, Ecuador, CDF (available at www.darwinfoundation.org). 147 pp.

Tye, A., Snell, H.L. Peck, S.B. & Adserson, H. 2002. Outstanding terrestrial features of the Galapagos archipelago. *In* R. Bensted-Smith, ed. *A biodiversity vision for the Galapagos Islands*, pp. 12-23. Charles Darwin Foundation and World Wildlife Fund. Puerto Ayora, Galapagos, Ecuador, CDF (available at www.darwinfoundation.org). 147 pp.

