IUCN AsESG Wild Elephant and Elephant Habitat Management Task Force

EXTENT AND DISTRIBUTION OF SOME INVASIVE PLANT SPECIES IN ASIAN ELEPHANT HABITATS

Report from preliminary online survey

Summarized by
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SSC
Species Survival Commission

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Abstract

Although it has been recognized that invasive plants pose a threat to native flora and fauna, invasive plants are very poorly documented in tropical Asia. Results from a preliminary survey which covered respondents working in nine countries having Asian elephants indicate that invasive plants are ubiquitous and, one or the invasive plant species has begun to dominate the vegetation in most Asian elephant habitats. Findings from this preliminary survey suggests that quantitative assessment of invasive plants in Asian elephant habitat should be taken up without further delay to assess impacts of invasive plants on Asian elephants and also to help forest managers deal with invasive plants in a scientific manner.

Introduction

Invasive plant species is a term applied to non-native plant species which have colonized natural areas and dominate the vegetation composition of the colonized areas. Invasive plants have been shown to adversely impact native biodiversity and ecosystem processes in complex ways (Colautti and MacIsaac 2004). Invasive plant species alter native plant and animal populations, communities and can even modify nutrient cycling within invaded environments (Didham et al.2005, Strayer et al. 2006, Didham et al. 2007). However, there have been very few studies that have focused on invasive plants in tropical Asia. There is no systematic assessment of the extent of invasive cover within protected areas, the susceptibility of different habitats to invasion or the threats posed by invasive plants to native flora and fauna. In some protected areas of tropical Asia where invasives dominate vast landscapes, forest managers have had to device measures to deal with them. however, given the paucity of information on invasives and their scientific management in this region, managers have generally resorted to eradicate invasive plants using brute-force techniques and their efforts have often been counter-productive.

Observations by some Asian elephant biologists about the potential threats posed by invasive plants to Asian elephants prompted us to carry out this preliminary survey to document the extent of invasive plants across Asian elephant habitat. Invasive plants could potentially reduce the quantity of forage available to Asian elephants, and this could lead to increased levels of human-elephant conflict. An additional concern is that Asian elephants could themselves be dispersing many of these invasive plants in their habitats. However, such threats need to be assessed systematically and the first step towards this is to ascertain the extent of the problem across the present-day range of the Asian elephant. Since there was very little literature available documenting invasives at different sites harboring Asian elephant populations, we proceeded to carry out an online survey to understand the extent of the problem in-order to gauge the extent of the problem.

Fig. 1. Asian elephant in tropical dry forests of Mudumalai, invaded by *Lantana camara* and *Chromolaena odorata*

Fig. 1. Asian elephant in tropical dry forests of Mudumalai, invaded by *Lantana camara* and *Chromolaena odorata*

Methods

We used a free online survey (survey monkey) and the survey focused on some common invasives in Asian landscapes. We aimed to keep this prelimnary survey simple and exploratory in nature. Since there is little quantitative information on density or cover of invasives in protected areas of this region, we choose to use relative qualitative terms (extensive, common etc) for this prelimnary survey. Each respondent was asked to provide contact information, location of their study sites and address the following questions:

a. Common invasives in Asian elephant habitat: Based on our combined field experience and some initial discussions with scientists working on both Asian elephants and invasive plants in this region, we shortlisted 7 invasive plants species for the preliminary online survey. For these 7 invasive plants, respondents were asked to note the extent / cover within their study sites on an ordinal scale (Not present, Rare, Common, Very Common, Extensive). The invasive plants included for this question were:

Lantana camara, Chromolaena odorata, Mikania micrantha, Prosopis juliflora, Parthenium h*ysterophorus, Ageratum conyzoides and Eichhornia crassipes*

b. Any other invasives in Asian elephant habitat? We also asked the respondents to mention any other invasives plants that they were aware of within Asian elephant habitats at their sites.

c. Has there been any research on invasive species at your site? Respondents were also asked to provide details of any research on invasives at their sites and email published literature or unpublished repors to WEEHMTF@gmail.com

d. Any other comments / suggestions: We also received several inputs to improve the survey. Some respondents also expressed their concerns about the impact of invasives on Asian elephants.
Respondents who had information on more than one location, were asked to fill up separate forms for each location.

Fig. 2. Invasive plants considered for the online survey: Clock-wise from top left: *Lantana camara* (with a Oriental white-eye feeding on its fruits); *Chromolaena odorata; Mikania micrantha, Ageratum conyzoides, Eichhornia crassipes Prosopis juliflora, and Parthenium hysterophorus*

Results

There were a total of 39 responses, with some respondents reporting for more than one location. Locations were grouped into 18 regions based on a visual examination of connectivity and proximity in forest cover maps for these areas. Some regions like the Nilgiris-Eastern Ghats complex (India), Terai Arc landscape (India-Nepal and southern Srilanka had more than 3 respondents each, and locations within these regions were fairly well-represented in the survey. Other Asian elephant habitats such as north-east India (respondents covered only one location), Myanmar (a single respondent), Malaysia (only one respondent from Peninsular Malaysia), Thailand (only two sites represented) were inadequately represented. There were no respondents from some countries with Asian elephant populations such as Vietnam, Cambodia and also for the Sabah region (Malaysia). Table 1 presents the number of respondents from each region.

Every site and region covered by this survey (Fig. 3) reported at least one of the 7 invasives queried in the survey (*Lantana camara, Chromolaena odorata, Mikania micrantha, Prosopis juliflora, Parthenium hysterophorus, Ageratum conyzoides and Eichhornia crassipes*). Over 60% of the Asian elephant habitat covered in this survey (11 out of the 18 regions) documented one or the other of these 7 invasive plants to be extensive or very common at their sites. Most of the areas that did not have an extensive cover of these 7 invasive plant species, reported that other invasive plants such as *Mimosa spp*., *Clidemia hirta, Meremia peltata, Acacia* species or bamboo species were extensive at their sites (30% of the surveyed regions, i.e., 5 out of 18 sites). Just two out of the 18 surveyed regions did not report any invasive to be dominant in Asian elephant habitat at their sites. These results indicate that invasive plants are found everywhere and, one or the invasive plant species has begun to dominate the vegetation in most Asian elephant habitats.

Lantana camara appears to be the most common invasive in Asian elephant habitat (Fig. 4) and was reported from almost all the sites, and for 17 of the 18 regions (the only exception was Tessa Nilo, Riau, Indonesia). *Chromolaena odorata, Parthenium hysterophorus* and *Ageratum conyzoides* were also reported from c.75% of the surveyed regions. Among the surveyed invasive plants, *Lantana, Chromolaena, Mikania* and *Eichornnia* appear to be the most dominant invasive plants in Asian elephant habitats, being classified as “Extensive” or “Very common” in 38%, 33%, 28% and 22% of the 18 surveyed regions respectively.

Table 1. Asian elephant habitats covered by respondents to the online survey

	Region	# of respondents
1	Assam, North-east India	2
2	Chittagong Hills, South-east Bangladesh	1
3	Maymenshing, Central Bangladesh	1
4	Perak, Peninsular Malaysia	1
5	Kachin, Northern Myanmar	1
6	North Bengal, North India	2
7	Nilgiris - Eastern Ghats, Southern India	10
8	North-Central Srilanka	1
9	Orissa, Eastern India	1
10	Southern Srilanka	3
11	Southern Western Ghats, India	2
12	Southern China	1
13	Aceh, Northern Sumatra	1
14	Lampung, Southern Sumatra	2
15	Riau, Central Sumatra	1
16	Terai-Arc Landscape, India-Nepal	4
17	Kui Buri, Southern Thailand	2
18	Salakpra, West Thailand	2

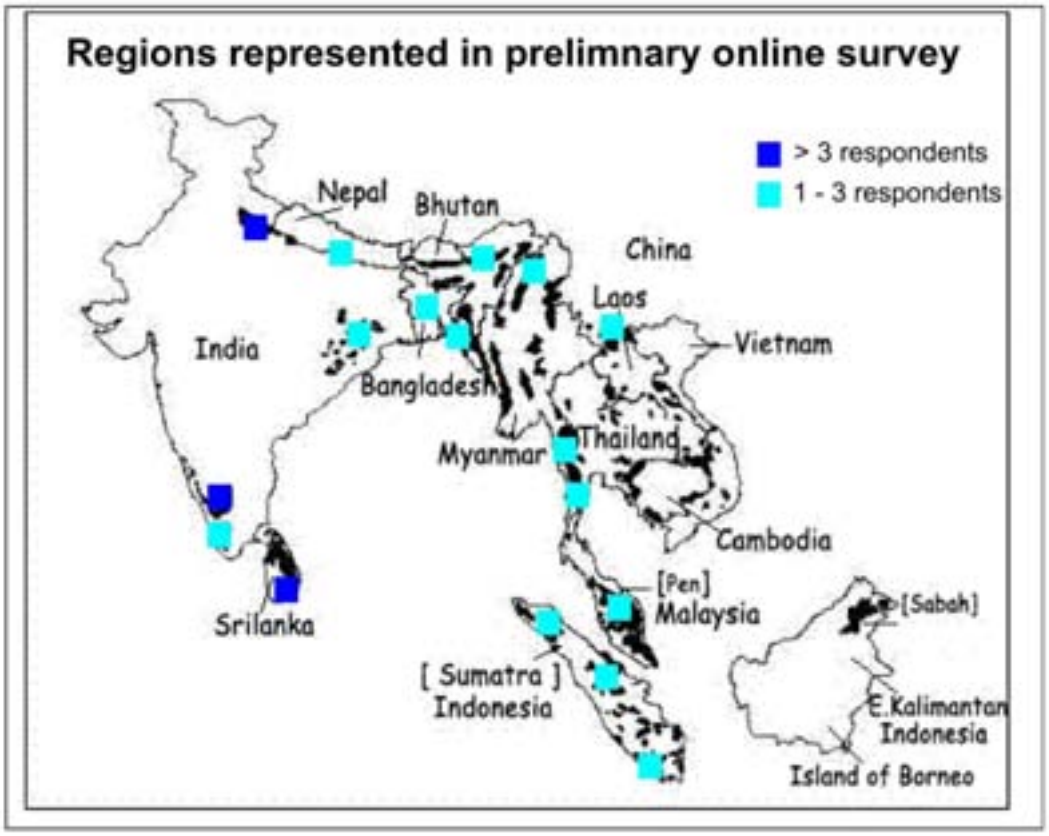


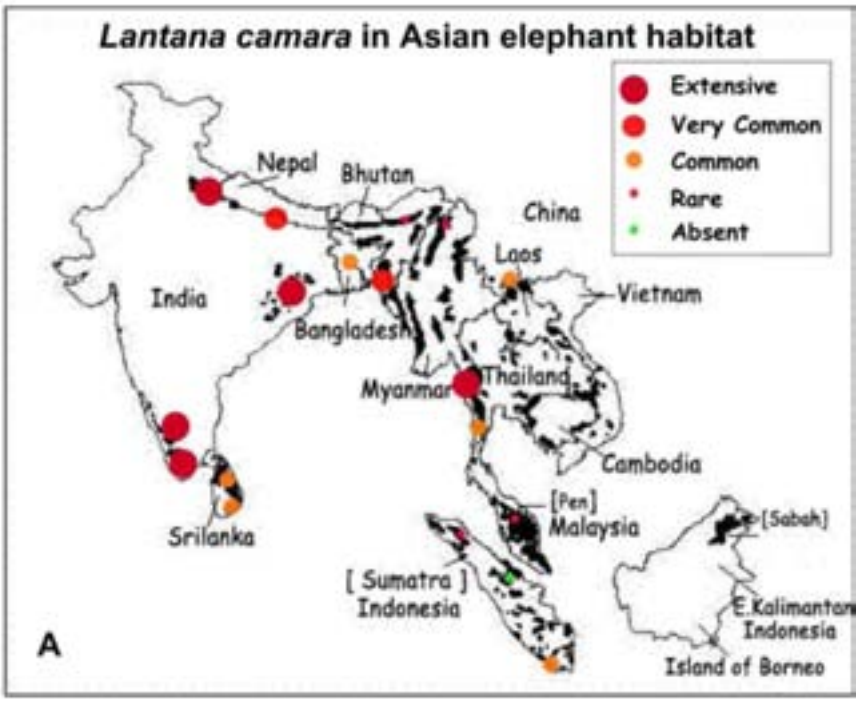
Fig. 3. Regions represented in preliminary online survey to examine the extent of invasive plants in Asian elephant habitat

While most respondents expressed that invasive plants were a threat to Asian elephants, some respondents reported some invasive plants found at their sites such as *Prosopis* (in southern coastal Srilanka), bamboo (in Minneriya and Kaudulla National Parks, North Central Srilanka) and grass species (Kui Buri National Park, Thailand) were part of the diet of Asian elephants.

Respondents also indicated that invasive plants were habitat-specific – for example,

Eichhornia crassipes is found in fresh water ponds and lakes, *Prosopis juliflora* is common in arid regions with high soil salinity.

Eight of the eighteen regions represented in the survey reported that there had been research on invasive plants at their sites. However, none of these research projects had resulted in peer-reviewed publications, and the project reports were not easily accessible (except in two cases where the reports were available on the web: www.wildlifetrustofindia.org; www.kfri.org)



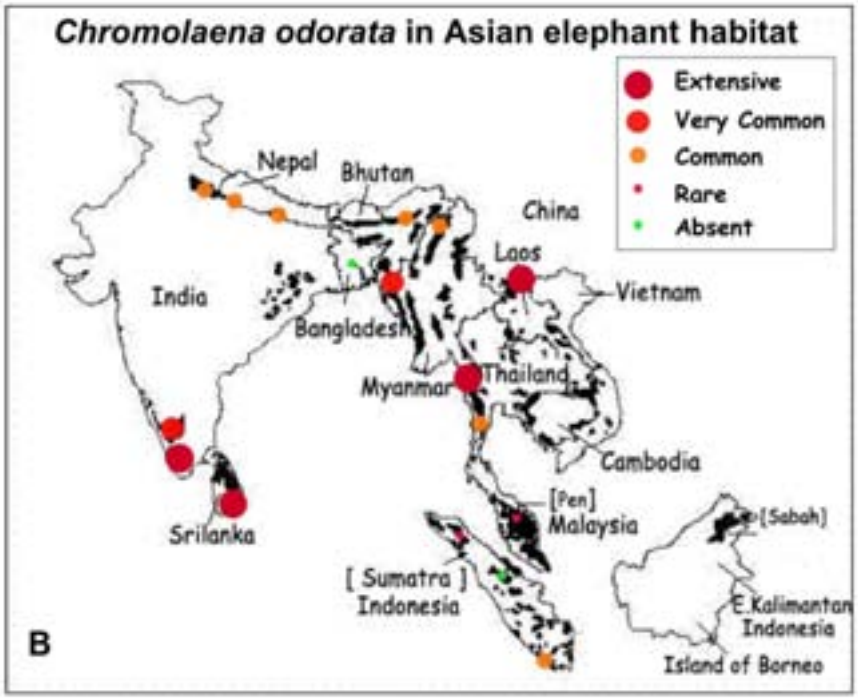
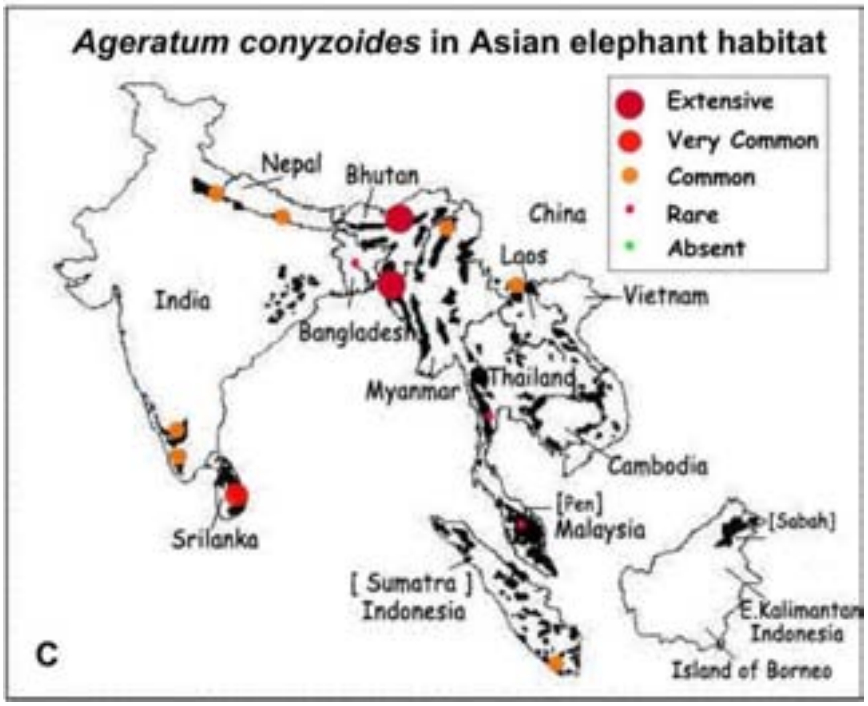


Fig. 4 (A, B) Extent of two common invasive plants (*Lantana camara*, *Chromolaenaodorata*) in Asian elephant habitat indicated by prelimnary online survey



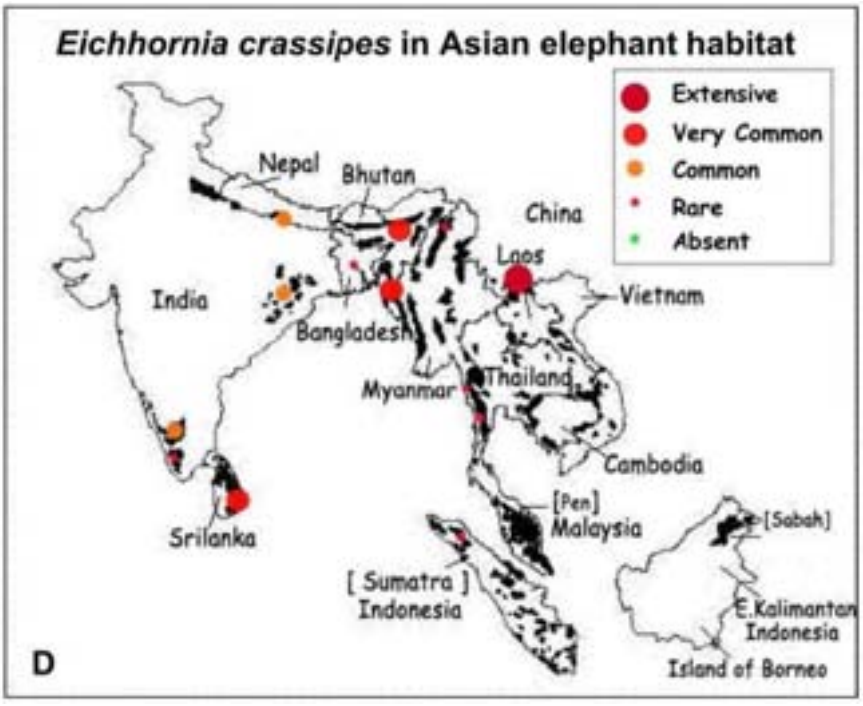


Fig. 4 (C, D) Extent of two common invasive plants (*Ageratum conyzoides, Eichhornia crassipes*) in Asian elephant habitat indicated by preliminary online survey

Suggestions for future research and management actions:

During this survey and also during interactions with both Asian elephant biologists, forest managers and ecologists working on invasive species we identified the following questions / lacunae which need to be addressed immediately:

1. *How extensive are invasive plants in Asian elephant habitat?*
The qualitative survey indicates that invasive plants have begun to dominate Asian elephant habitat at most sites. As indicated by several respondents, we need to adopt a more quantitative approach to mapping invasive plants within key Asian elephant habitats without further delay. Firstly, we need to inventory plants with select Asian elephant habitats (identified based on their conservation value and the degree of involvement of forestry departments in scientific management practices). Using a grid-based approach combined with remote-sensing data, select invasive plants for mapping at these sites and carry out mapping in collaboration with forestry departments and local botanists. Tools and approaches developed by the US Fish and Wildlife Service <http://www.fws.gov/invasives/staffTrainingModule/assessing/inventory.html> and other agencies such as the Global Invasive Species Program http://www.gisp.org/ecology/strategies.asp. The presence and relative densities of different invasive plants in different habitats within protected areas and also regions surrounding protected areas need to be mapped. Areas outside of protected and managed forests need to be considered both because elephants frequently move out of protected areas and also because invasives often move in from the matrix surrounding protected areas.

2. *Does presence of invasive plants lead to increased levels of human-elephant conflict?*
Invasive plants might differ in the extent to which they modify Asian elephant habitat use. Identifying invasive species that can significantly alter habitat use by Asian elephants can help target invasive species that need to be prioritized for management. To address these questions we need to develop research projects adopting comparative approaches – to examine differences in between invaded areas and areas free of invasive plants w.r.t. to forage availability and levels of human elephant conflict; and also, examining regions with different degrees of human-elephant conflict to understand the extent to which plant invasive species can explain the variation in human-elephant conflict.

3. *How do we manage invasive plants in Asian elephant habitat?*
Invasive plants have become the focus of scientific management in developed countries such as the United States of America and Australia. Research and management protocols from these regions have shown that:

A. Examining stages of invasion: *Can all invasive plants be effectively eradicated from our landscapes?*

Plant invasions (i.e. becoming widespread and locally dominant) typically go through a series of invasion stages. Potential invaders arrive through dispersal (by animals or abiotic vectors), and pass through a series of filters that determine abundance and distribution of non-native species within landscapes. A non-native species may be localized and numerically rare, widespread but rare, localized but dominant or widespread and dominant (Colautti and MacIsaac 2004). It is often easier to device management techniques to eradicate and monitor invasive plants that are localized (either rare or dominant) and occasionally some species that are widespread but rare (Veitch and Clout 2002) . Since, successful eradication is dependent on early detection of nonindigenous species within landscapes, it is critical to identify invasive plants which have the potential to influence Asian elephant habitat-use significantly, and proceed to inventory the Asian elephant distribution range for these invasive plant species so that they can be successfully eliminated from sites where they are still localized or rare. For invasive plants that are widespread and dominant within protected areas and the matrix surrounding protected areas, managers are left with few options. Such widespread and dominant species can only be removed locally by repeated eradication programs from critical wildlife habitats. Attention should also be given to eradicating low density infections within landscapes which could help attenuate further intensification of widespread and dominant invasive plants (van Klinken et al. 2007).

2. Incorporating seed dispersal patterns: *Where do we look for invasives within our landscapes?*

Native frugivores, including Asian elephants and human beings, effectively disperse several non-native plants. Incorporating disperser movement and behavior gives us better abilities to predict where invasive seeds are like to arrive within landscapes. Managers often fail to completely eradicate invasive plant species since they cannot locate low density infections. Strategic approaches such as incorporating patterns of seed dispersal into models that can guide managers allows them to narrow down their searches and thus use available resources more effectively in combating invasives as demonstrated by casestudies in the Austrialan tropical regions (Westcott et al. 2005, Westcott et al. 2008).

3. Monitoring invasive plants in time: *Evaluating management actions*

If resources permit, critical parameters and trends of selected invasive species should be monitored over time and space in order to examine effectiveness of management actions and design better locally-adapted strategies. It is critical to back our management action with strong data for effective management of

invasives in Asian elephant habitat.

APPENDIX I - Conversations

On 16 Aug 2010, at 16:45, Ashok Kumar wrote:

Invasive species are not just a threat to elephants, but to tigers also. One example is Valmiki Tiger reserve in North Bihar on Nepal border, infested with Mikenia and Phoenix. There could be similar issues in Madya Pradesh tiger areas as well.

Why not let Cat specialist group into this dialogue.

Ashok Kumar

On 17 Aug 2010, at 10:46, Li Zhang wrote:

Dear Christy,

Thanks for the great work. I think an official report or publication by the AsESG could help us to engage local government to take actions.

Best,
Aster

On 17 Aug 2010, at 22:56, Ullas Karanth wrote:

My dear Ashok:

Let us please stop these seat of the pant opinions. And clarion calls for "action" on extotics. This is a problem that is complex, BUT, in many cases these EXOTIC species are very helpful to tigers and prey and regeneration of native species in the 20-30 year time frame (but who has the those time scales of observations?). and extracting invasive exotics has become a profitable, multicrore growth industry in some areas for officials.. So Let us reflect a more calmly, and make careful recommendations that are very site specific after due studies and not just launch an official IUCN Jihad on lantana and the suchlike, which is exactly what the growth industry I mentioned above will capitalize on.. Causing huge damage to tigers and prey...I am copying Jhala and Qumar as we have talked about this in relation to Madhya Pradesh/tigers.

Best,
Ullas

On 17 Aug 2010, at 23:40, Ullas Karanth wrote:

And, I would like someone to explain to me how in the 1967-2010 period in NAGARAHOLE during which I observed it, Lantana Camara has been harmful to elephants, large ungulates and tigers. and more importantly, what else could have been done that would have been more beneficial in terms of practical interventions given the available resources?

Ullas

On 17 Aug 2010, at 23:44, A. Christy Williams wrote:

Dear Ullas,

I have great respect for your science with regard to tigers. But, given what I have seen in over 17 years in Mudumalai and Rajaji (and in many other elephant and tiger habitats across Asia) I find your statement " in many cases these EXOTIC species are very helpful to tigers and prey and regeneration of native species in the 20-30 year time frame" a bit of stretch. No right minded ecologist would make that claim without solid proof. The 2005-2007 study in the highly managed tourism zone of Bandipur by Ayesha and Madhu (on which I presume that you are basing your sweeping statement above) does not certainly fit the bill of "solid proof". I can also show you vast stretches in the Terai where not a single blade of grass grows under lantana. I sense in both your emails on this subject that your opposition is due to forest department corruption in these weed eradication schemes rather than a well thought out scientific argument. That extracting exotic invasives could become a multi-core should not become an excuse for inaction and I hope that you will push for "due studies". After all those officials who become crorepatis could also accuse us of running multicrore NGO business on tigers and elephants:)

Best regards
Christy

On 18 Aug 2010, at 05:51, Prithiviraj Fernando wrote:

Dear all,

I think we should take a non-extremist path because in nature nothing is black and white. I agree with Ullas that we need at the least very site specific recommendations and not sweeping statements on eradication of exotics. I also agree with Christy that in specific cases exotics 'seem' to be very bad. I may add that for each site we should also consider the management objectives and what species the 'exotics' may benefit, as well as the impact of removal. I think the cost of removal should also be considered - especially if it means diverting precious conservation funds and resources that could be better used.

In Sri Lanka Lantana seems to be a problem in some areas - especially inside protected areas in that it covers extensive areas which presumably otherwise would have been covered with more palatable species - which is I guess the argument against it in most cases. However Lantana does provide cover for a large number of species and possibly increases? diversity of small mammals and birds. I have observed elephants browsing on Lantana but it does not form part of their regular diet. I have also observed native species regenerating through and shading out Lantana over the course of decades. However whether Lantana is just one stage in succession or becomes stuck in some kind of climax probably depends on climatic and soil conditions as well as human impact from cutting/burning. We need to better understand how these factors interact and the resultant effects if we are to think of eradication or control.

Removal of Lantana seems to be particularly problematic. We have tried manual and mechanical removal at very high cost and disturbance, which is basically unsustainable. I think the only hope for controlling something as wide spread and tenacious as Lantana is biological control which of course has its own dangers, in addition to not being available for Lantana as far as I know.

On the other hand exotics such as Paniccum grass are heavily utilized by elephants and other grazers. In Sri Lanka we have Prosopis that is a more recent invasive. Initially a few male elephants were browsing on the pods and now herds are also increasingly browsing on the pods as well as the plant. With time it will possibly become a major food species of elephants and increase the carrying capacity in some areas.....

Best
Pruthu

On 18 Aug 2010, at 18:07, Belinda Stewart-Cox wrote:

Dear Christy,

Thanks for this a splendidly South Asian exchange! My understanding is that only butterflies are keen on Lantana camera, for example, and that its dominance and spread represents the absence of available food rather than any direct threat. But, as you say, who knows what? At the very least, let's try to study the problem. I have circulated your report and the email exchanges within Thailand to see if anyone has an MSC student interested in doing a study.

All the best,
Belinda

On 18 Aug 2010, at 21:09, Jayantha Jayewardene wrote:

Dear Christy,

Thank you for an excellent Report. Your colleagues and you should be congratulated for highlighting and bringing this well studied aspect of elephant conservation that tends to be neglected, to the forefront. I am following the comments that are being made by some with interest.

Hope Kashmiri and you are well.

Sincerely
Jayantha Jayewardene

On 19 Aug 2010, at 19:22, Heidi Riddle wrote:

Dear Christy and Arnold - thank you for this informative report that has generated some interesting comments.

I support the report being posted as an AsESG document and in light of the earlier comments would like to offer some brief suggestions:

As this report is the result of a preliminary survey only, the title should perhaps read "Extent and distribution of SOME invasive plant species in Asian elephant habitats" as it is not yet a full comprehensive report. Yet these preliminary results could be used to encourage further site specific study, and/or engage local government, as other members have already noted.

Arguably, other plants such as the oil palm could also be considered "invasive planT species in Asian elephant habitats" so another suggestion is to include in this report a short list of definitions specific to the purpose of this survey - i.e. define "invasive plant" in this particular context, clarify why 7 specific plants were chosen for the initial survey, etc. Thank you again for compiling this information.

Heidi

On 24 Aug 2010, at 22:27, Vinod Rishi wrote:

Hi there!

I am in full agreement with Ullas. I am residing at the outskirts of Rajaji National Park for the last three years, and I have continued my link with wildlife, visiting RNP quite often, even after my retirement. I have not found any one giving any reasonable comment on how long does it take an exotic species to become naturalized - lantana is more than a hundred years in India. Also how do we eliminate the chance possibility that the generations of tigers and other wild animals have adapted to the presence of lantana in their habitats. Moreover, India's forests are not primary forests anymore; they are secondary regenerations established as biotic climax cover because of heavy human interference. Tigers do make use of lantana cover for various purposes. In Rajai, removal of lantana has reduced the jungle fowl and peafowl populations. There are enough evidences on the ground in RNP to indicate that removal of lantana has adversely affected the wildlife community structure in the NP. We need more intensive study before the reported conclusions deserve to be accepted.

Vinod Rishi

On 25 Aug 2010, at 04:39, Peter Stroud wrote:

May I add that in Australia, lantana is also a great problem on parts of the east coast. Removal is handled carefully, when it is possible, because the sudden absence of cover has proven disastrous for some small birds and mammals. A sequential approach is taken.

Peter Stroud

On 25 Aug 2010, at 12:26, sushant wrote:

Dear Christy,

I have gone through your document on the invasive plant species and also have read several opinions expressed in for and against controlling /lantana/. The fact remains that the invasive species has impacted the natural community structure and processes. However, the pathways or mechanism are still poorly understood; this indisputably requires several experimental research and scientific discussions. The ecological and economic debate whether /lantana /is good for few species and bad to other is a complicated issue and no one has intensive hard information to substantiate that. Therefore, arguing and counter-arguing this will not lead us anywhere with current state of knowledge.

I think we all will agree that lantana invasion has gone higher to such sites where disturbance regime are high and forest naturalness has gone down. In such habitat fires are frequent, /lantana /provides good fuel for this and in turn perpetuate more vigorously. The process over the years, change subsoil moisture and impacts regeneration of forest communities. The intensive spread of lantana may favor certain species but that is not the kind of forest naturalness we expect due to natural regeneration failures.
I think the thoughts steered by this initiative should continue and discuss the issue so that more researches on this aspect should come up. I appreciate the efforts taken by you,

Best wishes,
Sushant Chowdhury, WII, Dehradun

On 25 Aug 2010, at 15:35, Arun Venkataraman wrote:

Dear Christy and AESG Task Force Members

I thank this task-force for coming up with this vital report which though preliminary in nature, provides useful directions forward in addressing an issue of immense conservation concern.

To begin with a slightly personal note, I've spent many days crawling through Lantana thicket in the Moyar and Sigur areas in the Niligiris, have been quite impressed by the significant predator and prey assemblages within (along with other species such as sloth bear and thriving communities of frugivorous birds) and ended up with acute dermatitis that nearly put my field career to an abrupt end!

However I cannot resist pointing out that this report focusses on the impact of invasive species on elephant habitat and therefore initially confine myself to this species.

1. If we all agree that invasive species proliferation impedes graze growth (and more studies are certainly needed here) we do have a fairly sound case where we can expect a escalation of HEC due to paucity of graze species and shifts in home-ranges to maximize foraging efficiency, deleterious demographic consequences such as reduction in birth rates through reduced fecundity, infant mortality and higher mortality of breeding individuals and increased competition with other large herbivores.

We do have some unpublished data to show that HEC frequencies correlate with increased habitat alteration of swampy grassland. A similar argument can be used to show that swampy grasslands covered with invasive species will result in reduced accessibility to graze and hence increased HEC. In the Wyanad Sanctuary, I have seen the results of weed-eradication in swamps: weed-infested areas rapidly transformed to those with near natural herbaceous vegetation. Unfortunately I could not determine the extent of this exercise or its efficacy in reducing conflict. But I certainly did think that this went beyond a mindless, money spinning growth industry with potential to achieve a few strategic objectives if it was ever expanded and monitored. With some further elaboration Suggestion Number 3 in the report is highly relevant and should be acted upon on a priority basis.

2. I would also like to question the ethics of being satisfied with higher carnivore numbers simply through the proliferation of exotics at the cost of other fauna, flora and indeed

overall biodiversity. Reading between the lines here, I suspect that the sympathy for exotics in carnivore habitats is their role in the succession of native species. I'd be happy if anyone could point us to references that refer to this.

3. And what about carnivore-human conflict especially in scrubby, weed-infested areas surrounding settlements. My anecdotal sense tells me that much sloth-bear and leopard (and even elephant) attacks on human beings do occur in these areas. In the interests of promoting more harmony between wildlife and humans, is this something we want to promote?

4. I often wonder about the disruption of prey assemblages by invasive species infesting forage grounds and its consequences on predation patterns. I have personally seen large herds of chital disappear over time in areas where Lantana extraction ceased, leading to decreased visitation by dhole packs. Could this also impact foraging by leopards and tigers who frequent known prey assemblages.
Just a few thoughts on a very relevant debate.

Best
Arun

On 25 Aug 2010, at 16:36, avenkataraman@wwf.org.my wrote:

Dear Rishiji

I had sent a note on this matter a while ago but then noticed your very valid point that Lantana has been around for 100 years now and perhaps wildlife has adapted to it. While this may be true we could still ask whether Lantana proliferation has crossed a tipping point due to a deterioration of forest (and fire management) techniques and increased anthropogenic impacts, making the present levels of invasion quite unsustainable for wildlife.

Best wishes
Arun

On 26 Aug 2010, at 18:28, Dr. A.J.T Johnsingh wrote:

Dear All,

Just returned from Bandipur TR where one exotic (Cassia spectabilis, an ornamental tree produces bunch of golden yellow flowers) is rapidly spreading from the Bandipur campus (where 500-600 chital yard at night from April to September). Already it has spread for a kilometer around the campus. Any one can easily identify the species: does not grow into a huge tree, produces bunch of golden yellow flowers at the tip of the branches and the pinnate leaves have pointed tips, see the picture attached). If you have this in your protected area please eradicate it immediately. If not present please don't allow people to bring the species into your protected area for ornamental purposes.

In Bandipur the disperal of this species is possibly through the pigs/civets which may disperse the seeds. It is able to spread because it is not eaten by any ungulate including the versatile sambar. I took the Field Director (Mr. Hosmath) and Deputy Director (Mr. Hanumanthappa) of the Reserve around and both are convinced that this is a menace

which needs to be urgently addressed.

Most of Indian protected areas are plagued with an abundance of unpalatable exotic and native species while regeneration of most of the palatable species is a failure. If any one shows me a large sapling of a Grewia taelifolia, an important forage tree for elephants and other ungulates in Rajaji NP, for example, I would give him/her an award of US$ 100.00 (hundred US dollars)!!!.

Unpalatable species need to be controlled as much as possible. Lantana is a good example. True it offers cover to tigers and jungle fowls but the same function can be effectively done by the various bamboo species as they did before lantana was introduced. Another species that needs to be controlled is Prosopis juliflora. The forests east of Mudumalai WLS is home to blackbuck and tiger and is throttled by P. juliflora which is an aggressive, alien invasive.

Species that need to be totally eradicated are Opuntia dillenii (huge problem in three ranges in the lower Nilgiris) and Cassia spectabilis. I can give many more examples.
Eradication and control is difficult and expensive but should be done. At the same time wildlife managers should revive their nurseries (a forgotten art) and start growing thousands and thousands of palatable species and plant them in the cover of bushes like lantana at the onset of the rainy season. Some of our forests presently may have a high density of ungulates and tigers but if we don't address the problem of noxious plants and lack of regeneration of palatable species ungulate abundance will eventually decline followed by that of the predators. Honestly many of our forests are dying due to the abundance of non-palatable species and lack of regeneration. If we see ungulates nibbling lantana it is not because they like it but because they don't have much else to eat.
One major reason for the decline of jungle and pea fowl in Rajaji NP is due to snaring...Rajaji is surrounded by a human population extremely fond of meat...many are expert in snaring.

A.J.T. Johnsingh

On 26 Aug 2010, at 22:30, Dr. A.J.T Johnsingh wrote:

One has to watch the areas where from lantana has been eradicated by the above method. Studies in BRT WLS, Karnataka by ATREE, clearly show that lantana can come up again from the seeds that lie dormant in the soil. These seedlings have to be continuously removed and the area needs to be planted with desired species. In Mudumalai WLS, near Game Hut, the location where from lantana was removed has been densely planted with tall grass and it looks like lantana is not coming back.
We are aware of the corruption but we have to find ways to overcome this problem and try and reduce the problem of unpalatable species in our wildlife landscapes as much as possible.

A.J.T. Johnsingh

On 26 Aug 2010, at 22:19, Ajay A Desai wrote:

Dear All,

Thanks to the habitat task force we have some idea of how people connected with

elephant conservation view invasive species. There are differing vies but by and large we seem to see it as a problem. I think most would actually agree to this view if we see things in a neutral way and also stick to the basic line of discussion and what it is we are talking about. We often get side tracked into looking at other issues and then making statements that do not reflect on the invasive plant or its role but rather a secondary issues which in reality does not help us decide if the impact of the invasive is good or bad but rather if we should or can act on the decision or not.

ThatI think is the wrong approach - In south India we have lost most of the tuskers to poaching sex ratios are heavily biased in favor of females. We unfortunately have not been able to curtail poaching to a level where we would have had better sex ratios. In India we have lost the tiger in most of its former range and even in the highly funded and high profile Tiger Reserve we have lost tigers and in fact they have become extinct in a couple of Tiger Reserves. Does it then mean that poaching is something we cannot manage? and should be then say forget it the money would be better spent in trying to save a hundred other species? I think most of you know the answer - while assessing the impact we need focus on deciding the nature of impact and the scale of impact. Once that decision is made we then need to start thinking about how to deal with it if it is a serious problem - we may or may not be able to solve it quickly or not at all, we may decide to put it on hold or we may work at it slowly. But if the impact is deemed negative to conservation (to the natural system) at no time should we ignore it and certainly not justify it. It has to remain a problem that needs attention.

Looking at all the discussions I think the importance of the subject is clearly highlighted by those considering it a serious problem and those claiming. I discuss about Lantana as people refer to it most often. There are other contenders in the fray and I am not ignoring them but rather trying to clear the air with lantana as an example.

With invasive species we need to specify what we are talking about in the first place as Heidi pointed out. I think the objective of the Habitat Task Force in this case was to look at those invasive that are becoming or are being perceived as becoming harmful to elephant conservation. It would also reflect well on us if we look at the issue in the context of what it is we are talking about rather than going off on a tangent. Let us therefore not talk about natural dispersals (other than man induced) or of species that are apparently not harmful or beneficial (appear to be, that is). Let us also keep off issue like naturalization as that is not the issue. We are talking about the adverse (if any) effects of an exotic species that was brought in by man and what we need to do about it.

Is lantana a good forage species for herbivores? We have all seen lantana being browsed on by a range of species starting from elephants to deer to langur at some point in time. However anyone who has studied foraging behavior and who knows how to quantify diet will know that occasional feeding generally goes into a mixed category that constitutes a minor 5% or less of the overall diet and is composed of several species which individually and collectively contribute negligibly to the diet (in terms of quantity). Despite several studies on herbivores in the last couple of decades I have yet to hear of any large herbivore which feeds on lantana as a significant part of its diet. So let's stop mentioning lantana as a food species.

Lantana is also claimed to facilitate regeneration of native species. There are two issues here, first trees are not the only native species that need to regenerate. Grass, herbs and woody shrubs are all essential to the plant community and these are by and large absent

in dense lantana. Lantana eliminates grass and herbs which are a major source of food for mammalian herbivores. While the remaining natural habitat in the PA may support the herbivore populations this is not an ideal situation where 20 - 50% of the areas has been taken over by an exotic. Second we need to remember that natural vegetation was regenerating perfectly well before the arrival of lantana. Most of our forests are far older (I have seen trees 200 - 300 years old in the forest) than the 30 - 40 years most people see forests in their working lives. These to me, show regeneration of the past without lantana! Forests do not exist because of lantana. If however we argue that certain other problems do not allow natural vegetation to regenerate without lantana then we are basically trying to solve one problem by using another problem. The question we then need to ask ourselves 'is the cure more harmful than the disease?' and also will be saddled with two problems instead of one? Why are we not solving the original problem? Mind you theirony is that some people who don't mind lantana actually shy away from idea of using a biological control for lantana because they feel it is an exotic and may have adverse impact on the native vegetation! Basic information on lantana suggests that it actually suppresses regeneration. For example management action taken to facilitate regeneration in Lantana areas is by way of making small opening around the native sapling to allow it to access light implying that dense lantana cover is harmful. All that we are doing is using lantana as a fence to stop herbivore browsing and nothing more. 'The intensive spread of lantana may favor certain species but that is not the kind of forest naturalness we expect due to natural regeneration failures' as Sushant puts it correctly, we need to think about what it is that we are struggling to conserve?

Some consider lantana beneficial for tiger and prey conservation, we forget the purpose of conservation is to save biodiversity. Lantana and the changes it brings have no real role in this. Arun calls into question the ethics of conservation that focuses on a few species at the cost of other biodiversity.

Do tigers require lantana cover for survival? Tigers were there before lantana; a recent study WWF India in the Nilgiris shows that tiger densities in the open dry thorn forest habitat (with very little lantana) has tiger densities that are on par with Nagerhole or Mudumalai. So how important is cover really or rather what do we really understand what constitutes for tigers? The reality is that tiger is a habitat generalist and does not require dense cover at every 1 meter intervals to survive. People also talk of cover for other species, reality is that these species have existed in their native habitats prior to lantana so where is the need for extra cover? or extra food or whatever. Are we again saying that cover has declined due to some other problem? And as we are unable to manage that problem so we solve it by living with another problem. The required natural cover is available for all species in every natural habitat types that they naturally occur in.

Does lantana facilitate increases in the population size of some species and also increase biodiversity? Any disruption will benefit some species and harm others. Some populations will increase while others will decline. But our objective is not that, but to let natural communities persist in a natural system (as natural as possible). By creating grasslands or dense forests we can bring about these changes that benefit some and harm some species. But is that what we want? I do not think biodiversity or its conservation is about bring in exotics and then facilitating increases in numbers of certain species by changing the natural system. We might as well start planning coconut tree and the like to really bring about significant changes.

In the near past we were crying foul about Forest Department raising exotic plantations in

the 70's and 80's. People seem to forget that. We are also totally against the introduction of exotic animals. I recently met someone who made a huge issue about the release of an exotic snake and explained in great detail how he and the others tried to search and find it, He cursed the department for releasing the snake without thinking. Later, he went on to tell me that lantana was not such a big issue as many species of herbivores browse on it! We seem to have great tolerance for invasive plants but not to invasive animals.

We need to get our act together and decide if accidental introductions are good news or bad - do we actually want them? For example, to my knowledge there is not a single invasive (accidentally introduced by man) species in the Indian sub-continent that has been managed (let alone eradicated). It seems to suggest that all invasive species have been beneficial or we just stand and watch or ignore them. I think that the later is true. We have numerous reasons for not doing anything. Corruption is one of the problems "apparently" - as Ashok Kumar rightly points out that is not an excuse for not doing anything as it is going to be there as a problem irrespective of lantana. So are we going to sit back and watch the 2nd problem (Lantana) grow because we do not want to solve the 1st problem (corruption). So are we ignoring lantana because it is good or because of corruption?

The most important suggestion is about making a study about the issue and about the means to resolve it if needed. We have scanty information so we need to work towards resolving that. And I think that the task force has made the right move by initiating a general assessment of weeds (invasive). It appears quite a number of people consider it a problem. While it is always good to do a cost-benefit analysis such things are generally never done for any management actions. It seems to be a special requirement for lantana but it would be a good step - especially when one considers the scarce resources available for conservation. Right now we manage without any cost benefit analysis and this needs to change.

Ullas rightly asks about could have been done differently during 1967 to 2010 period to change things for the better and also how lantana has harmed wildlife in that period. Ideally if someone had studied lantana and its impacts we would today have had a fairly nice database on the impact of lantana - good or bad. Actually the question can also be reversed - what good has lantana done in all these years? What is to say the ecosystem would not have been in a far better state without lantana? Is there any study to show that it has benefitted the wildlife and their habitat? Sushant correctly points to a lack of data to get a clear decision either way - but even the scanty details available point to problems. It's not logical to believe that 20+% grazing areas are lost and there is no harm to the grazing communities or the grass community itself. And it certainly is not correct to feel that an invasive on this scale is acceptable. Yes things maybe beyond our current resources but that does not make its presence justifiable - we cannot sit back and say it fine when it is not. We at least need to state that something is wrong and try towards making it right - how that is done will depend on the effort we put in.

I think the time has come to recognize that invasives is not what we need in an already overburdened conservation area network. The idea is not about looking at all the disturbances and changes we have made and then wondering if a few more really matter but rather to recognize that we have made numerous mistakes and its time to undo some. That is the premise of conservation - we have been responsible for making numerous species extinct so we struggle today to save a few. We certainly do not state that the tiger, elephant and rhino are just three more species nothing bad about the world without 3

more species after all are losing species by the dozen. I hope we are all able to give more attention to invasives and start looking at the habitat more seriously - Asia is fast running out of space for large mammals - especially elephants so lets focus a bit more on space and its quality.

Thanks to very one and hoping that you all will continue to take this forward.

Ajay

On 1 Sep 2010, at 18:20, Witt, Arne (CABI-Africa) wrote:

Thanks Christy had a quick at some of the comments made find it worrying that many individuals still claim that lantana and other invasive shrubs have no impact on biodiversity with absolutely no scientific evidence to back up these statements. To that end I have attached two papers which you may want to circulate amongst adversaries interesting to note that in Australia 19 endangered and threatened species are threatened thanks to lantana. In the Galapagos lantana caused the extinction of the native plant Linum cratericola. It should also be noted that because lantana is introduced it has a depauperate insect fauna associated with it no food for native insectivores in fact researchers have found more than 550 phytophagous insects associated with Lantana spp. in Central and North America there are probably less than 20 generalist phytophagous insects associated with this plant in Asia. Although lantana may attract butterflies it is this very species that displaces the native food plants so important for the survival of these pollinators in addition, lantana may actually be reducing pollination in native species by attracting pollinators to it although this has been disputed. Suffice to say that lantana is not something we want in our PA's.

Regarding collaboration what would be good at this stage is if you could identify sites where you are actively working in at this stage we are limited to working in forests but could work in buffer zones or on invasive species which are close to forests but may threaten biodiversity within them in due course. We have to find sites in Vietnam, Cambodia, Philippines, Indonesia and hopefully next year also in India. As a start it would therefore be good if you could provide me with a list of PA's where you are actively working in.

Regards
Arne

On 2 Sep 2010, at 10:27, Geoffrey W. Howard wrote:

Dear Christy et al.,

I am very interested to be part of this discussion and, although I am probably branded amongst the bad guys who promote the control (or, possibly and hopefully, eradication) of invasive plants (and animals in some cases - eg. the House Crow, Corvus splendens, in Eastern Africa) in protected areas and, in fact any area from which they can spread to IBAs, KBAs and other not-always protected areas important for biodiversity. Sorry for the long sentence. CABI Africa and IUCN have been working together for quite some years to draw attention to the threats of alien and invasive species to biodiversity in a range of situations in Eastern, Central and Southern Africa and, as you can see, Arne is assisting

to do the same in some parts of Asia; while we both have interests in South America as well.

The temptation is to say lots - but I would like to mention, having read the attached string of email discussion, that plants like Lantana camara are spreading rapidly in most tropical areas where they are not native - and, lantana, prosopis, parthenium and chromolaena especially, are known for their allelopathic capacities as well as their ability to do serious harm to herbivores (and cause sickness and death in cattle and goats). And the list of threats is endless.

Of late we have been trying to point out that invaded wild areas, especially PAs, can readily become havens for the growth and spread of invasive plants because of the protection provided by PA managers and those who want to leave affected ecosystems untouched. The end result can be serious invasions into nearby (and not-so-nearby) farming and forestry and peri-urban areas where these same species can do even more damage to crops and livestock as well as livelihoods in general.

IUCN is concerned about the increasing prevalence of biological invasions that threaten biodiversity as well as human development - but ears are not always open, especially those of donors, to this perspective. This is why we rely on the Commissions and Specialist Groups of IUCN to assist with the basic information necessary and the local and especially field knowledge to put the necessary pieces together to have some impact. The Invasive Species Specialist Group is a classic case - and is one of the main sources of information for many people interested and involved in this topic. But so are the other SSC Specialist Groups with expertise on small and large animals, plants, etc. So please keep this debate going and let us see if we can reduce the threats. Your AsESG report has already stimulated the AfESG to think about elephant habitat and some assessment of impacts on this continent (we are in the same IUCN campus in Nairobi) and the bird and plant SGs are also starting to assist; while the Red List folks have added "invasive species" as an important threat item in their evaluations of endangered species.

Enough for now! Sorry for verbosity, again, but it is my business, after all.

With regards, Geoffrey Howard

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APPENDIX II - Fact sheets of invasive species

Lantana camara

Taxonomic name: *Lantana camara* L.1753
Synonyms: *Camara vulgaris*, *Lantana scabrida*
Common names: ach man (Cambodia), angel lips, ayam (Malaysia), big sage, blacksage, bunga tayi (Malaysia), cambara de espinto (Brazil), cuasquito (Nicaragua), flowered sage (Jamaica), lantana, lantana wildtype, largeleaf lantana (USA), latora moa (Tahiti), pha-ka-krong (Thailand), prickly lantana, shrub verbean, supirrosa (Spanish-Galapagos Islands), Wandelroeschen (German), white sage (Trinidad), wild sage
Organism type: shrub

Lantana camara is a significant weed of which there are some 650 varieties in over 60 countries or island groups. It is established and expanding in many regions of the world, often as a result of clearing of forest for timber or agriculture. It impacts severely on agriculture as well as on natural ecosystems. The plants can grow individually in clumps or as dense thickets, crowding out more desirable species. In disturbed native forests it can become the dominant understorey species, disrupting succession and decreasing biodiversity. At some sites, infestations have been so persistent that they have completely stalled the regeneration of rainforest for three decades. Its allelopathic qualities can reduce vigour of nearby plant species and reduce productivity in orchards. Lantana camara has been the focus of biological control attempts for a century, yet still poses major problems in many regions.

Description
Lantana camara is a low erect or subscandent, vigorous shrub with stout recurved prickles and a strong odour of black currents; it grows to 1.2-2.4 metres (or even more); its root system is very strong, and it gives out a new flush of shoots even after repeated cuttings; Leaf ovate or ovate-oblong, acute or subacute, crenate-serrate, rugose above, scabrid on both sides; Flower small, usually orange, sometimes varying from white to red in various shades and having a yellow throat, in axillary heads, almost throughout the year; Fruit small, greenish-blue black, blackish, drupaceous, shining, with two nutlets, almost throughout the year, dispersed by birds. Seeds germinates very easily. (Sastri and Kavathekar, 1990).

It is an artificial hybrid species that has been subject to intense horticultural improvement in Europe since the sixteenth century and now exists in many different forms or varieties throughout the world. Flower colour has been the primary feature for distinguishing between different forms. In Australia, these are Red, Pink, White/Pale Pink and Orange (Parsons and Cuthbertson 1992, in Thomas and Ellison 1999). Scott (1998) has proved with RAPD analysis that there is great genetic diversity within *L. camara* and challenged the assertion that flower colour is the primary determining factor in describing varieties (in Thomas and Ellison 1999). Inflorescences are produced in pairs in the axils of opposite leaves. In almost all colour forms, the flower opens yellow and changes to pink, white or red depending on the variety. In the forms where this does not occur, a yellow ring is present around the opening to the corollary tube (Sinha and Sharma 1984, in Day *et al*. 2003). The yellow colouration is known to be a visual cue to pollinating insects, and the act of pollination may stimulate colour change (Barrows 1976, Mohan Ram and Mathur 1984a, in Day *et al*. 2003).

Occurs in:
agricultural areas, coastland, natural forests, planted forests, range/grasslands, riparian zones, ruderal/disturbed, scrub/shrublands, urban areas, wetlands

Habitat description
The diverse and broad geographic distribution of lantana is a reflection of its wide ecological tolerances. It occurs in diverse habitats and on a variety of soil types. It generally grows best in open unshaded situations such as wastelands, rainforest edges, beachfronts, and forests recovering from fire or logging. Disturbed areas such as beside roads, railway tracks and canals are also favourable for the species (Thaman 1974;Winder and Harley 1983; Thakur *et al*. 1992, Munir 1996, in Day *et al*. 2003). Lantana does not invade intact rainforests, but is found on its margins (Diatloff 1975; Humphries and Stanton 1992, in Day *et al*. 2003).Where wet sclerophyll forests and rainforests have been disturbed through logging, gaps are created; this allows lantana to encroach on the forests. Further logging aggravates the condition and allows the lantana to spread or become thicker (Waterhouse 1970, in Day *et al*. 2003).

Lantana benefits from the destructive foraging activities of introduced vertebrates such as pigs, cattle, goats, horses, sheep and deer (Thaman 1974; Denton *et al*. 1991; Fensham *et al*. 1994, in Day *et al*. 2003), and grows well on rich volcanic soils (Humphries and Stanton 1992, in Day *et al*. 2003). It can grow at altitudes from sea-level to 2000m (Matthew 1971 in Day *et al*. 2003). It can tolerate some shade, growing in plantations and open eucalypt forests in Australia, but it does not flower readily under these conditions (Humphries and Stanton 1992, Wells and Stirton 1988, in Day et al. 2003). In Brazil, lantana rarely grows in secondary forest and commercial plantations (Winder and Harley 1983, in Day *et al*. 2003). Wapshere (1970) suggested that when there is reduced herbivory by natural enemies, original habitat restrictions, such as climate and soil type, may become less significant and lantana can expand into previously marginal habitats.

Lantana grows under a wide range of climatic conditions. In Australia, the inland limit of its geographical range coincides with the 750mm isohyet in southern Queensland and the 1250mm isohyet in the north (Harley 1973, in Day *et al*. 2003), with infestations being restricted to creek lines in drier areas (Diatloff 1975, in Day *et al*. 2003). It does not appear to have an upper temperature or rainfall limit and is often found in tropical areas receiving 3000mm of rainfall per year, provided that soils are sufficiently well drained. Lantana seldom occurs where temperatures frequently fall below 5°C (Cilliers 1983, in Day et al. 2003), and in South Africa it is found in areas with a mean annual surface temperature greater than 12.5°C (Stirton 1977, in Day *et al*. 2003). Some varieties can withstand minor frosts, provided these are infrequent (Graaff 1986 in Day *et al*. 2003). Prolonged freezing temperatures kill aerial woody branches and cause defoliation.

In most of the high volcanic island groups in the Pacific, the distribution of lantana is limited by: its inability to survive under dense, intact canopies of taller native forest species; its susceptibility to frosts and low temperatures; its low tolerance to saline soils; its tendency to rot in boggy or hydromorphic soils; it having never been introduced to some islands; insufficient water, due to low rainfall and/or coralline soils with poor water-holding capacities; and high incidence of tropical hurricanes (Thaman 1974, in Day *et al*. 2003).

General impacts
Lantana is now a major weed in many regions of the Palaeotropics where it invades natural and agricultural ecosystems (Thomas and Ellison 1999). The plants can grow individually in clumps or as dense thickets, crowding out more desirable species. In disturbed native forests it can become the dominant understorey species, disrupting succession and decreasing biodiversity. As the density of lantana in forest increases species richness decreases (Fensham *et al*. 1994, in Day *et al*. 2003). Its allelopathic qualities can reduce vigour of plant species nearby and reduced productivity in orchards (Holm *et al*. 1991, in Day *et al*. 2003). At some sites, lantana infestations have been so persistent that they have completely stalled the regeneration of rainforest for three decades (Lamb 1991, in Day *et al*. 2003). Such is its impact that, for example, in southeast Queensland lantana was ranked as the most significant weed of non-agricultural areas (Batianoff

and Butler 2002, in Day *et al*. 2003). Lantana competition may have caused the extinction of the shrub *Linum cratericola* Eliasson (Linaceae), and is a major threat to other endangered plants in the Galapagos Archipelago (Mauchamp *et al*. 1998, in Day *et al*. 2003). The replacement of native pastures by lantana is threatening the habitat of the sable antelope in Kenya (Greathead 1971b, inDay *et al*. 2003). Lantana can greatly alter fire regimes in natural systems (Humphries and Stanton 1992, in Day *et al*. 2003).

It can affect agriculture in a number of ways. In plantations in south-east Asia and the Pacific Island communities it can reduce productivity and interfere with harvesting. It may affect economic viability of crops such as coffee, oil palm, coconuts and cotton (Holm *et al*. 1977, in Thomas and Ellison 1999). In Queensland, loss of pasture is the greatest single cost of lantana invasion in grazing areas (A$3m per year at 1985 values) (Culvenor 1985, in Day *et al*. 2003). In dense stands of lantana, the capacity of the soil to absorb rain is lower than under good grass cover (Cilliers 1983, in Day *et al*. 2003). This could potentially increase the amount of run-off and the subsequent risk of soil erosion in areas infested with lantana. Lantana has been implicated in the poisoning of a number of animals including cattle, buffalo, sheep and goats (Sharma et al. 1988, in Day *et al*. 2003) (its leaves and seeds contain triterpenoids, which cause poisoning and photosensitivity). Poisoning mainly occurs in newly introduced young animals without access to other fodder (Everist 1974, Yadava and Verma 1978; Sharma 1994, in Day *et al*. 2003).

Lantana has many secondary impacts, especially in many tropical countries where it can harbour severalserious pests. Malarial mosquitoes in India (Gujral and Vasudevan 1983 in Day *et al*. 2003) and tsetse flies in Rwanda, Tanzania, Uganda and Kenya shelter in bushes and are the cause of serious health problems (Greathead 1968, Katabazi 1983, Okoth and Kapaata 1987, Mbulamberi 1990 in Day *et al*. 2003).

Uses

Lantana camara has several uses, mainly as a herbal medicine and in some areas as firewood and mulch (Sharma *et al*. 1988; Sharma and Sharma 1989, in Day *et al*. 2003). In some countries, it is planted as a hedge to contain or keep out livestock (Bradley 1988, Ghisalberti 2000 in Day *et al*. 2003). There has been much work conducted, especially in India, on the chemical constituents of lantana; extracts from the leaves exhibit antimicrobial, fungicidal, insecticidal and nematicidal activity (Chavan and Nikam 1982, Sharma and Sharma 1989, Begum *et al*. 2000, in Day *et al*. 2003). The use of lantana extracts as potential biocides has been suggested. For example, aqueous leachate at 1–3% can kill water hyacinth, a troublesome weed in many tropical countries (Saxena 2000, in Day *et al*. 2003). Its application as a weedicide would depend on the size of the waterbodies being treated and the cost of extraction of the leachate. Verbascoside, which possesses antimicrobial, immunosuppressive and antitumor activities, has been isolated (Mahato *et al*. 1994, in Day *et al*. 2003). Lantanoside, linaroside and camarinic acid have been isolated and are being investigated as potential nematocides (Begum *et al*. 2000, in Day *et al*. 2003). Lantana oil is sometimes used for the treatment of skin itches, as an antiseptic for wounds (Anon. 1962), and externally for leprosy and scabies (Ghisalberti 2000). Plant extracts are used in folk medicine for the treatment of cancers, chicken pox, measles, asthma, ulcers, swellings, eczema, tumors, high blood pressure, bilious fevers, catarrhal infections,tetanus, rheumatism, malaria and atoxy of abdominal viscera (Anon. 1962, Kirtikar and Basu 1981, Ghisalberti 2000, in Day *et al*. 2003).

The stems of lantana, if treated by the sulphate process, can be used to produce pulp for paper suitable for writing and printing (Gujral and Vasudevan 1983, in Day *et al*. 2003). However it is hard to harvest, so is likely to be uneconomical. The roots of lantana contain a substance that may possibly be used for rubber manufacture (Gujral and Vasudevan 1983) although the economic viability of production has not been examined. Lantana twigs and stems serve as useful fuel for cooking and heating in many developing countries (Sharma *et al*. 1988), although it is less important than other fuel sources such as windrows, woodlots or natural bush (Bradley 1988, in Day *et al*. 2003).

In many regions, lantana has become a dominant component of natural and agricultural ecosystems. The rapid removal of natural forests without replacement by structurally similar native vegetation may be partially replaced with thickets of lantana. Consequently, the amount of available habitat for native animals may decrease. In some areas, weeds such as lantana mayprovide shelter and vital winter food for many native birds. A number of endangered bird species utilise lantana thickets when their natural habitat is unavailable. In Australia, the vulnerable black-breasted buttonquail, *Turnix melanogaster*, feeds and roosts in lantana thickets adjacent to its more favoured habitat, vine forest (Smith *et al*. 1998, in Day *et al*. 2003). While buttonquails prefer intact vine forest, lantana provides an important temporary refuge for them between forest remnants (Smith *et al*. 1998, in Day *et al*. 2003). In central Kenya, where natural riverine thickets have been almost completely cleared, the endangered Hinde's babbler, *Turdoides hindei*, has become dependent on lantana thickets, and unless sufficient suitable natural habitat can be restored the survival of this species depends on the retention of lantana infestations (Njoroge *et al*. 1998). Apart from benefiting some bird species, lantana is a major nectar source for many species of butterflies and moths.

Notes

Lantana camara is a highly variable species. It has been cultivated for over 300 years and now has hundred of cultivars and hybrids. These belong mostly to the *L. camara* complex. Cultivars can be distinguished morphologically (variation in: flower size, shape and colour; leaf size, hairiness and colour; stem thorniness), physiologically (variation in: growth rates, toxicity to livestock) and by their chromosome number and DNA content (Pierre Binggeli, 1999).

Introduction of six bird species (including Chinese turtledove, *Streptopelia chinensis*, and the Indian mynah, (*Acridotheres tristis*) that feed on lantana berries, has been implicated in the spread of the weed throughout the Hawaiian Islands as no native bird in Hawaii has been observed to eat the fruit (Perkins and Swezey 1924 in Day *et al*. 2003). In Guam, it has been suggested that, as a result of the introduced brown treesnake (*Boiga irregularis*) preying on native bird populations, there are fewer frugivorous birds to disperse lantana seeds (R. Muniappan UG, pers. comm., in Day *et al*. 2003). Consequently lantana infestations are increasing more slowly, and this may partially explain why Guam has had better success with biological control of lantana than other nearby islands (Muniappan 1988, in Day *et al*. 2003).

Geographical range

Native range: The genus *Lantana* is of tropical origin and it reaches its greatest diversity in Central and northern South America and the Caribbean. *Lantana camara sensu stricto* is known from Mexico, Florida, Trinidad, Jamaica and Brazil and has not been recorded from the Old World (Sanders 1987; Sanders Pers. Comm., in Day *et al*. 2003).

Known introduced range: Lantana is now naturalised in approximately 60 countries or island groups between 35°N and 35°S. It is found in many African countries including some arid regions and is widespread in Kenya, Uganda and Tanzania. In South Africa it is common along the east coast and in the tableland area of the north near Tzanee (Day *et al*. 2003). Lantana is found throughout India, occurring from the north near Jammu to the south near Trichmur, on the west coast near Bangalore and in the central region near Jabalpur (Thakur *et al*. 1992, in Day *et al*. 2003). It occurs in the Middle East and on low-lying coral

The distribution of lantana is still increasing, with many of the countries and islands that were listed in 1974 as not having lantana being infested more recently (e.g. Galapagos Islands, Solomon Islands, Palau, Saipan, Tinian, Yap, and Futuna Island) (Thaman 1974, in Day *et al*. 2003). Even in areas such as South Africa, India and larger islands such as New Zealand, where lantana has been established for long periods of time, there is evidence that it is still spreading (Stirton 1977, Cilliers 1983, Hill and Seawright 1983, Sharma *et al*. 1988, Wells and Stirton 1988, in Day *et al*. 2003).

Not only is the geographic range of lantana still expanding in many areas, but the density of

infestations within its range is increasing. This has been recognised as a future threat to ecosystems in Australia (Haseler 1966, in Day *et al*. 2003), the Solomon Islands and Vanuatu (Harley 1992, in Day et al. 2003) and is probably occurring in many other countries. Also, there are several regions where lantana is currently limited by the distribution of intact forest, which inhibitsits growth (Duggin and Gentle 1998, in Day *et al*. 2003). Increasing logging and habitat disturbance in many regions of the world provides further suitable habitats for the plant (Wells and Stirton 1988, in Day *et al*. 2003). In countries where there are still large areas of native forests, such as in Papua New Guinea, lantana is currently restricted to small, isolated infestations in abandoned settlement sites (W. Orapa SPC, pers. comm., in Day *et al*. 2003), but it has the potential to spread widely following further clearing of forest for timber or agriculture.

Introduction pathways to new locations
For ornamental purposes: Dutch explorers introduced the plant into the Netherlands in the late 1960s from Brazil (Ghisalberti 2000) and it was then grown in glasshouses in Europe before its importation to other countries as an ornamental (Day *et al*. 2003).
Nursery trade:

Local dispersal methods
Consumption/excretion: L. camara flowers prolifically and the seeds are dispersed by birds (Swarbrick *et al*. 1998, in Day *et al*. 2003).
Garden escape/garden waste:

Management information
The key to good management of lantana is constant vigilance (Day *et al*. 2003). Repeated control of regrowth is critical to success. Control of new infestations should be a priority because the species is able to expand its range during good seasons.
Mechanical: Mechanical clearing and hand pulling are suitable for small areas and fire can be used over large areas.

Biological: Biocontrol agents have decreased the volume of individual plants making other control methods considerably easier. None of the over 40 agents trialled have resulted in total control but some have been partially successful including *Teleonemia scrupulosa* StÍl (Hemiptera), *Octotoma scabripennis* (Coleoptera), *Uroplata girardi* Pic (Coleoptera) and *Ophiomyia lantanae* (Froggatt) (Diptera) (Day *et al*. 2003).

L. camara was the first weed ever targeted for classical biological control at the turn of the century, and since then 36 insect species have been released in 33 countries throughout the exotic range. Despite these efforts, control of the weed has generally been disappointing (Thomas and Ellison 2000). Many reasons have been suggested for this failure: the great genetic diversity of the plant, its ability to hybridise, and that fact that its origin as a hybrid ornamental plant complicates the search for its centre of origin and thus for potential agents (Thomas and Ellison 1999; Day *et al*. 2003). Twenty nine biotypes exist in Australia alone (Smith and Smith 1982, in Thomas and Ellison 1999). No insect agent released to date has caused significant damage to the very important Common Pink biotype homas and Ellison 1999). In general, the insect agents released have a restricted host range within this complex, and, in addition, the weed is able to tolerate wider climatic and geographical areas (Thomas and Ellison 1999). Searches have been made in Mexico, Central America, the West Indies, and Brazil, and insects have been collected from several different lantana species. These insects have been host-tested and released in Hawaii, South Africa, Australia, several countries in east Africa, south and east Asia, and the Pacific (Day . 2003).

Fungi have been used for many years to control arthropod pests but have been underexploited against invasive weeds. Evans (1987) considered fungal pathogens to have great potential as agents for classical biological control of weeds. Barreto *et al*. (1995) examined the mycobiota of *L. camara* in Brazil and selected several fungal pathogens as potential biological control agents including *Prospodium tuberculatum*, *Puccinia lantanae* and *Ceratobasidium lantanae-camarae*.

P. tuberculatum is a rust limited to the tropical and subtropical regions of North and South America. Glasshouse inoculations indicate that the agent is pathogenic to two major weed biotypes in Australia: the Common Pink (a highly invasive biotype) and Pinkedged Red (extremely toxic to cattle). *P. lantanae* is a rust of tropical origin and initial results show that it is pathogenic to a wider range of weedy cultivars of lantana than *P. tuberculatum*. Successful infection has been obtained with ten biotypes to date: two from Australia, three from South Africa, two from Madagascar and one from Thailand, India and Hawaii (Thomas and Ellison 1999).

A strain of the rust *Prospodium tuberculatum* from Brazil was screened as a potential biocontrol agent against 40 Australian *Lantana camara* forms and 52 closely related, non-target plant species. Results under glasshouse conditions showed that the Brazilian rust strain is pathogenic to only two flower colour forms: pink and pink-edged red. Macro- and microsymptoms were recorded using 11 assessment categories and four susceptibility ratings. No macrosymptoms were observed on any of the non-target plants (Thomas *et al.* 2006).

Reproduction

Lantana flowers in most places all year round if adequate moisture and light are available (Gujral and Vasudevan 1983, Graaff 1986, in Day *et al*. 2003), with flowering peaking during the wet summer months. In cooler or drier regions, flowering occurs only in the warmer or wetter months, due to frost or drought damage (Winder 1980, Swarbrick *et al*. 1998 in Day *et al*. 2003). Plants can flower as early as the second growing season. Initially, lepidopteran species were thought to be the primary pollinators of lantana (Dronamraju 1958, Schemske 1976, Kugler 1980, Hilje 1985, in Day *et al*. 2003). Some butterfly species visit certain lantana taxa more frequently than others due to differences in corolla length, inflorescence diameter and number of flowers per inflorescence. According to this view, different varieties of lantana may have different species of pollinators. Therefore, there may be little cross-pollination between species or varieties of lantana both in the naturalised and native ranges of the section *Camara* (Dronamraju 1958, Schemske 1976, in Day *et al*. 2003). More recently, it has been suggested that thrips play a more important role in the ollination of lantana than Lepidoptera; unlike butterflies, thrips are present all year round, and are more efficient pollinators (Mohan Ram and Mathur 1984b, Sinha and Sharma 1984, in Day *et al*. 2003). In India, the exclusion of butterflies did not reduce seed-set and Mathur and Mohan Ram (1986) proposed the introduction of biocontrol agents to reduce thrips populations in an attempt to decrease pollination and the quantities of seed produced by lantana. In addition to butterflies and thrips, sunbirds (India) and hummingbirds (Brazil) are believed to play a minor role in pollination (Winder 1980). There are conflicting reports over lantana's ability to selfpollinate. Pollination results in 85% fruit-set (Hilje 1985), with each infructescence bearing about eight fruits (Barrows 1976, in Day *et al*. 2003). Seeds are widely dispersed, predominantly by birds, but also by kangaroos, bearded dragons, sheep, goats, cattle, foxes, jackals, monkeys and possibly rodents (Bisht and Bhatnagar 1979, Clifford and Drake 1985, Sharma et al.1988, Wells and Stirton 1988, in Day *et al*. 2003). In continental areas, many indigenous bird species feed on the lantana fruits, while on some of the island groups, seed dispersal has been mainly facilitated by the introduction of exotic bird species. Birds are very important in exacerbating the weed problem and should not be underrated. By feeding on exotic species such as lantana, birds may increase the density and distribution of the weed at the expense of native vegetation thereby displacing other bird species (Loyn and French 1991, in Day *et al*. 2003). Lantana seeds need high light conditions for germination and early growth (Gentle and Duggin 1997b; Duggin and Gentle 1998, in Day *et al*. 2003), and seedlings are unlikely to survive beneath parent bushes. The germination rate of lantana is low under both laboratory and field conditions, with estimates of 4–20% (Graaff 1987) and 44.5% (Duggin and Gentle 1998, in Day *et al*. 2003). Germination rates increased from ten per cent to 46 per cent when the fleshy pulp was manually removed from the seed. This higher germination rate is comparable to that obtained from seeds collected from the faeces of wild birds. Seeds germinate at any time of the year given sufficient soil moisture, with most seed germinating after the first summer storms in northern Australia (Parsons and Cuthbertson 2001, in Day *et al*. 2003).

This species has been nominated as among 100 of the "World's Worst" invaders

Reviewed by: Major update under progress
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Chromolaena odorata



Taxonomic name: *Chromolaena odorata* (L.) King & Robinson
Synonyms: *Eupatorium affine* Hook & Arn., *Eupatorium brachiatum* Wikstrom, *Eupatorium clematitis* DC., *Eupatorium conyzoides* M. Vahl, *Eupatorium divergens* Less., *Eupatorium floribundum* Kunth, *Eupatorium graciliflorum* DC., *Eupatorium odoratum* L., *Eupatorium sabeanum* Buckley, *Eupatorium stigmatosum* Meyen & Walp., *Osmia conyzoides* (Vahl) Sch.-Bip., *Osmia divergens* (Less.) Schultz-Bip., *Osmia floribunda* (Kunth) Schultz-Bip., *Osmia graciliflora* (DC.) Sch.-Bip., *Osmia odorata* (L.) Schultz-Bip.
Common names: agonoi (Philippines), bitter bush (English), chromolaena (English), hagonoy (Philippines), herbe du Laos (French), huluhagonoi (Philippines), jack in the bush (English), kesengesil (Chamorro-Guam), mahsrihsrihk (Kosrae), masigsig (Chamorro-Guam), ngesngesil (Palau), otuot (Chuuk), rumput belalang (Indonesian Bahasa-Indonesia), rumput golkar (Indonesian Bahasa-Indonesia), rumput putih (Indonesian Bahasa-Indonesia), Siam weed (English), Siam-Kraut (German), triffid weed (English), wisolmatenrehwei (Pohnpei)
Organism type: herb

Chromolaena odorata is a fast-growing perennial shrub, native to South America and Central America. It has been introduced into the tropical regions of Asia, Africa and the Pacific, where it is an invasive weed. Also known as Siam weed, it forms dense stands that prevent the establishment of other plant species. It is an aggressive competitor and may have allelopathic effects. It is also a nuisance weed in agricultural land and commercial plantations.

Description
Chromolaena odorata is an herbaceous perennial that forms dense tangled bushes 1.5-2.0m in height. It occasionally reaches its maximum height of 6m (as a climber on other plants). Its stems branch freely, with lateral branches developing in pairs from the axillary buds. The older stems are brown and woody near the base; tips and young shoots are green and succulent. The root system is fibrous and does not penetrate beyond 20-30cm in most soils. The flowerheads are borne in terminal corymbs of 20 to 60 heads on all stems and branches. The flowers are white or pale bluish-lilac, and form masses covering the whole surface of the bush (Cruttwell and McFadyen 1989).

C. odorata is a big bushy herb with long rambling (but not twining) branches; stems terete, pubescent; leaves opposite, flaccid-membranous, velvety-pubescent, deltoid-ovate, acute, 3-nerved, very coarsely toothed, each margin with 1-5 teeth, or entire in youngest leaves; base obtuse or subtruncate but shortly decurrent; petiole slender, 1-1.5cm long; blade mostly 5-12cm long, 3-6cm wide, capitula in sub-corymbose axillary and terminal clusters; peduncles 1-3cm long, bracteate; bracts slender, 10-12mm long; involucre of about 4-5 series of bracts, pale with green nerves, acute, the lowest ones about 2mm long, upper ones 8-9mm long, all acute, distally ciliate, flat, appressed except the extreme divergent tip; florets all alike (disc-florets), pale purple to dull off-white, the styles extending about 4mm beyond the apex of the involucre, spreading radiately; receptacle very narrow; florets about 20-30 or a few more, 10-12mm long; ovarian portion 4mm long; corolla slender trumpet form; pappus of dull white hairs 5mm long; achenes glabrous or nearly so (Stone 1970). The seeds of Siam weed are small (3-5mm long, ~1mm wide, and weigh about 2.5mg seed-1 (Vanderwoude *et al*. 2005).

Occurs in:
agricultural areas, natural forests, planted forests, range/grasslands, riparian zones, ruderal/disturbed, scrub/shrublands

Habitat description
Chromolaena odorata grows on a wide range of soils and grows in a range of vegetation types, e.g. Forests (annual rainfall 1500mm), grassland and arid bushveld (annual rainfall less than 500mm) (Goodall and Erasmus 1996, in Vanderwoude *et al*. 2005). In arid areas, it is restricted to riverbanks and it will only become invasive in the frost-free areas of medium to arid woodland which are not water-stressed in the
growing season (Honu and Dang, 2002 in Vanderwoude *et al*. 2005). For good growth of Siam weed seedlings, the relative humidity should be in the range of 60 – 70%; at values higher than 80% the growth performance was poor (Ambika 2002, in Vanderwoude *et al*. 2005). Experiments show that Siam weed seedlings grew well at 30°C and even better on mulched soils at 25°C (Ambika 2002, in Vanderwoude *et al*.
2005). In heavy shade, Siam weed will not seed. It has a negative relationship with tree canopy cover and appears to be most abundant on the edge of forested areas (Feleke 2003, Luwum 2002, in Vanderwoude *et al*. 2005). Witkowski (2002) reports that in north-eastern India, Siam weed is regarded as a nutrientdemanding early successional species (Ramakrishnan 1992, in Vanderwoude *et al*. 2005). It takes
advantage of the flush of soil that becomes available after a disturbance, such as fire or land clearing for agriculture, and exhibits relatively high foliar N, P and K contents (Saxena and Ramakrishnan 1983, in Vanderwoude *et al*. 2005).

General impacts
Chromolaena odorata forms dense stands preventing establishment of other species, both due to competition and allelopathic effects. When dry, *C. odorata* becomes a fuel which may promote wild bushfires (PIER 2003). *C. odorata* may also cause skin complaints and asthma in allergy-prone people. It is a major weed in plantations and croplands, including plantations of rubber, oil palm, forestry and coffee plants.

C. odorata is also a weed of national parks. In the Greater St. Lucia Wetland Park, a recently acclaimed World Heritage Site in South Africa, it is reported to interfere with natural ecosystem processes. Nesting Nile crocodiles (see *Crocodylus niloticus* in IUCN Red List of Threatened Species) require open, sunny, sandy areas in which to deposit their eggs. *C. odorata* shades and overtakes nesting sites creating fibrous root mats unsuitable for egg chamber and nest construction. As well as altering this natural habitat, *C. Odorata* produces shade resulting in colder temperatures in any nests that do get constructed, an effect that produces a female-biased sex ratio in the offspring, as well as perhaps preventing embryonic development altogether (Leslie and Spotila 2001).

Uses
Chromolaena odorata is an ornamental plant that is sometimes encouraged for use in shifting slash-andburn agriculture to compete with *Imperata cylindrica* (alang alang or cogon grass), which is harder to control.

Notes
The University of Guam publishes a newsletter on *Chromolaena odorata*. *C. odorata* is on the State of Hawaii noxious weed list. Subject of an eradication programme in Queensland, Australia. A declared noxious weed in South Africa.

Geographical range
Native range: Tropical America.
Known introduced range: Siam weed has become a serious weed in South Africa, India, China, Indonesia, East Timor and the Philippines (Vanderwoude *et al*. 2005).

Introduction pathways to new locations

Agriculture:

Biological control: Introduced to Ivory Coast in 1952 to control *Imperata* spp. following a recommendation bya famous botanist, Auguste Chevalier.

For ornamental purposes:

Other: The tiny seeds may contaminate imported forestry and pasture seed supplies.

Road vehicles (long distance):

Road vehicles (long distance): Longer distance dispersal has been reported for seeds lodged in vehicle bodywork (Blackmore 1998, in Vanderwoude *et al*. 2005).

Taken to botanical garden/zoo: Initial introduction to Southeast Asia probably occurred via introduction into the Calcutta Botanic Garden.

Translocation of machinery/equipment: Used vehicles, mining and earthmoving machinery are often transported between countries in the Asia/Pacific region including Australia. These machines have often been in contact with soil at their source and are therefore potential carriers of weed seeds (Vanderwoude *et al*. 2005). Earthmoving machinery such as dozers, graders and back-hoes are frequently implicated as vectors of weed seeds including Siam weed. Earthmoving machinery is frequently transported to new locations without washing-down or other hygiene provisions and is undoubtedly implicated in the spread of Siam weed (Vanderwoude *et al*. 2005).

Transportation of domesticated animals: Chromolaena odorata probably spread through Indonesia through live cattle shipments.

Transportation of habitat material: Sand and gravel extraction businesses operate in both the Thuringowa and Tully River catchments in Queensland, Australia. These are located within preferred Siam weed habitat and therefore present a high risk of spreading Siam weed seeds which could remain viable for a number of years post-dispersal. Sand and gravel are used in large quantities for road construction which by their nature are already favourable sites for establishment. These sites are therefore a major risk pathway. Soil, sand and gravel are rarely transported long distances as the major cost for these resources are those associated with transport. Thus, there are market barriers to long-distance dispersal by this means (Vanderwoude *et al*. 2005).

Transportation of habitat material:

Local dispersal methods

Hikers' clothes/boots: The seeds have small spines that can adhere to clothes, fur and feathers, especially when these are wet (Vanderwoude *et al*. 2005). There is substantial traditional and contemporary movement of people through islands in Australia and SE Asia. Seeds could be transported in personal belongings or trade goods being carried by this means (McFadyen, 1996, Vanderwoude *et al*. 2005).

On animals: Both native and feral animals utilise land that is infested with Siam weed and therefore they are potential vectors for seed spread. The distance that seeds might be dispersed are dependent on the home ranges of the animal in question. Feral pigs and larger macropods, for example, can move substantial distances and carry seeds on their coats or trapped in soil adhering to hooves. Birds are also potential vectors (Vanderwoude *et al*. 2005).

On animals (local): Although *Chromolaena odorata* seed is not in itself palatable to birds, it is possible that they might come into contact with Siam weed seeds while searching for other seeds or prey (Vanderwoude *et al*. 2005).

On animals (local): The achenes of the seeds bear a small stiff pappus which enables the seed to be spread by wind (Witkowski and Wilson 2001, in Vanderwoude *et al*. 2005). Field trials show that seeds are rarelydispersed by wind more than 80 metres from the parent plant, with the vast majority dispersing less than 10 metres.

Road vehicles: A considerable number of seeds can be transported by light vehicles (4WDs, utes and passenger vehicles). In a study designed to measure the amount of seed transport, a mean 39 seeds remained attached to light vehicles after driving 15 km (Blackmore 1996, in Vanderwoude *et al*. 2005). Zachariades and Goodall (2002) maintain that spread through southern Africa was facilitated by seed attached to vehicles. In north Queensland, regular traffic between infested and uninfested properties, including movements by hunters and government officers should be considered as possible pathways (Vanderwoude *et al*. 2005).

Translocation of machinery/equipment (local): Seeds have tiny barbs that stick to machinery

Water currents:

Water currents: Chromolaena odorata appears to readily disperse along waterways downstream from infestations in both the dry and wet tropics. Possible factors include: the fact that seeds float downstream after landing on water; periodic flooding exposes receptive seedbeds of mineral soil; flood events transport seed-bearing silt downstream, and/or a combination of these factors. Regardless of the exact mode of establishment, waterways represent a significant pathway for this species (Vanderwoude *et al*. 2005).

Management information

Preventative measures: A Risk assessment of *Chromolaena odorata* for the Pacific region was prepared by Pacific Island Ecosystems at Risk (PIER) using the Australian risk assessment system (Pheloung, 1995). The result is a score of 34 and a recommendation of: reject the plant for import (Australia) or species likely to be of high risk (Pacific).

Using a revised climate model (Kriticos *et al*. 2005) of the estimated potential distribution of *C. odorata* it was predicted that mediterranean, semi-arid and temperate climates are unsuitable for its establishment. Much of tropical Africa, the north-eastern coast of Australia and most Pacific islands are at risk of invasion. The distribution of *C. odorata* in South Africa extends further south than predicted by the model based on Asian and American distribution records, supporting the claim that the South African variety of *C. odorata* has different climatic requirements to the varieties elsewhere (EPPO 2005).

Physical: Manual slashing and use of bush-cutter or tractor-drawn implements are commonly used methods of control. Slashing causes regeneration unless followed by other control methods. Manual weeding is labour intensive. The use of tractor drawn equipment is limited to areas that are accessible (Ecoport).

Chemical: Chemical control using herbicides applied at the seedling stage or on regrowth has given encouraging results. Triclopyr has proven to be the most effective. However, problems in herbicide use include the high cost of the chemicals and their application, ecological concerns and, non-compatibility in many cropping and other environmental situations (Ecoport). Removing seed and flower heads and spraying with 2,4-D Amine plus Picloram (Tordon in Australia) kills top growth and (picloram kills the root system is recommended (Rod Randall, pers. comm. 2000).

Biological: The biological control agent *Pareuchaetes pseudoinsulata* has been introduced into Guam, where it effectively defoliates pure stands. It is less successful in scattered plants and patches. It has also been introduced into Palau, Kosrae, Pohnpei, Yap and Saipan Island (Mariner Islands) where it has been effective in reducing *C. odorata*. It has also been released on Sumatra, Indonesia, where it is effective in reducing densities of the weed. Releases into other parts of Indonesia appear to have failed.

Another species, the stem gall fly *Cecidochares connexa* (originally collected from *C. odorata* in Mexico, Brazil and Bolivia Cruttwell 1974) is a suitable biological control agent for *C. odorata* (Cruttwell McFadyen Chenon and Sipayung 2003). Most gall-forming species of the tephritid genera *Cecidochares* Bezzi are highly host specific, sometimes attacking only a single plant species (Foote *et al*. 1993, in Cruttwell McFadyen Chenon and Sipayung 2003). Based on the results of host testing of *C. connexa* was granted Indonesian Government allowance for field release in 1995 and is now established on most of the larger Indonesian islands (Tijitrosemito 2002, Wilson and Widayanto 2002, in Cruttwell McFadyen Chenon and Sipayung 2003). Since then it has been released in Palau, Papau New Guinea and the Philippines (Esguerra 2002, Orapa *et al*. 2002, in Cruttwell McFadyen Chenon and Sipayung 2003; Dr. Muniappan, pers. comm.). Die-back and death of plants have been recorded at many sites within 3 to 5 years of release, especially in low altitude sites (less than 300m) with a short dry season (Cruttwell McFadyen Chenon and Sipayung 2003). At higher altitude sites (over 600m) or where cloudy conditions, cold temperatures or long dry seasons limit the number and activity of flies control is slower and less adequate (Cruttwell McFadyen Chenon and Sipayung 2003).

Reproduction
Sexual reproduction. Although the plant may resprout from the root crown following fire or death of old stems it is not known to reproduce vegetatively. Seed production is prolific with estimates up to 260,000 m-2 (Witkowski 2002) with about 20–46% of seeds produced being viable (Witkowski and Wilson 2001, in Vanderwoude *et al*. 2005). Some seed survives for up to 5 years, whether these are located on the surface of the soil or buried; three month-old seed that has been buried has a viability of about 50% compared with about 6% when on the soil surface (M. Setter, pers. comm. in Vanderwoude *et al*. 2005). Plants can germinate and set seed within a 12-month period.

This species has been nominated as among 100 of the "World's Worst" invaders

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Principal sources: Pacific Islands Ecosystems at Risk, (PIER)

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Mikania micrantha



Taxonomic name: *Mikania micrantha* (L.) Kunth.
Synonyms:
Common names: American rope (English), Chinese creeper (English), Chinesischer Sommerefeu (German), fue saina (Niuean), liane americaine (French), mile-a-minute weed (English), ovaova (Fijian), usuvanua (Fijian), wa bosucu (Fijian), wa mbosuthu (Fijian), wa mbosuvu (Fijian), wa mbutako (Fijian), wa ndamele (Fijian)
Organism type: vine, climber

Mikania micrantha is a perennial creeping climber known for its vigorous and rampant growth. It grows best where fertility, organic matter, soil moisture and humidity are all high. It damages or kills other plants by cutting out the light and smothering them. A native of Central and South America, Mikania micrantha was introduced into India after the Second World War to camouflage airfields and is one of the most widespread and problematic weeds in the Pacific region. Its seeds are dispersed by wind and also on clothing or hair.

Description
A branched, slender-stemmed perennial vine. The leaves are arranged in opposite pairs along the stems and are heart-shaped or triangular with an acute tip and a broad base. Leaves may be 4-13cm long. The flowers, each 3-5mm long, are arranged in dense terminal or axillary corymbs. Individual florets are white to greenishwhite. The seed is black, linear-oblong, five-angled and about 2mm long. Each seed has a terminal pappus of white bristles that facilitates dispersal by wind or on the hair of animals (Pacific Island Ecosystems at Risk).

Occurs in:
agricultural areas, coastland, natural forests, planted forests, riparian zones, ruderal/disturbed, scrub/shrublands, urban areas, wetlands

General impacts
Once established, *Mikania micrantha* spreads at an alarming rate, readily climbing and twining on any vertical support, including crops, bushes, trees, walls and fences. Its shoots have been reported to grow up to 27mm a day. Vegetative reproduction is also efficient and vigorous. Although intolerant of heavy shade it readily colonises gaps.

Mikania micrantha damages or kills other plants by cutting out the light and smothering them. In this respect it is especially damaging in young plantations and nurseries. It also competes for water and nutrients, but perhaps even more importantly, it is believed that the plant releases substances that inhibit the growth of other plants.

Mikania micrantha is one of the three worst weeds of tea in India and Indonesia and of rubber in Sri Lanka and Malaysia. In Samoa, incursions of *M. micrantha* have caused the abandonment of coconut plantations, and the weed has been reported to kill large breadfruit trees. It also causes serious problems in oil palm, banana, cacao and forestry crops, and in pastures. While it does not grow well in rice paddies, it can encroach from the edges to smother the crop. (Northern Territory Department of Business, Industry and Resource Development)

Geographical range
Native range: *Mikania micrantha* is native to Central and South America, where it grows in and near forests, along rivers and streams and in disturbed areas such as roadsides.
Known introduced range: It has been reported as a weed in India, Bangladesh, Sri Lanka, Mauritius, Thailand, the Philippines, Malaysia, Indonesia, Papua New Guinea and many of the Pacific islands. It was first identified in Queensland, Australia in 1998, but had been present there for between 8 - 10 years already.

Introduction pathways to new locations
Other: Mikania micrantha was introduced into India after the Second World War to camouflage airfields (New Scientist, 2003)

Local dispersal methods
On animals: Seed dispersed in clothing or hair.
On animals (local): Seed dispersed by wind.

Management information
Chemical: Control of *Mikania micrantha* is difficult, because of the high output of viable seeds, and because new plants can grow from even the tiniest stem fragments. Other than complete destruction of all the stems, herbicides provide the only suitable method of control at present (Northern Territory Department of Business, Industry and Resource Development). "Probably susceptible to: 1) many residual herbicides at standard rates; 2) translocated herbicides including glyphosate and 2,4-D before flowering; 3) contact herbicides (including paraquat) while still a seedling; however established plants will probably recover from the base" (Swarbrick, 1997 in PIER, 2003).

Biological: *Liothrips mikaniae* was introduced into Solomon Islands in 1988, but failed to establish (Swarbrick, 1997). "A number of very promising (and probably specific) natural enemies are known in Central and South America… Of these a thrips, *Liothrips mikaniae* appears to be specific and to have considerable potential as a biological control organism. A bug, *Teleonemia* sp., several beetles and an eriophyid mite, Acalitus sp. Also warrant serious consideration. A number of other natural enemies of little known specificity also attack *Mikania micrantha*" (Waterhouse and Norris, 1987). Fungal pathogens have also been investigated in India as a potential biological control method (Swarbrick, 1997 in PIER, 2003).

Oceania: At two regional technical meetings on plant protection and biosecurity in March 2002 and March 2004, 11 Pacifc Ocean countries rated mile-a-minute (*Mikania micrantha*) and giant sensitive plant (Mimosa diplotricha) among their top 10 worst weeds.

The meetings further resolved for the Secretariat of the Pacifc Community (SPC) to assist Pacific Island Countries and Territories to address major weeds of the region. As a result, SPC submitted a proposal to ACIAR to fund a major biocontrol project against these two weeds. Both *M. micrantha* and *M. Diplotricha* were rated in the “most important” category and have good prospects for biocontrol. Three countries, PNG, Fiji and Samoa, which rated both weeds highly, were chosen to be initial implementers of the proposed project as they showed initial interest and had suitable facilities to implement the activities.

A project development visit to Fiji, PNG and Samoa was carried out by Warea Orapa, Coordinator Weed Management, and Michael Day, an Entomologist based at Alan Fletcher Research Station, Queensland to establish linkages and discuss the proposed project on the two weed pests. Because of conflicting views on Mikania in Samoa, Samoa has officially opted to wait till the research work is completed in Fiji and PNG. In addition, the proposed project may concentrate only on Mikania biocontrol since field populations of the psyllid *Heteropsylla spinulosa*, released in these countries under the GTZ Biocontrol Programme in Fiji and Samoa in the mid-1990s and independently released in PNG (by Ramu Sugar in 1992), are established.

Mikania micrantha in PNG has long been regarded as a problem weed, especially in large plantation areas as well as smallholder farms on New Britain Island and several other areas. Support for a biocontrol project has been aired since 2002 by the National Agricultural Research Institute (NARI) and the Cocoa and Coconut Institute. For more information contact WareaO@spc.int (Pacific Pest Info, No. 55, January 2005).

Nutrition
Grows best where fertility, organic matter, soil moisture, and humidity are all high. Can tolerate some shade (Pacific Island Ecosystems at Risk).

Reproduction
Reproduces sexually by seeds, and vegetatively by rooting at nodes (Joel Miles). A single plant may cover over 25 square metres within a few months, and release as many as 40,000 viable seeds every year. In some locations flowering and seed production are during short days only.

This species has been nominated as among 100 of the "World's Worst" invaders

Reviewed by: Major update under progress

Principal sources: Pacific Island Ecosystems at Risk (PIER).

Compiled by: IUCN/SSC Invasive Species Specialist Group (ISSG)
To contribute information, please contact Shyama Pagad.

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Ageratum conyzoides



Taxonomic name: *Ageratum conyzoides* L.
Synonyms: *Ageratum album* Willd. Ex Steud. 1821, *Ageratum caeruleum* Hort. ex. Poir., *Ageratum coeruleum* Desf., *Ageratum conyzoides* var *hirtum* (Lam.) DC. 1836, *Ageratum cordifolium* Roxb. 1832, *Ageratum hirsutum* Lam. 1810, *Ageratum hirtum* Lam. 1783, *Ageratum humile* Salisb. 1796, *Ageratum latifolium* Car., *Ageratum maritimum* H.B.K., *Ageratum mexicanum* Sims., *Ageratum nanum* Hort. Ex Sch. Bip. 1858, *Ageratum obtusifolium* Lam., *Ageratum odoratum* Vilm. 1866, *Ageratum suffruiticosum* Regal 1854, *Cacalia mentrasto* Vell.
Common names: a'amia (Samoan), agerato (Portuguese-Brazil), agerato (Italy), ageratum (English), ageratum (Netherlands), asipukpuk (Pangasinan), asipukpuk (Philippines), azier françois (French), bahu-bahu (Filipino), bahug-bahug (Filipino), bandotan (Indonesia), barba de chivo (Spanish), baume (French), baume blanc (French), baume mauve (French), belohanua (Ibatan), berokan (Indonesia), billy goat weed (English), blue Ageratum (English), blue flowered groundsel (English), blue top (English), boko-boko-wiwiri (Suriname), botebotekoro (Fijian), botekoro (Fijian-Fiji), bouton (French), bouton blan (French), bouton ble (French), budbuda (Bontoc), budbuda (Philippines), bulak-manok (Spanish), bulak-manok (Philippines), camará apeba (Portuguese-Brazil), camará iapó (Portuguese-Brazil), camará japę (Portuguese-Brazil), camará-opela (Portuguese-Brazil), catinga de barrão (Portuguese-Brazil), catinga de bode (Portuguese-Brazil), catinga de bode (Spanish), celestina (Italy), chuva (Spanish), co cut-heo (Vietnam), efoe momoe (Ghana), erva de santa maria (Portuguese-Brazil), erva de santa-lúcia (Portuguese-Brazil), erva de são joão (Portuguese-Brazil), erva de são josé (Portuguese-Brazil), goat weed (English), gobu (Gambia), gundhaubon (India), herbe a femme (French), herbe a pisser (French), herbe a sorcier (French), herbe de bouc (French), hierba del perro (Spanish), hierba del zorro (Spanish), hierbe de chivo (Spanish), huarmi (Spanish), huarmi (Peru), hwohsiang- ji (Taiwan), imiesu (Nigeria), jambo-serila (Gambia), kakalding (Bontoc), kakalding (Philippines), kakkoazami (Japan), kamabuag (Hawaiian), kamabuag (Philippines), kolokong-kabanyo (Philippines), kolokong-kabayo (Tagalog), kulong-kogong-babae (Bicolano), kulong-kogong-babae (Philippines), lau taioti (Samoan), Leberbalsam (German-Germany), macela de são joão (Portuguese-Brazil), macela francesa (Portuguese-Brazil), mahakaua (India), maile hohono (Hawaiian), maile honohono (Hawaiian), maile kula (Hawaiian), maire vaihi (Tahitian), maria preta (Portuguese-Brazil), mata mothemothe (Fijian), matruço (Portuguese-Brazil), mbotembotekoro (Fijian), mentrasto (Portuguese-Brazil), Mother Brinkly (English), mumutung (Chamorro), Neela Phulnu (India), ngmak (Palauan), olloowaisiip (Chuukese), Oochunt (Bangladesh), pain doux (French), petit pain doux (French), Phulkuri (Bangladesh), pica roxo (Portuguese- Brazil), picão roxo (Portuguese-Brazil), ruput tahi-ayam (Malaysia), sekose sea (Kwara'ae), sogovanua (Fijian), songovanua (Fijian), tae'oti (Samoan), tamasondji bata (Nigeria), te'ehosi (Tongan), tekote tea (Niuean), tropic ageratum (English), tropical whiteweed (English), white weed (English), winter weed (English), ya-sap-raeng (Thailand), ya-tabsua (Thailand), zerisson blanc (French)
Organism type: herb

Ageratum conyzoides is a weed distributed in many tropical and subtropical countries and is often difficult to control. It is an established weed in the Himalayas where several invasion research studies have been conducted in the Shiwalik Ranges. It has been found that Ageratum significantly reduces total biomass and species number, that is, biodiversity. It also changes

vegetation community structure and modifies the soil regieme.

Description
Ageratum conyzoides is an erect, herbaceous annual, 30 to 80 cm tall; stems are covered with fine white hairs, leaves are opposite, pubescent with long petioles and glandular trichomes (Ming 1999). It can gain height up to 2 m in the Shivalik hills (Dogra, 2008, in Dogra *et al*. 2009). The inflorescence contain 30 to 50 self-incompatible pink, white or violet flowers arranged as a corymb (Jhansi and Ramanujam 1987, Kaul and Neelangini 1989, Ramanujam and Kalpana 1992, Kleinschimidt 1993, in Ming 1999). The fruit is an achene with an aristate pappus and is easily dispersed by wind (Lorenzi 1982, Scheffer 1990, Kalia and Singh 1993,Lam *et al*. 1993, Paradkar *et al*. 1993, Waterhouse 1993, Kshatriya *et al*. 1994, in Ming 1999). Seeds are positively photoblastic, and viability is often lost within 12 months (Marlks and Nwachuku 1986, Ladeira *et al*. 1987, in Ming 1999). The optimum germination temperature ranges from 20 to 25°C (Sauerborn and Koch 1988, in Ming 1999). The species has great morphological variation, and appears highly adaptable to different ecological conditions.

Occurs in:
agricultural areas, natural forests, planted forests, range/grasslands, riparian zones, ruderal/disturbed, scrub/shrublands, water courses, wetlands

Habitat description
Ageratum conyzoides is a herb present in many tropical and subtropical environments. It is a weed of disturbed land in the Pacific island habitats including crops, pastures, plantations, waste land and roadsides (Swarbrick 1997, in PIER 2008). It is also found in clearings, grasslands, forests and along trails (Smith 1991, in PIER 2008).

A. conyzoides grows as a monoculture in grasslands, forests, agricultural, plantations and horticultural fields in India.

A. conyzoides thrives best in rich, moist, mineral soils with high humidity and tolerates shading. It is not tolerant to soils with poor fertility and therefore is only a minor weed on island atolls such as Niue. Hassan (Undated) observed that *A. conyzoides* in the Amani forest, Madagascar, is not found under the canopy but only in areas with light. This seems to suggest that the reproduction and distribution of this species is associated with light intensity. The study showed that the density of *A. conyzoides* was higher in open than in the semi-shaded areas.

One study, conducted in the north tropical and south subtropical mountainous zones in the Yunnan Province of China, found that the density of *A. conyzoides* was correlated with the distance of the plant from the road and that its maximum abundance occurred within 4 meters of the road. This supports the model of alien plants invading native plant communities in this part of China from primary colonisation points along road margins (Zhao *et al*. 2008).

A. conyzoides may grow from sea level to at least 2400 meters in altitude (Singh Undated). It is present from sea level to at least 1300 meters in Hawaii (Wagner *et al*. 1999, in PIER 2008) and in Himachal Pradesh the weed is established up to 1800 meters (Dogra *et al*. 2009).

General impacts
Agricultural: *Ageratum conyzoides* is a weed in many annual and perennial crops and has been reported as host of many crop diseases (Ekeleme *et al*. 2005). Weeds interfere with growth and production of crops and therefore exert significant ecological and economic impacts (Singh *et al*. 2001, Batish et al. 2009). For example, in Asia rice yield Asia has been negatively associated with *A. conyzoides* density (Roder *et al*. 1998). Some studies have demonstrated allelopathy in the weed, however, shoot competition for light appears to be a major mode of interference in crops (Ekeleme *et al*. 2005).

Allelopathy: Allelopathy is a type of biotic interference wherein a plant releases bioactive

metabolites into the surrounding environment. Growth of nearby vegetation is negatively affected and a selective advantage to the donor plant is provided (Batish *et al*. 2009a). Volatile components of *A. conyzoides* that contribute to phytoinhibition/allelopathy include precocenes and their derivatives monoterpenes and sesquiterpenes. There is much evidence that *A. conyzoides* inhibits germination and growth of other plants through chemicals produced by its root and shoot systems. Fresh leaves and volatile oils of *A. conyzoides* inhibit seedling growth of various crops (Kong *et al*. 1999) including peanut, redroot amaranth, cucumber and ryegrass (Kong Hu & Xu 2002). Studies have shown that shoot extracts of *A. conyzoides* inhibit germination of *Amaranthus caudatus*, *Digitaria sanguinalis* and lettuce (*Lactuca sativa*). Extracts of *A. conyzoides* inhibit germination of wheat and rice (*Oryza sativa*) seeds (Jha & Dhakal 1990, in Ming 1999). The phenolics present in leaf extracts and residues of *A. conyzoides* negatively interfere with the growth and development of wheat (Singh *et al*. 2003, in Batish *et al*. 2009a). Root and shoot length and biomass accumulation of rice are significantly reduced by 18 to 30% when grown in the rhizosphere soil of *A. conyzoides* (Batish *et al*. 2009a). Leaf debris of *A. conyzoides* deleteriously affects the early growth of rice (Batish *et al*. 2009b). Lastly, *A. Conyzoides* causes reduction in chickpea (*Cicer arietinum*) growth and nodulation and (Batish *et al*. 2004).

Phytoinhibition/allelopathy increases when plants are grown in nutrient-deficient conditions and decreases under fungal infection or aphid feeding (Kong Hu & Xu 2002).

Plant pathogen transmission: Kashina, Mabagala and Mpunami (2003) found that *A. conyzoides* is a weed host and disease reservoir of the *Tomato yellow leaf curl Tanzania virus* near tomato farms in Tanzania (Kashina, Mabagala & Mpunami 2003). *A. conyzoides* is a potentially important TYLCTZV reservoir because it occurs in abundant num¬bers within the tomato farms, it is associated with whitefly vectors, and it is found naturally infected with the virus. Elsewhere, *A. conyzoides* has been identified as host of *Ageratum* yellowvein virus.

Human health: *A. conyzoides* causes allergic reactions in some humans (Negi & Hajra 2007) and may pose a hazard to human health (Kohli & Batish 1996).

Case Study: Himalayan plant communities: The Shivilak Ranges form part of the North Indian Himalayas, well known for their rich floral diversity. However, *A. conyzoides* is poses a threat to the structure of natural plant grassland and forest communities and the dynamics of natural ecosystem processes (Singh *et al*. Undated A; Dogra *et al*. 2009). The weed replaces native grasses and medicinally important herbs and studies suggest it lowers biomass, biodiversity and creates homogenous monospecific stands (Dogra *et al*. 2009). It also negatively interferes with crop plants (wheat, chickpea, rice, maize, and sugarcane).

Uses

Medicinal: *Ageratum conyzoides* is an annual herb with a long history of traditional medicinal uses in many countries in the world, especially in the tropical and subtropical regions. A wide range of chemical compounds including alkaloids, flavonoids, chromenes, benzofurans and terpenoids have been isolated from this species. Extracts and metabolites from this plant have been found to possess pharmacological and insecticidal activities (Okunade 2002). *A. conyzoides* is widely utilized in traditional medicine by various cultures worldwide, although applications vary by region. In Central Africa it is used to treat pneumonia, but the most common use is to cure wounds and burns (Durodola 1977, in Ming 1999). Traditional communities in India use this species as a bacteriocide, antidysenteric, and antilithic (Borthakur and Baruah 1987, in Ming 1999), and in Asia, South America, and Africa, aqueous extract of this plant is used as a bacteriocide (Almagboul 1985, Ekundayo et al. 1988, in Ming 1999).

A crude material isolated from the leaves of *A. conyzoides*, a herb widely used by traditional medicine men for wound healing, is shown to exhibit antibacterial activity against *Staphylococcus aureus in vitro* (Durodola 1977).

It has been found that ingesting *A. conyzoides* can cause liver lesions and tumors. The plant contains the pyrrolizidine alkaloids lycopsamine and echinatine.

Insecticidal: *A. conyzoides* has natural biocide activity that may have agricultural insecticidal use, as shown by several research investigations in different countries. The leaves of the plant reportedly have mothrepellent properties (Pereira in 1929, in Ming 1999). The plant's terpenic compounds, mainly precocenes, with their antijuvenile hormonal activity are probably responsible for the insecticide effects. The affect of *A. conyzoides* on insect larva is to arrest juvenile development; this effect has been seen in *Musca domestica* (fly) larvae, *Chilo partellus* (Lepidoptera, Pyralidae), a sorghum pest, mosquitoes (*Culex quinquefasciatus*, *Aedes aegypti*, and *Anopheles stephensi*)

Essential oil extracts from the leaves of *A. conyzoides* caused significant morality of the maize grain weevil, *Sitophilus zeamais*. Mortality increased with the concentration of essential oil and the duration of exposure (Bouda *et al*. 2001).

Herbicidal: *A. conyzoides* showed strong inhibition of *Raphanus sativus* (radish) germination and growth in a bioassay. The leaves exhibited a greater suppression than the stem and root. The leaves of *A. Conyzoides* reduced about 70% of the growth of *Echinochloa crus-galli* var. *formosensis* and completely inhibited emergence of *Monochoria vaginalis* var. *plantaginea*) and *Aeschynomene indica* in calcareous soil condition. Application of *A. conyzoides* leaves caused about 75% paddy weed reduction and increased yield by 14% compared with a herbicide treatment. Three phenolic compounds were identified in the leaves, stem and root including gallic acid, coumalic acid, and protocatechuic acid, and catechin was found only in the stem. Phydroxybenzoic acid was detected in both *A. conyzoides* leaves and stem. Three additional putative allelochemicals were found in the leaves consisting of p-coumaric acid, sinapic acid, and benzoic acid. *A. conyzoides* might be a natural herbicide for weed control in paddy fields to reduce the dependence on synthetic herbicides (Xuan *et al*. 2004).

Notes
Ageratum is derived from the Greek "*a geras*", meaning non-aging, referring to the longevity of the flowers and the whole plant (Ming 1999).

Geographical range
Native range: *Ageratum conyzoides* ranges from Southeastern North America to Central America, but the center of origin is in Central America and the Caribbean. Most taxa are found in Mexico, Central America, the Caribbean, and Florida. *A. conyzoides* now is found in several countries in tropical and sub-tropical regions, including Brazil (Baker 1965; Lorenzi 1982; Correa 1984; Cruz 1985).
Known introduced range: *A. conyzoides* is a global weed. It is introduced and invasive in parts of the Pacific, for example Fiji. It is also reaking havoc in the North Indian Himalayas, including the Shivalik Ranges.

Local dispersal methods
Water currents: Seeds are mainly spread by wind and water (Holm *et al*. 1977, in PIER 2008).
Wind dispersed: Seeds are mainly spread by wind and water (Holm *et al*. 1977, in PIER 2008).

Management information
Integrated management: Experts recommend that future work on invasive plant species in the Shiwaliks in the Himalayas take an IPM approach. The problems associated with invasive species are aggravated due to lack of awareness, insufficient information on the species and its dimensions of the spread (Dogra, Kohli & Sood 2009). Batish (2008) recommends the compiling of comprehensive information on the invasive plant species, determining their possible modes of entry, understanding the biological and ecological attributes of the invasive plants, determining the socio-economic and ecological impact of the invasive plants in the area and disseminating this information to the general public and devising preventive measures for areas free of invasive

weeds.

Chemical: Pre-emergence application of simazine, atrazine, diuron, oxadiazon, oxyfluorfen, methazole ormetribuzin provides excellent control of this weed. Post-emergence application of 2.4-D controls established infestations (Rao 2000).

On the other hand eco-based, environment-friendly strategies for the effective control of *A. conyzoides* are suggested. Plant extracts of parthenin and eucalyptus (volatile essential oils) may hold promise in controlling *A. conyzoides* (Batish *et al*. 1997, Singh *et al*. 2002, in Batish *et al*. 2004) and some success has already been achieved using these and other natural plant extracts. For example, a study on the allelopathic effect of two volatile monoterpenes (cineole and citronellol) on *A. conyzoides* has revealed their potential for future weed management. Both the monoterpenes severely affected the germination, speed of germination, seedling growth, chlorophyll content and respiratory activity of *A. conyzoides* and after two weeks of exposure, the weed plants wilted. Cineole was the more toxic of the two monoterpenes (Singh Batish and Ravinder 2002).

The addition of activated charcoal, an inert material with high affinity for organic biomolecules, partly ameliorates the negative effects of *A. conyzoides* phenolic allelopathic root residues on rice (*Oryza sativa*) growth (Batish et al. 2009).

Field and crop management: Increased fallow length in slash-and-burn rice (*Oryza sativa* L.) Production systems of northern Laos decreases weed pressure (Roder *et al*. 1998). Compared with continuous rice treatments treatments with fallow or cowpea (*Vigna unguiculata*) in the previous year had 32% less herbaceous weed biomass and 90% fewer *A. Conyzoides*.

The timing of weed seedling emergence relative to the crop is important in planning and optimizing the time of weed control. Ekeleme and colleagues (2005) have predicted seedling emergence of tropical weed species, specifically in low-input and small-scale farms. To control weeds adequately, especially with limited use of herbicides, farmers need to know the timing and extent of weed seedling emergence before and during the growing season. Knowledge of when weeds emerge is equally applicable and beneficial to all forms of weed-management technologies (see: Ekeleme *et al*. 2005).

Research: To respond effectively to invasive species problems quantitative measurements of the impact of invasion on biodiversity are required (Schooler *et al*. 2006, in Dogra et al. 2009).

Lifecycle stages

Annual plants appear to have two great advantages: they reproduce early, so they have the potential for very high intrinsic rate of increase, and they can survive adverse condition as dormant seeds in the soil (Crawley, 1997, in Hassan Undated). *A. conyzoides* has the potential to produce many seeds (94,772 seeds per plant) and to shed seeds over extended times (5 to 8 months), as well as its extraordinary physiological plasticity, has enhanced its persistence in arable fields (Ekeleme *et al*. 2005). Invasiveness is enhanced by its ability to emerge in abundance (1000 plants per meter squared) (Anonymous 2000, in Ekeleme *et al*. 2005).

One plant of *A. conyzoides* may produce up to 40 000 seeds, with up to half of seeds germinating (Holm *et al*. 1977, in PIER 2008).

A. conyzoides flowers from July to March in India (Batish 2008). For the plant of equal biomass (both whiteand violet-flowered), Hassan (Undated) found that the white-flowered produce more flowers and attract more insect pollinators than violet ones.

Compiled by: IUCN/SSC Invasive Species Specialist Group (ISSG)

To contribute information, please contact Shyama Pagad.

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Eichhornia crassipes



Taxonomic name: *Eichhornia crassipes* (Mart.) Solms
Synonyms: *Eichhornia speciosa* Kunth, *Heteranthera formosa*, *Piaropus crassipes* (Mart.) Raf., *Piaropus mesomelas*, *Pontederia crassipes* Mart. (basionym)
Common names: aguapé (Portuguese-Brazil), bekabe kairanga (Fiji), bung el ralm (Palauan), bung el ralm (Palau), floating water hyacinth, jacinthe d'eau (French), jacinto de agua (Puerto Rico), jacinto-aquatico (Portuguese), jal khumbe (Fiji), jal kumbhi (Hindi-India), lechuguilla (Spanish), lila de agua (Dominican Repbulic), lirio acuatico, mbekambekairanga (Fijian), riri vai (Cook Islands), wasserhyazinthe (German), water hyacinth (English), water orchid, wota haisin (Papua New Guinea) Organism type: aquatic plant

Originally from South America, Eichhornia crassipes is one of the worst aquatic weeds in the world. Its beautiful, large purple and violet flowers make it a popular ornamental plant for ponds. It is now found in more than 50 countries on five continents. Water hyacinth is a very fast growing plant, with populations known to double in as little as 12 days. Infestations of this weed block waterways, limiting boat traffic, swimming and fishing. Water hyacinth also prevents sunlight and oxygen from reaching the water column and submerged plants. Its shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems.

Description
E. crassipes is a free-floating aquatic macrophyte growing generally to 0.5m in height but to nearly 1 metre in height in some southeast Asian locations (Gopal 1987, in Batcher Undated). *E. Crassipes* may form dense floating mats. Its leaves are thick, waxy, rounded, and glossy and rise well above the water surface on stalks. They are broadly ovate to circular, 10-20cm in diameter, with gently incurved, often undulate sides. Leaf veins are dense, numerous, fine and longitudinal. Leaf stalks are bulbous and spongy. The stalk is erect, to 50cm long, and carries at the top a single spike of 8-15 showy flowers. The flowers have six petals, purplish blue or lavender to pinkish, the uppermost petal with a yellow, blue-bordered central splotch. Its roots are purplish black and feathery (Gopal 1987, in Batcher Undated).

E. Crassipes forms a shoot consisting of a branched, stoloniferous rhizome, 6cm in diameter and up to 30cm in length, with several short internodes. Each node bears a leaf and roots. Axillary buds, which can also form stolons, grow at an angle of 60 degrees from the rhizome and remain at that angle or bend upward in dense stands, or become horizontal in open stands. Plants on the edge of a mat form stolon buds while those in the middle may not. Stolons are purplish violet and extend up to 50cm or more in length and are highly variable in diameter (Gopal 1987, in Batcher Undated).

Leaves form as the axillary bud grows, rupturing a tubular leaf-like structure called a "prophyll." As the internode between the first leaf and the prophyll elongates, roots are produced at the node bearing the primary leaf. Foliage leaves are formed after. Foliage leaves are petiolate with a glossy sheen, and arearranged spirally, appearing to be in a rosette. Each leaf consists of a petiole, isthmus (between petiole and blade) and blade. The petiole bears a large membranous stipule, which forms a sheath around the next younger leaf. Petioles are spongy and measure up to 5cm in diameter and 30-50cm in length (maximum 125cm). They may be elongated, swollen in the

middle and tapering towards the blade or they may form a bulbous float (Gopal 1987, in Batcher Undated) containing air-filled lacunate tissue (Sculthorpe 1985, in Batcher Undated).

As much as 50% of a single water hyacinth's biomass can be roots. Roots are adventitious and fibrous, 10- 300cm in length. As many as 70 lateral roots percm give the roots a feathery appearance. They are darkviolet to bluish or pinkish violet (though whitish if grown in total darkness) and contain soluble pigments, including anthocyanins that may protect the root from herbivory (Gopal 1987, in Batcher Undated).

Flowers are borne terminally on a lavender spike on an elongated peduncle and are subtended by two bracts. The lower bract has a distinct blade. Each spike has 4-25 flowers (maximum 35) with 8-15 being the most common. The perianth tube is 1.5-1.75cm long with a green base and pale top. Tepals are ovate to oblong, thin, lilac and up to 4cm long. The posterior tepal (labellum) has a central bright yellow diamondshaped region surrounded by a deep blue border with bright red radiating lines. When young, this labellum has a green spot. There are six stamens (sometimes 5 or 7) having curved filaments with glandular hairs. Three are small and close to the perianth tube. Anthers are violet and measure 1.4-2.2mm long (Gopal 1987, in Batcher Undated).

The fruit is a thin-walled capsule enclosed in a relatively thick-walled hypanthium developed from the perianth tube. Mature seeds can number 450 per capsule, are 4 x 1mm, with an oval base and tapering apex. The coat has 12-15 longitudinal ridges (Gopal 1987, in Batcher Undated).

Similar Species
Limnobium spongia

Occurs in:
estuarine habitats, lakes, urban areas, water courses, wetlands

Habitat description
Water hyacinth now flourishes in all continents but Europe (Lindsey and Hirt 1999, in Williams Undated) where it does exist but doesn't flourish as a result of climatic conditions. *E. crassipes* grows in shallow temporary ponds, wetlands and marshes, sluggish flowing waters, lakes, reservoirs and rivers (Batcher Undated). Plants can tolerate extremes of water level fluctuation and seasonal variations in flow velocity, and extremes of nutrient availability, pH, temperature and toxic substances (Gopal 1987, in Batcher Undated). Growth by water hyacinth is largely exuberated by nutrient rich waters, particularly those rich in nitrogen, phosphorus and potassium (FAO Undated). Originating from the tropical regions of South America, this weed exhibits frost sensitivity (Biosecurity New Zealand Undated) and does not tolerate brackish water (Holm *et al*. 1977). Salinity can limit or modify its distribution (for example, in the coastal lagoons of West Africa, where water hyacinth accumulates during the wet season and is reduced to saline regions during the dry season).

General impacts
E. crassipes is one of the world's worst weeds (Holm *et al*. 1977, in Room and Fernando 1992). People have spread it to most tropical and subtropical regions in the world where it forms thick mats that cover rice paddies, clog irrigation channels, impede navigation, halt fishing, sweep away buildings during floods and foster breeding by disease-transmitting mosquitoes (Carter 1950, Chow *et al*. 1955, Williams 1956, Kotalawala 1976, in Room and Fernando 1992). Doubling in biomass every 6 to 18 days, the exact time being dependent on location and time of year (Lindsey and Hirt 1999, in Williams Undated), this weed rapidly invades water-ways and has caused problems for people around the globe. Populations living along Lake Victoria in Africa have been negatively affected by the weed which clogged water ways, resulted in the closure of a hydroelectric plant at Jinga and increased cases of vector borne diseases (Williams Undated). In Papua New Guinea water hyacinth disrupted water transport by canoes, dinghies and larger vessels, obstructing people's access to schools, health centres, government services, food gardens, fishing grounds and local markets (Julien and Orapa 2001, in Plant Protection Services

2006).

Invasive plant theory predicts that a release from environmental constraints due to altered hydrology can often lead to a successful invasion (Galatowitsch *et al*. 1999, in Toft 2000). In other words: disrupted or modified environments that have been altered by humans pave the way for invasive species' establishment. Disruptions of wetland ecosystems involving irrigation canals, hydroelectric projects and construction of artificial lakes have made areas particularly susceptible to invasion by water hyacinth (Barret 1989, in Toft 2000). Dams are thought to have exuberated the effects of water hyacinth in the Sacramento/San Joaquin Delta in California, where the weed was present in 1947 but did not begin to hinder boat traffic until the 1980s (Toft 2000).

Environmental problems associated with the water hyacinth are exuberated in warm areas where the weed grows throughout the year and develops into dense large, free-floating, monospecific islands or mats which compete with other aquatic species for light, nutrients and oxygen (Gopal 1987, in Batcher Undated; FDEP Undated; Toft 2000). These mats shade out native submersed plant species and uproot native emergentspecies (FDEP Undated). They reduce dissolved oxygen levels and light, significantly altering ecosystems and plant and animal communities. Low oxygen levels harms native fish populations (FDEP Undated) and fish spawning areas may be reduced, as well as critical waterfowl habitat degraded (Schmitz *et al*. 1993, in Batcher Undated). Mats also deposit large amounts of organic matter which increases the organic content of sediments and greatly accelerates succession patterns, allowing emergent and riparian vegetation to colonise (Penfound and Earle 1948, Trivedy *et al*. 1978, Gopal 1987, Woods 1997, in Toft 2000).

E. crassipes has a detrimental impact on water use by humans. In drainage canals it reduces the flow, which can result in flooding and damage to canal banks and structures. In irrigation canals it impedes flow and clogs intakes of pumps used for irrigation. Water flow patterns have been disrupted in utility cooling reservoirs. Water hyacinth interferes with navigation of both recreational and commercial craft, negatively impacting fisherman, sports-fisherman, water-skiers and swimmers in recreational waters. Limitations on water use can reduce real estate values and tourism (Batcher Undated). Economic losses may be the result of attempts to control the weed. Manual removal of the weed in China alone cost an estimated 100 million RMB yuan (US$12m) each year but was neither economic nor effective (Jianqing *et al*. 2001).

Uses

There has been some use of *E. crassipes* for the removal of nutrients and heavy metals from sewage and sludge ponds (bioremediation) (Vietmeyer 1975, in Batcher Undated). In Kenya the experimental use of water hyacinth as an organic fertiliser and animal feed has been undertaken in places such as flower farms (The Nation Nairobi 2004). However there is some controversy as to the effect of the fertiliser on the soil due to its highly alkaline PH value (>9).

In China the weed was widely used as animal food from the 1950s to the 1970s. As at that time, the economy in rural areas was very depressed and there was great shortage of food for animals. It was also used for fertiliser in a few areas. Since the end of 1980s the use of water hyacinth has fallen greatly and its sole use now is for feeding ducks and as a test plant for the purification of polluted water (Jianqing *et al*. 2001).

Notes

A useful resource on the spread, impact and control of water hyacinth is: *M.H. Julien, M.P. Hill, T.D. Center and Ding Jianquig (eds.). Biological and Integrated Control of Water Hyacinth Eichhornia crassipes (Proceedings PR102 2001)*.

Geographical range

Native range: Water hyacinth is thought to have originated in the Amazon basin and the extensive lakes and marshes of the Pantanal region of western Brazil (Barrett 1989, in Batcher Undated).
Introduced range: *E. crassipes* now has a near worldwide distribution throughout the tropics and

has spread to more than 50 countries on five continents (Mansor 1996, Barrett 1989, Gopal 1987, in Batcher Undated).

Introduction pathways to new locations
For ornamental purposes: Water hyacinth has an attractive purple flower which has made it a favourite amongst ornamental pond and botanical garden enthusiasts. As a result humans have spread it widely and due to its fast growth rate it now flourishes in all continents but Europe (Lindsey and Hirt 1999, in Williams Undated).
Other: In the 1950s and 1960s, water hyacinth was distributed widely into almost all provinces in China for animal food. After artificial transplanting and mass rearing and breeding, water hyacinth was distributed to further areas in the 1970s (Jianqing *et al*. 2001).
Pet/aquarium trade: Most spread can be attributed to deliberate planting of water hyacinth in ponds or dams as an ornamental, or use in aquariums. Unwanted plant material is discarded into creeks, rivers and dams is a major mode of dispersal (Burton 2005).
Road vehicles (long distance):
Translocation of machinery/equipment: Seeds are translocated by machinery (Burton 2005).

Local dispersal methods
Boat: Water hyacinth can be spread by contaminated boating and waterway equipment (Burton 2005).
Hikers' clothes/boots: Seeds may be carried on boots (Burton 2005).
Off-road vehicles:
On animals (local): Seeds are carried in water flow, mud and by birds (Burton 2005).
Translocation of machinery/equipment (local): Seeds are translocated by machinery (Burton 2005).
Water currents: Stolons, solitary plants and drifting mats are readily distributed by water currents, winds andboat traffic. High water flows and floods can move infestations to new locations (Burton 2005).

Management information
Control strategies must address both watershed management (to reduce nutrient supply) and direct weed control (eg: by introduction of biological control agents) (FAO Undated). Nutrient run-off into infestations should be minimised. Heavy nutrient loadings in water come from erosion of cultivated land, cattle yards, domestic and municipal sewerage outfalls and wastewater discharges from factories. This nutrient inflow can be reduced or prevented by treating water before discharging it into waterways (Burton 2005).

Preventative measures: A Risk assessment of Eichhornia crassipes for Australia and the Pacific was
prepared by Pacific Island Ecosystems at Risk (PIER) using the Australian risk assessment system (Pheloung, 1995). The result is a score of 14 and a recommendation of: reject the plant for import (Australia) or species likely to be a pest (Pacific).

Mechanical: Small infestations of *E. crassipes* can be controlled by pulling (Randall and Rice. Unpub., In Batcher Undated). Specially designed harvesting machines may also be utilised. Permanent drainage of the water body will control *E. crassipes* (Smith *et al*. 1984) but may not be appropriate if the area is environmentally valuable.

Reproduction
Water hyacinth reproduces both vegetatively and sexually (Penfound and Earle 1948, Gopal and Sharma 1981, in Langeland and Burks Undated.). The plant flowers year-round in mild climates, producing abundant amounts of long-lived seeds (Penfound and Earle 1948; Sculthorpe 1971; FAO Undated). However it has been reported that sexual reproduction is limited and although the plant flowers profusely few observers have seen seeds or seedlings in the field (Gopal 1987, in Batcher Undated). Maximum fruiting occurs in 90% humidity and at 22.5°C to 35°C (Gopal 1987, in Batcher Undated). Several species of bee pollinate the flowers and several researchers report a highlvel of self-compatibility (Batcher Undated). High light intensity and altering high and low

temperatures (5°C to 40°C) favour germination (Batcher Undated).

Vegetative reproduction is more important. Water hyacinth grows and spreads rapidly under favourable temperature and nutrient conditions (Batcher Undated). Stolon buds develop that bear offshoots from axillary buds and stolons are readily distributed by water currents, winds and boat traffic.

This species has been nominated as among 100 of the "World's Worst" invaders

Reviewed by: Major update under progress

Compiled by: IUCN/SSC Invasive Species Specialist Group (ISSG)
To contribute information, please contact Shyama Pagad.

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Source:http://www.issg.org/database/species/ecology.asp?si=70&fr=1&sts=sss&lang=EN

Parthenium hysterophorus

Taxonomic name: *Parthenium hysterophorus* L.
Synonyms: *Parthenium lobatum* Buckl.
Common names: camomille balais (French-Reunion (La Réunion)), camomille z'oiseaux (French-Reunion (La Réunion)), congress grass (English), fausse camomille (French-New Caledonia), herbe blanche (French- Reunion (La Réunion)), Karottenkraut (German), parthenium weed (English), ragweed parthenium (English), Santa Maria feverfew (English), whitetop weed (English)
Organism type: herb

Parthenium hysterophorus is an annual herb that aggressively colonises disturbed sites. Native to Mexico, Central and South America, Parthenium hysterophorus was accidentally introduced into several countries including Australia, India, Taiwan and Ethiopia. In some areas it has become an extremely serious agricultural and rangeland weed. Parthenium hysterophorus is also known to be allergenic to some people and consumption by livestock can taint meat.

Description
An erect ephemeral herb known for its vigorous growth. It is light green with branching stems, finely lobed leaves and grows up to 1.5 metres, occasionally reaching 2m in deep rich soils. Young plants form a basal rosette of strongly dissected leaves that are up to 30cm in length. Once stem elongation is initiated, smaller leaves are produced and the plant becomes much-branched in its extremities.

Occurs in:
agricultural areas, range/grasslands, ruderal/disturbed, scrub/shrublands, urban areas

General impacts
Infestations of parthenium weed can degrade natural ecosystems. The plant can produce serious allergenic reactions in humans. Parthenium aggressively colonises disturbed sites and has major impacts on pasture and cropping industries, spreading to and impacting on new areas. Outcompetes native species, in part due to allelopathy.

Geographical range
Native range: Native to Mexico, Central and South America.
Known introduced range: An aggressive invader of agricultural and rangeland habitats in Australia, India, Taiwan and Ethiopia. Also present in Papua New Guinea, Madagascar, South Africa, Caribbean region and Florida USA.

Introduction pathways to new locations
Agriculture: Thought to have been introduced into Ethiopia and India with contaminated cereal grain, and into Australia in contaminated pasture seed from the USA.

Local dispersal methods
On animals:
Other (local): Transport of hay and grain.

Road vehicles:
Translocation of machinery/equipment (local):
Water currents:

Management information
Control of parthenium weed can be managed using a combination of methods depending on the site, including biological control agents, pasture management, cultivation and chemicals.

Preventative measures: Emphasis must be laid on establishing detection/monitoring procedures and stopping the spread of parthenium weed *via* vehicles and as a contaminant. A Risk assessment of *Parthenium hysterophorus* for Australia was prepared by Pacific Island Ecosystems at Risk (PIER) using the Australian risk assessment system (Pheloung, 1995). The result is a score of 18 and a recommendation of: reject the plant for import (Australia) or species likely to be a pest (Pacific).

Biological: Biological control using insects and fungi is being pursued in Australia and in India.

Reproduction
Sexual reproduction. Highly prolific. An average plant can produce 15,000 seeds and large plants are known to produce 100,000 seeds.

Lifecycle stages
Germination temperatures for Parthenium occur across the 8 to 30° C range with the optimum germination temperature being 22 to 25° C. Persistence tests demonstrated that more than 70% of parthenium seeds buried at 5cm below the soil surface survived for at least 2 years whereas surface-lying seeds survived for no longer than 6 months. Parthenium weed seeds were found to be very persistent in the soil and there was relatively little change in their abundance over an 18 month period. The germination rate of parthenium weed seeds was also significantly faster than that of all other species present (Sheldon Navie, 2003).

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Lantana camara

The Asia-Pacific Forest Invasive Species Network (APFISN) has been established as a response to the immense costs and dangers posed by invasive species to the sustainable management of forests in the Asia-Pacific region. APFISN is a cooperative alliance of the 33 member countries in the Asia-Pacific Forestry Commission (APFC) - a statutory body of the Food and Agricultural Organization of the United Nations (FAO). The network focuses on inter-country cooperation that helps to detect, prevent, monitor, eradicate and/or control forest invasive species in the Asia-Pacific region. Specific objectives of the network are: 1) raise awareness of invasive species throughout the Asia- Pacific region; 2) define and develop organizational structures; 3) build capacity within member countries and 4) develop and share databases and information.

Scientific name:*Lantana camara* L.
Synonyms: *Camara vulgaris, Lantana scabrida*
Common names: Sleeper weed, lantana, wild sage
Taxonomic position: Division: Magnoliophyta
Class: Magnoliopsida, Order: Lamiales
Family:Verbenaceae.

Distribution: 0 0 Naturalized in approximately 60 countries or island groups between 35 N and 35 S latitudes. Occurs widely in the Asia-Pacific region, Australia, New Zealand, Central and South America, West Indies and Africa. The plant is still widening its range.

Habit: *Lantana camara* is a low, erect or subscandent, vigorous shrub which can grow to 2 - 4 meters in height. The leaf is ovate or ovate oblong, 2 - 10 cm long and 2 - 6 cm wide, arranged in opposite pairs. Leaves are bright green, rough, finely hairy, with serrate margins and emit a pungent odour when crushed. The stem in cultivated varieties is often non- thorny and in weedy varieties with recurved prickles. It is woody, square in cross section, hairy when young, cylindrical and up to 15 cm thick as it grows older. Lantana is able to climb to 15 m with the support of other vegetation. Flower heads contain 20 - 40 flowers, usually 2.5 cm across; the colour varies from white, cream or yellow to orange pink, purple and red. Flowering occurs between August and March, or all year round if adequate moisture and light are available. Pollinators include lepidopteran species and thrips. The fruit is a greenish blue-black colour, 5 - 7 mm in diameter, drupaceous, shining, with two nutlets; seed setting takes place between September to May with 1 - 20 seeds on each flower head. Mature plants produce up to 12,000 seeds annually. Seed germination occurs when sufficient moisture is present; germination is reduced by low light conditions. The root system is very strong with a main taproot and a mat of many shallow side roots.

Seed dispersal: Fruit dispersal is through frugivorous birds, fox and rodents. Germination rate of fresh seed is generally low, but the germinability gets improved when the seed passes through the digestive system of birds and animals. High light intensity and soil temperature will stimulate germination of seeds which means that clearing of forest areas, inappropriate burning and other disturbances will help spread of the weed. Seeds are capable of surviving the hottest fires.

Habitat: The diverse and broad geographic distribution of lantana is a reflection of its wide ecological tolerance. It occurs in diverse habitats and on a variety of soil types. Lantana generally grows best in open, un-shaded conditions such as wastelands, the edges of rain forests, on beachfronts, in agricultural areas, grasslands, riparian zones, scrub/shrub lands, urban areas, wetlands and forests recovering from fire or logging. Roadsides, railway tracks and canal banks

are favored by the species. It doesn't grow at ambient o temperatures below 5 C. The plant is found at altitudes from sea level to 2,000 m and can thrive very well under rainfall ranging from 750 to 5000 mm per annum. Lantana does not invade intact rain forests, but is found on their margins. Where natural forests have been disturbed through logging creating gaps, Lantana encroaches in the gaps. Further logging aggravates the condition and allows lantana to spread or become thicker in its growth. It cannot survive under dense, intact canopies of taller native forest species. The plant is susceptible to frosts and low temperatures, saline soils, boggy or hydromorphic soils, low rainfall, coralline soils with poor water-holding capacities and high incidence of tropical hurricanes.

Mode of infestation: Lantana grows impenetrable thickets that can suppress the growth of native species. The plant can also grow individually in clumps or as dense thickets, crowding out more desirable species. In disturbed native forests it can become the dominant understorey species, disrupting succession and decreasing biodiversity. As the density of Lantana in natural forest areas increases, species richness decreases. Layering is a form of vegetative reproduction in Lantana where the stem send roots into soil, allowing it to quickly form very dense stands and spread short distances.

Uses: Lantana is mainly used as a herbal medicine and in some areas as firewood and mulch. In some countries it is planted as a hedge to contain or keep out livestock. Leaf extracts of Lantana exhibit antimicrobial, fungicidal, insecticidal and nematicidal properties. Verbascoside, which possesses antimicrobial, immunosuppressive and antitumor activities, has been isolated from Lantana. Lantana oil is sometimes used for the treatment of skin itches, as an antiseptic for wounds and externally for leprosy and scabies. Also, the plant extracts are used in folk medicine for the treatment of cancers, chicken pox, measles, asthma, ulcers, swellings, eczema, tumors, high blood pressure, bilious fevers, catarrhal infections, tetanus, rheumatism and malaria.
The stems of Lantana, if treated by the sulphate process, can be used to produce writting and printing paper. Its other uses include, making baskets and temporary shelters and fuel for cooking and heating. In some areas, Lantana may provide shelter and vital winter food for many native birds. A number of endangered bird species utilize Lantana thickets when their natural habitat is unavailable. In Australia, the vulnerable black-breasted buttonquail, *Turnix melanogaster,* feeds and roosts in Lantana thickets adjacent to vine forest, which is its more favoured habitat. While buttonquails prefer intact vine forest, Lantana provides an important temporary refuge for them between forest remnants. In central Kenya, where natural riverine thickets have been almost completely cleared, the endangered bird *Turdoides hindei*, has become dependent on Lantana thickets, and unless sufficient suitable natural habitat can be restored the survival of this species depends on the retention of Lantana bushes. Apart from benefiting some bird species, lantana is a major nectar source for many species of butterflies and moths. The plant can prevent soil compaction and erosion and is a source of organic matter for pasture renovation. In Australia, ornamental Lantana is an excellent source of income in the nursery sector.

Threat and damage: Lantana threatens natural habitats and native flora and fauna. In Australia, nineteen endangered and threatened species are under threat due to the weed. It infests pastures, grazing lands, orchards and crops like, tea, coffee, oil palm, coconut and cotton, and reduces the economic viability of the crops. The allelopathic qualities of Lantana reduce the vigour of native plant species and limits their productivity. Lantana infestations can sometimes be so persistent that they can completely stall the regeneration of rain forests for several years. In the Galapagos Archipelago, Lantana competition has caused extinction of the shrub *Linum cratericola* (Linaceae), and it is also a major threat to other endangered plants. The replacement of native pastures by Lantana is threatening the habitat of the sable antelope inKenya. Lantana can affect agriculture in a number of ways. In plantations in South-East Asia and the Pacific Islands, besides reducing the productivity of crops, Lantana also interferes with harvesting. In Queensland, Australia, loss of pasture is the greatest single cost of Lantana invasion in grazing areas. Lantana has also been identified as a potential threat to more than 60 plant and animal species of conservation significance in Queensland.
In dense stands of Lantana, the capacity of the soil to absorb rain is lower than under good grass

cover. This could potentially increase the amount of run-off and the subsequent risk of soil erosion in areas infested with the weed. Lantana has been implicated in poisoning of a number of animals including cattle, buffalo, sheep and goats since its leaves and seeds contain the toxic triterpenoids, Lantadene A and Lantadene B. Ingestion of the plant parts can cause pink nose disease, jaundice and muzzle in cattle. Heavy outbreaks of Lantana poisoning occur during drought. The plant has many secondary impacts, especially in tropical countries where it can harbour several serious pests. Malarial mosquitoes in India and tsetse flies in Rwanda, Tanzania, Uganda and Kenya shelter in Lantana bushes and cause serious health problems.

Control:

Mechanical control: Stickraking, bulldozing, ploughing and grubbing (medium sized plants) are the main methods of control. Hand cutting using brush cutters, hand pulling, chain pulling and flame weeding are also used. Re-growth will be imminent if the rootstock is not removed while weeding. In India, use of elephants to uproot Lantana was practiced. However, mechanical control is suitable only for small areas and is not recommended in areas susceptible to erosion. Fire is often used prior to mechanical or herbicidal control to improve their effectiveness or as a follow-up to such methods. Fire itself can provide some control when used under the right conditions, especially if the fires are hot and the Lantana is actively growing. But, while using fire as a management tool, the risk to people and property must be avoided. Burning is not recommended in natural forest areas and vine thickets for various reasons. Re-vegetation of a treated site by planting trees or encouraging naturally occurring seedlings is a key component of a Lantana management program. Another possibility of revegetation is sowing a pasture that outcompetes with and smothers Lantana. Preventing grazing for the first six months to one year will assist the growth of the pasture.

Chemical: During the active growing period, use of fluroxypyr @ 0.5 to 1 liter / 100 l water, glyphosate @ 1l / 100 l water, triclopyr @ 1l / 60 l of water and Grazon DS (300 g/l triclopyr + 100 g/l picloram) @ of 350 ml/100 l water per ha is recommended. Post emergence -1 application of glyphosate (2 kg ha) may provide good control. Applications are to be done when there is good soil moisture and during the active growing period, either in the morning or late in the afternoon.

Biological: None of the over 40 biocontrol agents released in 32 countries have been successful in controlling the weed effectively. However, of the species that have becomeestablished, some have had a major impact on the weed, including the sap-sucking bug, *Teleonemia scrupulosa* (Hemiptera), leaf mining beetles, *Octotoma scabripennis* (Coleoptera) and *Uroplata girardi* (Coleoptera) and the seedfeeding fly, *Ophiomyia lantanae* (Diptera). Apart from these agents, a sap-sucking bug, *Leptobyrsa decora*, a mealybug, *Phenacoccus parvus*, and a rust fungus, *Prospodium tuberculatum* are used in Australia for the biocontrol of Lantana. Many of the leaf feeding insects are unable to maintain high enough populations to cause significant damage to Lantana, since it drops leaves to withstand extended periods of drought. *Puccina lantanae*, a rust of tropical origin, is pathogenic to a wider range of weedy cultivars of Lantana than *P. tuberculatum*. In inoculation trials with this fungus, successful infection has been obtained with ten biotypes to date: two from Australia, three from South Africa, two from Madagascar and one each from Thailand, India and Hawaii. Further studies are underway. Release of a Lantana leaf feeding mirid, *Falconia intermedia* in South Africa and Australia was frustrated by winter leaf loss in Lantana and failure in persistence of the insect. Several other candidate agents are undergoing host specificity and potential impact studies.
Biological control, in itself, has not been effective in controlling Lantana infestation wherever it has been attempted, the main reasons being the extreme variability of the plants, the extensive climatic range it invades and the high level of parasitism on the natural enemies. On the other hand, mechanical and cultural methods are expensive and most often ineffective. Chemical methods are effective in the short-term, but the chemicals are environmentally damaging and cannot be used on a long-term basis. In this situation, biological, mechanical, chemical and cultural methods will have to be used in an integrated way to control Lantana infestation in our ecosystems.

Strategies to avoid further spread: Preventing the spread of Lantana is the most cost-effective management tool. This would require the restriction of further importation of Lantana into your country, restriction of sale and use of Lantana in gardens and strategically controlling infestations wherever it currently occurs.

This fact sheet is compiled and edited by Dr. K.V. Sankaran, APFISN Coordinator (sankaran@kfri.org), Kerala Forest Research Institute, Peechi, Kerala, India, on behalf of the Asia-Pacific Forest Invasive Species Network. For more information on APFISN and its activities, please contact your national focal point or the APFISN Coordinator or Mr. Patrick Durst, Senior Forestry Officer, FAO Regional Office for Asia and the Pacific, 39 Phra Atit Road, Bangkok. E-mail: patrick.durst@fao.org. The fact sheet is supported by the Food and Agriculture Organization of the United Nations (FAO) and USDA Forest Service.

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