RISK ANALYSIS REPORT OF NON-NATIVE ORGANISMS IN BELGIUM

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Risk analysis of the Pallas's squirrel *Callosciurus erythraeus*

Wallonie

Université de Liège

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Contents

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Etienne Branquart (Cellule Espèces Invasives, Service Public de Wallonie) developed the risk analysis template that was used for this exercise.

The general process of drafting, reviewing and approval of the risk analysis for selected invasive alien species in Belgium was attended by a steering committee, chaired by the Federal Public Service Health, Food chain safety and Environment. RBINS/KBIN was contracted by the Federal Public Service Health, Food chain safety and Environment to perform PRA's for a batch of species. ULg was contracted by Service Public de Wallonie to perform PRA's for a selection of species. INBO and DEMNA performed risk analysis for a number of species as in-kind contribution.

Steering committee members were:

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Rationale and scope of the Belgian risk analysis scheme

The Convention on Biological Diversity (CBD) emphasises the need for a precautionary approach towards non-native species. It strongly promotes the use of robust and good quality risk assessment to help underpin this approach (COP 6 Decision VI/23). More specifically, when considering trade restrictions for reducing the risk of introduction and spread of a non-native organisms, full and comprehensive risk assessment is required to demonstrate that the proposed measures are adequate and efficient to reduce the risk and that they do not create any disguised barriers to trade. This should be seen in the context of WTO and free trade as a principle in the EU (Baker et al. 2008, Shine et al. 2010, Shrader et al. 2010).

This risk analysis has the specific aim of evaluating whether or not to install trade restrictions for a selection of absent or emerging invasive alien species that may threaten biodiversity in Belgium as a preventive risk management option. It is conducted at the scale of Belgium but results and conclusions could also be relevant for neighbouring areas with similar eco-climatic conditions (e.g. areas included within the Atlantic and the continental biogeographic regions in Europe).

The risk analysis tool that was used here follows a simplified scheme elaborated on the basis of the recommendations provided by the international standard for pest risk analysis for organisms of quarantine concern[1] *produced by the secretariat of the International Plant Protection Convention (FAO 2004). This logical scheme adopted in the plant health domain separates the assessment of entry, establishment, spread and impacts. As proposed in the GB non-native species risk assessment scheme, this IPPC standard can be adapted to assess the risk of intentional introductions of non-native species regardless the taxon that may or not be considered as detrimental (Andersen 2004, Baker et al. 2005, Baker et al. 2008, Schrader et al. 2010).*

The risk analysis follows a process defined by three stages : (1) the initiation process which involves identifying the organism and its introduction pathways that should be considered for risk analysis in relation to Belgium, (2) the risk assessment stage which includes the categorization of emerging non-native species to determine whether the criteria for a quarantine organism are satisfied and an evaluation of the probability of organism entry, establishment, spread, and of their potential environmental, economic and social consequences and (3) the risk management stage which involves identifying management options for reducing the risks identified at stage 2 to an acceptable level. These are evaluated for efficacy, feasibility and impact in order to select the most appropriate. The risk management section in the current risk analysis should however not been regarded as a full-option management plan, which would require an extra feasibility study including legal, technical and financial considerations. Such thorough study is out of the scope of the produced documents, in which the management is largely limited to identifying needed actions separate from trade restrictions and, where possible, to comment on cost-benefit information if easily available in the literature.

This risk analysis is an advisory document and should be used to help support Belgian decision making. It does not in itself determine government policy, nor does it have any legal status. Neither should it reflect stakeholder consensus. Although the document at hand is of public nature, it is important to realise that this risk assessments exercise is carried out by (an) independent expert(s)

[1] A weed or a pest organism not yet present in the area under assessment, or present but not widely distributed, that is likely to cause economic damages and is proposed for official regulation and control (FAO 2010).

who produces knowledge-based risk assignments sensu Aven (2011). It was completed using a uniform template to ensure that the full range of issues recognised in international standards was addressed.

To address a number of common misconceptions about non-native species risk assessments, the following points should be noted (after Baker et al. 2008):

- *Risk assessments are advisory and therefore part of the suite of information on which policy decisions are based;*
- *The risk assessment deals with potential negative (ecological, economic, social) impacts. It is not meant to consider positive impacts associated with the introduction or presence of a species, nor is the purpose of this assessment to perform a cost-benefit analysis in that respect. The latter elements though would be elements of consideration for any policy decision;*
- *Completed risk assessments are not final and absolute. New scientific evidence may prompt a re-evaluation of the risks and/or a change of policy.*

Executive summary

PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

Entry in Belgium	It is likely that the Pallas's squirrel could enter in Belgium by the way of natural spread from a population present at the Dutch border or by escaping from cages of pet traders or private citizens. The case of Dadizele, where Pallas's squirrels were successfully removed, also confirms a possible entry through the release of individuals.
Establishment capacity	From only a few individuals,Callosciurus erythraeus can establish viable populations. Thus, the Pallas's squirrel is likely to establish self-sustaining populations in Belgium and neighbouring areas if introduced because it has a high invasive capability and adaptive potential and because suitable climatic conditions, habitats and food supplies are met in our ecoregion.
Dispersion capacity	The Pallas's squirrel can spread from introduction places to new areas by using different elements of its perceptive range. The dispersal capacity of juveniles away from their natal home range is considered to be lower than 5 km/year. The mean areal expansion rate observed in Japan and Argentina varies between 6 and 22 km²/year and is known to increase after the establishment phase. Human assistance may also amplify the potential of expansion of C. erythraeus by translocation.

EFFECT OF ESTABLISHMENT

Environmental impacts	It is likely that the establishment of the Pallas's squirrel in Belgium and neighbouring areas will induce problems of herbivory, particularly because of its bark stripping behaviour in woodland areas, but also because of potential depredation in plantations and orchards. The predation on native fauna is expected to be very low and the transmission of pathogens could likely cause a risk but, currently, it is not documented enough. Competition with native species like Sciurus vulgaris has been mentioned but not proven as yet.

RISK MANAGEMENT

An important problem concerning the dispersal capacity of C. erythraeus is its possible undetection at first stages of invasion which may increase the risk of imperceptible diffusion.

Establishment of Pallas’s squirrel in Belgium is likely to occur either due to escape/release from captivity or from a natural expansion of the population established in the Netherlands near the Belgian border, where eradication actions are currently undertaken. The prohibition of Pallas’s squirrel import, trade and keepingcould be considered as an efficient measure for reducing the risk of entry to an acceptable level. As a transitional measure, drastic security rules including ear-tagging and systematic sterilization combined with an official surveillance system and the obligation to rapidly report any escape should be imposed for Pallas’s squirrels already kept in captivity.

Those preventive measures, linked to a good citizens’ awareness, have to be preferred over early detection and population control as the Pallas’s squirrel may easily establish feral populations after escape. Eradication actions are only feasible at the very beginning of the invasion process and are difficult to implement because of the species’ low detection rate at low densities, rapid expansion from the release site when suitable ecological conditions are met and strong public opposition towards killing actions. Besides that, it is necessary to have a good overview of the food supply available for the species to prevent the species expansion.

Résumé

PROBABILITE DE NATURALISATION ET DE DISSEMINATION DANS L'ENVIRONNEMENT

Introduction en Belgique	La probabilité d'introduction de l'écureuil à ventre rouge en Belgique, par expansion naturelle à partir de populations présentes à la frontière néerlandaise, est importante. Les individus s'échappant de captivité (animalerie, particuliers) représentent une autre voie d'entrée possible. Le cas de Dadizele, où l'écureuil à ventre rouge a été éradiqué avec succès, confirme la possibilité d'introduction de l'espèce par le biais d'individus échappés de cages.
Capacité de naturalisation	A partir de seulement quelques individus fondateurs, *Callosciurus erythraeus* est capable d'établir des populations viables. La Belgique et les régions limitrophes réunissent les conditions de vie (climat, ressources alimentaires, habitat) propices au développement de l'espèce. Ajoutons à cela la capacité d'invasion de l'écureuil à ventre rouge et son potentiel d'adaptation : en cas d'introduction, ce dernier est capable de former une population viable dans l'écorégion.
Capacité de dissémination	*C. erythraeus* peut étendre son aire de distribution à partir de zones d'introduction en utilisant différent éléments de dispersion présents dans son domaine de perception. La capacité de dispersion natale (qui concerne les juvéniles) est faible : moins de 5km/an. La capacité d'extension de l'aire de répartition observée au Japon et en Argentine varie entre 6 et 22 km²/an et peut se développer rapidement après la phase d'établissement. L'assistance humaine peut également accroître le potentiel d'expansion géographique de l'espèce par translocations d'individus.

EFFETS DE LA NATURALISATION

Impacts environnementaux	L'établissement de C. erythraeus pourrait avoir un impact négatif sur la flore indigène, particulièrement en raison de son comportement d'écorçage dans les zones boisées, mais également à cause de son potentiel de déprédation dans les plantations et les vergers. La prédation sur la faune indigène semble anecdotique et la transmission de pathogènes est un risque potentiel qui n'est pas scientifiquement documenté à ce jour. Une compétition avec la faune indigène tel que l'écureuil roux européen a été mentionnée dans divers articles sans être néanmoins prouvée jusqu'ici.

GESTION DU RISQUE

Un problème important qui concerne la capacité de dispersion de l'écureuil à ventre rouge est son faible taux de détection lors des premiers stades d'une invasion, ce qui augmente le risque de diffusion de l'espèce dans l'environnement.

L'arrivée de l'écureuil à ventre rouge en Belgique pourrait tout aussi bien être due à une remise en liberté intentionnelle ou accidentelle d'individus captifs qu'à une expansion naturelle à partir de la population établie à la frontière néerlandaise, où des actions d'éradication sont actuellement en cours.

L'interdiction d'importation, de commercialisation et de détention est considérée comme une mesure de gestion efficace pour réduire le risque d'entrée à un niveau acceptable. De façon transitoire, des mesures de sécurité drastiques (marquage, stérilisation systématique) devraient être appliquées aux individus déjà présents en captivité dans des parcs animaliers, ainsi que l'obligation de renseigner rapidement toute évasion dans le milieu naturel. Ces mesures de prévention, liées à une campagne de sensibilisation des citoyens, doivent être préférées à la mise en place d'un système de détection et de contrôle précoce, au vu des capacités d'invasion de l'écureuil à ventre rouge.

Les actions d'éradication ne sont possibles qu'au tout premier stade d'invasion. Elles sont difficiles à mettre en œuvre à cause de la difficulté de détection de l'espèce à faible densité, de l'expansion rapide de la population et de l'opposition publique envers des actions d'éradication. A côté de cela, il est important d'avoir une idée de la disponibilité alimentaire de l'espèce afin de prévenir son expansion.

Samenvatting

WAARSCHIJNLIJKHEID VAN VESTIGING EN VERSPREIDING (BLOOTSTELLING)

Introductie in België	De Pallas eekhoorn (of roodbuikeekhoorn) kan België binnenkomen door natuurlijke verspreiding vanuit populaties die zich ophouden aan de Nederlandse grens of door ontsnapping uit kooien van verkopers van huisdieren (hoewel de soort niet als huisdier gehouden mag worden) . Het geval van Dadizele, waar een populatie Pallas eekhoorns met succes verwijderd werd, bevestigt het belang van vrijgelaten individuen bij de vorming van nieuwe populaties.
Vestigingsvermogen	Een beperkt aantal individuen volstaat om leefbare populaties te vestigen. Door zijn hoog invasief vermogen en omdat de gepaste klimaatomstandigheden, habitats en voedselbronnen aanwezig zijn, bestaat bijgevolg de kans dat de soort zich na introductie in België en de omliggende gebieden handhaaft. In Vlaanderen hebben zich reeds populaties succesvol gevestigd uit ontsnapte individuen.
Verspreidingsvermogen	De Pallas eekhoorn kan zich gemakkelijk vanuit de introductieplaatsen naar nieuwe gebieden verspreiden. Het verspreidingsvermogen van onvolwassen dieren buiten het leefgebied waar ze zijn geboren, wordt geraamd op minder dan 5 km/jaar. De gemiddelde snelheid van de ruimtelijke expansie die in Japan en Argentinië werd waargenomen, varieert van 6 tot 22 km²/jaar en kan na de vestigingsfase nog oplopen. Translocatie van dieren door de mens kan de expansie van C. erythraeus nog verder in de hand werken.

EFFECTEN VAN VESTIGING

Milieu-impact	Het is waarschijnlijk dat de vestiging van de Pallas eekhoorn in België en omliggende gebieden sociaal-economische problemen zal veroorzaken, met name doordat deze soort in bosgebieden schors eet (bark-stripping), en door dit gedrag schade kan veroorzaken aan aanplantingen en boomgaarden. Verwacht wordt dat de predatie van inheemse fauna eerder beperkt zal blijven. De overdracht van pathogenen vormt weliswaar een risico, maar daarover zijn momenteel onvoldoende gegevens bekend. Competitie met inheemse soorten zoals de rode eekhoorn Sciurus vulgaris werden aangehaald, maar zijn tot dusver niet aangetoond.

RISICOBEHEER

Een van de voornaamste problemen voor een effectieve snelle respons op een introductie van C. erythraeus is dat de soort in het prille invasiestadium nauwelijks waarneembaar is, wat de kans op onopgemerkte introductie en verspreiding verhoogt.

Het is waarschijnlijk dat de Pallas eekhoorn zich in België zal vestigen door ontsnapping van populaties die in gevangenschap worden gehouden of door een natuurlijke verspreiding van populaties gevestigd in Nederland nabij de Belgische grens, waar weliswaar momenteel uitroeiingscampagnes worden gevoerd. Het verbod op de invoer, verkoop en het houden van de soort kan dan ook beschouwd worden als een efficiënte maatregel om het risico op introductie tot een aanvaardbaar niveau terug te dringen. Als overgangsmaatregel voor de dieren die momenteel in gevangenschap leven in zoo, dient te worden teruggegrepen naar drastische beveiligingsmaatregelen, waaronder het oormerken en het systematische steriliseren, samen met een officieel toezichtsysteem en de onverwijlde meldplicht van ontsnapte exemplaren.

Preventieve maatregelen, gecombineerd met goede sensibiliseringscampagnes bij de burgers, dienen de voorkeur te krijgen boven een vroege detectie en populatiecontrole omdat na ontsnapping verwilderde populaties van Pallas eekhoorn zich snel kunnen vestigen. Uitroeiingsacties zijn enkel haalbaar in een pril stadium van invasie en blijken bijzonder moeilijk te implementeren door de lage detectiekans bij lage densiteiten, de snelle verbreiding vanaf de plaats van uitzetting en door het mogelijk lage draagvlak bij het publiekvoor het afmaken van deze aaibare dieren.

STAGE 1: INITIATION

Precise the identity of the invasive organism (scientific name, synonyms and common names in Dutch, English, French and German), its taxonomic position and a short morphological description. Present its distribution and pathways of quarantine concern that should be considered for risk analysis in Belgium. A short morphological description can be added if relevant. Specify also the reason(s) why a risk analysis is needed (the emergency of a new invasive organism in Belgium and neighbouring areas, the reporting of higher damage caused by a non native organism in Belgium than in its area of origin, or request made to import a new non-native organism in the Belgium).

1.1 ORGANISM IDENTITY

Scientific name : *Callosciurus erythraeus* Pallas, 1779
Common names: Pallas's squirrel (GB), Pallas'eekhoorn (roodbuikeekhoorn) (NL), Pallas-Hörnchen (DE), Ecureuil à ventre rouge (Ecureuil de Pallas, Ecureuil de Formose) (F).
Taxonomic position: Chordata (Phylum) > Mammalia (Class) > Rodentia (Order) > Sciuridae (Family).

Note: Within the Sciurid family,Wilson and Reeder (2005) consider 15 species in the genus *Callosciurus,* all coming from Southeast Asia: *C. adamsi*, *C. albescens*, *C. baluensis*, *C. caniceps*, *C. erythraeus*, *C. finlaysonii*, *C. inornatus*, *C. melanogaster*, *C. nigrovittatus*, *C. notatus*, *C. orestes*, *C. phayrei*, *C. prevostii*, *C. pygerythrus*, *C. quinquestriatus*). Among them, the Pallas's (*C. erythraeus*) and Finlayson's squirrels (*C. finlaysonii*) have both been introduced outside their native range in new recipient areas.

Twenty-seven subspecies of *Callosciurus erythraeus* are known in the native range (Wilson & Reeder 2005, Li *et al.* 2006). Among them, *C. erythraeus thaiwanensis* has been much more studied than the others: its common name is known as "Formosan squirrel". In this risk analysis, we will use this appellation when talking specifically about that subspecies.

Out of the 27 subspecies, 26 of them were classified by Wilson & Reeder (2005) and the last one (*C. e. zhaotongensis*) has been described by Li *et al*. in 2006. It seems necessary to clarify the complex taxonomy of this species in Laos (Evans *et al*. 2000) because confusions are frequent (*C. erythraeus/C. flavimanus*), reflecting the difficulty of squirrel identification in that region (Duckworth *et al.* 2008). Many named and unnamed forms are present in Thailand, Laos and Vietnam.

1.2 SHORT DESCRIPTION

The Pallas's squirrel (*C. erythraeus*) is a sciuromorph species usually presenting an orange red belly, sometimes yellowish, with approximately the same size as a red squirrel. Its weight varies from 240 to 480g for a head-body length of 20-26 cm and a tail length of 16-20 cm. The back fur colour is olive green to brown with a lightly striped tail which extremity is sometimes slightly grey. Therefore, it has more and less the same general measurements as the red squirrel but can be easily distinguished by the belly colour which is totally white for *Sciurus vulgaris*.

1.3 ORGANISM DISTRIBUTION

Native range

C. erythraeus is widely distributed in the north-eastern part of South Asia, especially in central and southern China (Smith & Xie 2008), and mainland Southeast Asia (Duckworth *et al.* 2008). The countries concerned are: Bangladesh, north-eastern India (Molur *et al*. 2005), Myanmar, northern Thailand, Laos, southern and northern Vietnam, eastern Cambodia, Peninsular Malaysia and Taiwan(Moore & Tate 1965, Wilson& Reeder 2005, Duckworth *et al*. 2008, Bertolino & Lurz 2011).

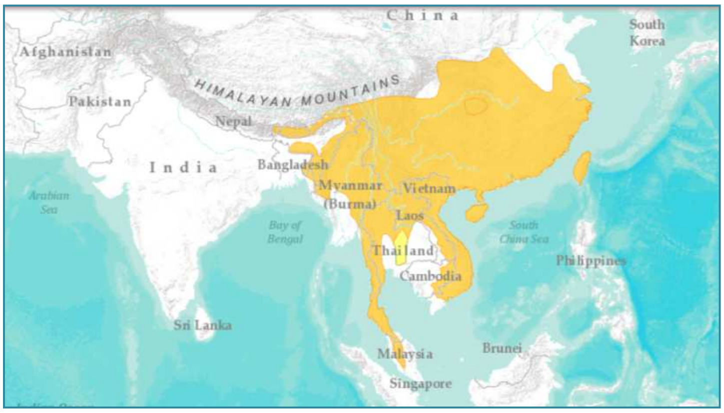

Fig1.*Callosciurus erythraeus's* native range (IUCN 2008).

Introduced range

Belgium: The species is not established in Belgium. The population reported in Dadizele seems to have been eradicated in 2008 (Stuyck *et al*. 2009). Some new sightings occurred and in 2010 some captures were reorganized. Since then, no new validated observation has been done in that area but other sightings have also been reported close to the Dutch border (Weert) within the last few years.

Rest of Europe: Different populations are established in southern France (Peninsula of Cap d'Antibes; Alpes-Maritimes) since 1998 (Gurnell & Wauters 1999; Duff & Lawson 2004) and in the Netherlands (1 population in the area between Weert and Thorn and 1 in America, Province of Limburg) since 2005. The Weert population set up from individuals escaped from an animal trader in 1998 (Dijkstra *et al.*2009).Its eradication is in progress.

Other continents: In South America, five populations (Luján, Escobar, Cañada de Gómes, La Cumbrecita, Buenos Aires)are known as established in Argentina (Bertolino & Lurz 2011). *Callosciurus erythraeus* is also present in new recipient areas of Asia: in Japan (at least 13 areas), where the species was introduced in the years 1930 (Chapuis *et al.* 2011), and in Hong Kong (2 known populations since 1972, Ho 1994,Chung&Corlett 2006). It was successfully removed in one area of Japan in 1967 (Nogeyama).

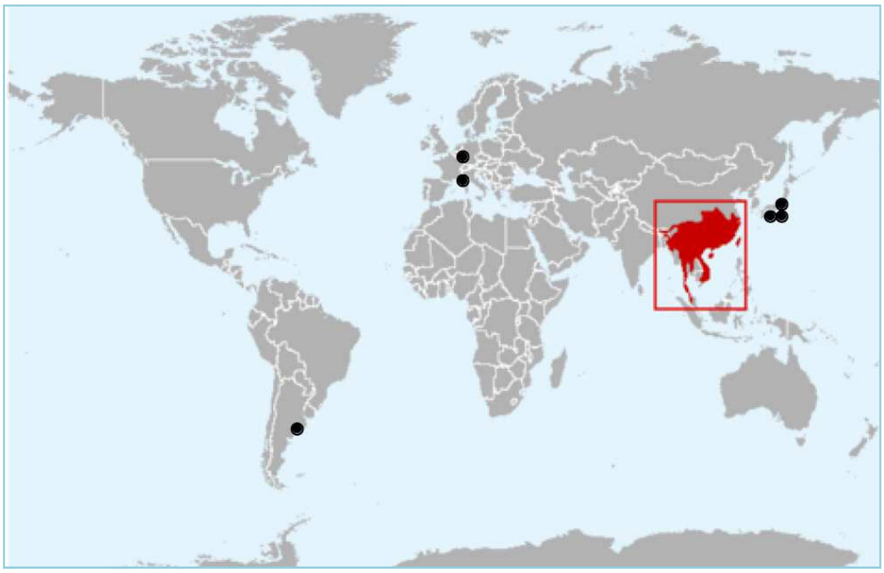

Fig 2. Original range of *Callosciurus erythraeus* (Duckworth*et al.* 2008, Chapuis *et al.* 2011) and areas of introduction (•)

1.4 REASONS FOR PERFORMING RISK ANALYSIS

Translocation of exotic species to new environments is often due to human activities such as shipping or international trade (especially for mammals) (Genovesi & Shine 2004, Bertolino & Lurz 2011). In many cases, only some individuals are needed to establish viable populations of squirrels (Wood *et al.*2007, Bertolino 2009). This may lead to negative impacts on native wildlife, on crops or forests (Shorten 1954, Tamura & Ohara 2005, Nogales *et al*. 2006). This clearly argues in favour of national and continental policy strategies.

The Pallas's squirrel may sometimes reach high population densities (5-10 individuals/hectare) (Dijkstra *et al.* 2009,Benitez *et al*. 2010, Provincia di Varese, 2012). It has similar food habits as the native red squirrel* and could outcompete it. It damages trees in forests, parks and gardens by bark stripping and may be the cause of substantial economic loss of profit in tree plantations (Jouanin 1992, Stuyck *et al*. 2009) and damages to infrastructures

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD (EXPOSURE)

Evidence should be available to support the conclusion that the non-native organism could enter, become established in the wild and spread in Belgium and neighbouring areas. An analysis of each associated pathways from its origin to its establishment in Belgium is required. Organisms intentionally imported maybe maintained in a number of intended sites for an indeterminate period. In this specific case, the risk may arise because of the probability to spread and establish in unintended habitats nearby intended introduction sites.

2.1.1 Present status in Belgium

Specify if the species already occurs in Belgium and if it makes self-sustaining populations in the wild (establishment). Give detail about species abundance and distribution within Belgium when establishment is confirmed together with the size of area suitable for further spread within Belgium.

In Belgium, a small potential population has been suspected by Dijkstra *et al*. in 2009 at a short distance of the Dutch population of Weert which has probably crossed the Belgian border and confirmed since then. At least, one individual of Pallas's squirrel was mentioned close to Mariahof, in the community of Bree (Dijkstra *et al*. 2009). In the same area, some other possible observations were done in Lozen in 2010 and 2011, with respectively 4 and 1 individuals seen (Dijkstra et al. 2011). A bit further, a sighting of Pallas's squirrel has been mentioned in Beek, close to Bree since 2006-2007 but it has not been seen anymore since 2011. The most recent observations (2013) done in the same border area concern Molenbeersel (95% certainty on identification) and Bocholt where 5 nests where found at Achelsedijk (Van Gossum H., pers. comm). Eradication actions are taking place.

A second isolated population of Pallas's squirrel was detected in Dadizele (near Kortrijk) in 2005 and confirmed by morphometric and DNA analyses (Stuyck *et al*. 2009). The animals were supposed to have escaped from a pet shop or from a zoo, but their exact origin remains unclear. In October 2005, because of damages (bark stripping/cables gnawing), a trapping campaign was initiated: an unexpected number of 45 individuals was caught and removed from the area during the first three months. The trapping attempts were maintained in 2006 but many sightings were still done in the Dadizele park and surroundings. A systematic eradication was decided and between February and April 2008, before the reproductive season, the trapping efforts were increased resulting in the removal of 76 additional individuals. Some more captures occurred in 2010 and the population seems currently eradicated but, however, some sightings made in 2010 correspond to a Pallas's squirrel observation.

2.1.2 Present status in neighbouring countries

Mention here the status of the non-native organism in the neighbouring countries

As mentioned above, the Pallas's squirrel already occurs (occurred)in neighbouring countries. However, this species has a very limited range in Europe (Genovesi *et al*. 2008). In Southern France, the introductions started at the end of the 1960s, while in The Netherlands, Italy and Belgium the populations reported are quite recent (from 1998 onwards).

In the southern Netherlands, two isolated populations of Pallas's squirrel are known (Dijkstra & Dekker2008, Dijkstra *et al*. 2009) in the province of Limburg. The area concerned by the first population is comprised between Weert, and Thorn (Dijkstra V., pers. comm). It has been progressively colonized since 1998 by 10 to 12 individuals escaped from an animal trader. In 2010, it reached a size of some tens of individuals (50 to 110) according the data collected (by hair and camera traps + direct observations), in an area of 550 ha, that was still supposed to increase and disperse further. Considering the risks linked to the species presence, since December 2011, the Dutch government, municipalities of Weert and Leudal helped by the Province of Limburg and Zoogdiervereniging NGO started a trapping session of *C. erythraeus* to remove the species from this area. In less than 8 months, more than 200 individuals have already been trapped (Dijkstra 2012), which means the double of the estimated population. A new monitoring has been held during the summer 2012 and a second capture campaign took place during winter 2012/2013 and an additional 32 animals were trapped. It is estimated that about a few dozen animals are still present (Dijkstra V., pers. comm).

C. erythraeus was also reported in the locality of America (proximity of Venlo), at a distance of 35 km northeast of Weert (Dijkstra *et al.* 2009). In November 2006, 2 individuals were photographed in a park there. But, early 2006, the presence of about 30 exotic squirrels in that area was announced in a Belgian newspaper (Het Laatste Nieuws 21-01-06). Dijkstra *et al*. (2009) estimated only 12 individuals with at least two squirrels escaped from their cage. The male squirrels were reported as being castrated but no detailed information was available on the methodology used and efficiency of the general *modus operandi*. Finally, it seems these squirrels originated from the Belgian population of Dadizele, and were brought there after sterilization and then escaped in the wild (or were released?). Despite their yellowish -and not red- belly, the species was identified by Jan Stuyck and Peter Breyne (INBO) as the Pallas's squirrel thanks to a DNA analysis (Dijkstra *et al.* 2009).

A third report appeared at Zeeland (province of Brabant) near Uden. In 2012 two animals were reported by a veterinarian. After a few days the animals were disappeared. They were probably shot by hunters or recaptured by the (unknown) owner (Dijkstra V., pers. comm).

In the late 1960s, the introduction of Pallas's squirrels in southern France resulted in a citizen private initiative for ornamental reasons (Jouanin 1986,Duff & Lawson 2004, Chapuis & Marmet 2006, Menigaux 2010). The subspecies introduced on the peninsula of Cap d'Antibes (department of Alpes-Maritimes) was *C. erythraeus erythrogaster* from Myanmar and Assam (Gurnell & Wauters 1999). In 1999, Gurnell & Wauters estimated the population size greater than 100 individuals and considered the Pallas's squirrels as more abundant than the Red squirrels living in the same area.

According to Le Louarn & Quéré (2003), the population expansion seemed to be rather limited during some decades because of the presence of natural and anthropogenic barriers (sea, urban belt). However, this statement was maybe reflecting a lack of data because based on unvalidated data, Tillon *et al.*(2007) suspected an extension of the Pallas's squirrel population outside its known area, suggesting the species had crossed the Juan-les-Pins barrier at the end of the 1990s. Moreover, it seems that urban areas form a barrier only if there is no green areas available for *C. erythraeus*, otherwise they are used as an habitat. A new study (Chapuis *et al*. 2011) recently appraised the population size at several thousand individuals of *C. erythraeus,* and the western communes of Vallauris and Le Cannet are already colonized (Chapuis *et al*. 2011). Fortunately, it seems the A8 motorway could still represent a serious obstacle for the progression of that exotic squirrel to northern areas (Chapuis *et al.*2011).

In Italy, from 2007, the species was also reported in the locality of Brezzo di Bedero, in Lombardia at 5 km of the Swiss border (Chapuis & Marmet 2006 ; Chapuis *et al.*2011). The capture and euthanasia of Pallas's squirrels has started with the aim to remove this exotic species from the study area (Provincia di Varese, 2012).

2.1.3 Introduction in Belgium

Specify what are the potential international introduction pathways mediated by human, the frequency of introduction and the number of individuals that are likely to be released in Europe and in Belgium. Consider potential for natural colonisation from neighbouring areas where the species is established and compare with the risk of introduction by the human-mediated pathways. In case of plant or animal species kept in captivity, assess risk for organism escape to the wild (unintended habitats).

On a worldwide scale, non-native squirrel introductions peaked from 1900 to 1930, but the phenomenon is still important, with 15–20 new introductions every 10 years. 7 introduced squirrel species are currently established in Europe. The main vector of introduction was the intentional importation of live animals that were either deliberately introduced or escaped from captivity. In the past, the translocation of squirrels into new areas was thought to be appropriate to the public interest and it was accomplished until the 1970s by game and wildlife management agencies also (Davis & Brown, 1988). With the recently increasing awareness about the threat entailed in biological invasions, many national laws and international agreements either ban or discourage new introductions. Nevertheless, animal trade has increased during the last few decades and squirrels are still being sold as pets everywhere. In fact, in recent times the main pathway of Pallas's and other squirrel introductions has been connected to private citizens and animal traders who keep animals in captivity, with consequent risk of escape or release them into public estates and parks (Davis & Brown 1988, Westphal *et al.* 2008, Bertolino 2009). At least, deliberate releases have occurred in Dadizele and Weert (Dijkstra *et al*. 2009, Stuyck *et al*. 2009). In Weert, animals could have escaped from a transport crate, according the pet trader.

A review of the species *Callosciurus erythraeus* in Europe was recently realized by the UNEP-WCMW (2010). The information collected is the result of an Internet survey led between 4th and 12th October 2010. It proves that, for the specified period, some Pallas's squirrels were available for sale in Denmark (3 offers; 6 individuals) and Sweden (1 offer; 7 individuals) from pet retailers or even private people. This Internet inquiry also confirmed the presence of the Pallas's squirrel in Denmark (with some individuals kept in outdoor cages) and in Sweden (as pets owned by private persons) but no specific information was found in Belgium and neighbouring countries (UNEP-WCMW 2010). Pallas's squirrel is also known to be sold as a pet species in Belgium and in the Netherlands, but with a lower frequency than other squirrel species like *Tamias sibiricus* or *Sciurus spp*. (Dijkstra & Dekker 2008, Stuyck *et al.* 2009) although since 2001 only *Tamias sibiricus* and *T. striatus* are allowed as pets (Royal Decree of 16/07/09).

ENTRY IN BELGIUM

It is likely that the Pallas's squirrel could enter in Belgium by the way of natural spread from a population present at the Dutch border or by escaping from cages or deliberate release by pet traders or private citizens, as already observed in Dadizele (and Weert, NL).

2.1.4 Establishment capacity and endangered area

Provide a short description of life-history and reproduction traits of the organism that should be compared with those of their closest native relatives (A). Specify which are the optimal and limiting climatic (B), habitat (C) and food (D) requirements for organism survival, growth and reproduction both in its native and introduced ranges. When present in Belgium, specify agents (predators, parasites, diseases, etc.) that are likely to control population development (E). For species absent from Belgium, identify the probability for future establishment (F) and the area most suitable for species establishment (endangered area) (G) depending if climatic, habitat and food conditions found in Belgium are considered as optimal, suboptimal or inadequate for the establishment of a reproductively viable population. The endangered area may be the whole country or part of it where ecological factors favour the establishment of the organism (consider the spatial distribution of preferred habitats). For non-native species already established, mention if they are well adapted to the eco-climatic conditions found in Belgium (F), where they easily form self-sustaining populations, and which areas in Belgium are still available for future colonisation (G).

A/ Life-cycle and reproduction

The Pallas's squirrel is usually diurnal or crepuscular. In areas of introduction, breeding was reported to take place throughout the year (Tang & Alexander 1979, Chapuis *et al*. 2011) with two main peaks: one in spring and one in summer, in both native and introduced areas. For the red squirrel*, these peaks occur in winter and spring. As for our native species, the mating system of the red-bellied squirrel is promiscuous with males and females able to mate with several individuals. A female can mate with an average of 8-9 males in Taiwan and in Japan (Tamura *et al.* 1989). The number of yearly litters is from 1 to 3 in Japan, with an average of 1.4 weaned offspring.

In Cap d'Antibes, the females have 1 or 2 litters a year, as for the red squirrel* females, but with 1 to 3 individuals (1.9 ± 0.5 ; n=19) while it averages 1 to 6 individuals for *Sciurus vulgaris*. In France, the sex ratio of *C. erythraeus* is of 1.1, slightly in favour of males. The sexual maturity is reached after one year of life, as for *S. vulgaris**. The gestation lasts 47 to 49 days (38-40 days for *S. vulgaris**) and the maximum longevity is of 4 years (Chapuis *et al.*2011). The mean yearly survival rates for *C. erythraeus* in Japan (Tamura 2004) are of 0.3 for adults older than 3 years. The life expectancy is of maximum 4 years old. These elements of population dynamics argue for a lower reproductive potential of the Pallas's squirrel compared to the European red squirrel*. But it could be possible that Pallas's squirrels also produce 3 litters a year if the mast production (food supply) is high (Dijkstra, com. pers.)

In areas of introduction, the population growth follows an exponential curve, leading to a fast expansion of the species if not managed, as noticed in Japan (Tamura 2004) and in Argentina (Guichon & Doncaster 2008). This tendency confirms a high potential for expansion of new populations of *C. erythraeus* (Bertolino & Lurz 2011) when they get established.

The population density of the species has been investigated in different countries and habitats:

- in Taiwan (native range), it is 2.5 individuals/ha (Lin & Yo 1981);
- in Argentina (Benitez *et al.* 2010), it can be higher than in the native range, varying from 0.5 to 18 individuals/ha in different sites of the country (census 2006-2009);
- in Japan, the population density has been estimated at 3.9 to 4 Pallas's squirrels/ha (Tamura 2004);
- in Italy (Brezzo di Bedero), the reported density in 2007 was 5.2 ± 1.2 individuals/ha (Provincia di Varese 2012, Martinoli *et al*. 2011) and the estimated population is comprised between 320 to 968 individuals (with an average of 610 individuals);
- in France (Cap d'Antibes), O. Gerriet reported a density of 8 individuals/ha (Dijkstra *et al.* 2009), while the average red squirrel density is around 0,5 to 1,5 individuals/ha.
- in the Netherlands, the Weert population was assessed as twice the red squirrel* population level. This evaluation was done by counting indirect signs of presence (via hair traps) and by taking into account the quality of forest patches, as defined by Verbeylen *et al*. (2003) for similar habitats, squirrel densities varying according the quality and suitability of inhabited woods.

B/ Climatic requirements[2]

A climate matching is often required to enable a population establishment in a new area of introduction from the native range, but not always. When the latitudinal distance between these areas enlarges, the likelihood of success in the recipient area is normally lower (Duncan *et al.* 2001, Forsyth *et al.* 2004). For *C. erythraeus*, individuals coming from Taiwan have produced different established populations in Japan. If they initially originate from tropical and subtropical broadleaf forests, due to their flexibility, they were also able to colonize warm temperate environments, like on Tomogashima Island in Japan (Setoguchi 1990, Helin *et al.* 1999) as well as subalpine broadleaf and coniferous forests until 3000 m of altitude (Smith & Xie 2008), but it seems they were not able to colonize the northern deciduous forests of Japan because of harsh winter conditions(i.e. large snow precipitations and a mean temperature of coldest months lower than -4°C) (Setoguchi 1990, Bertolino 2009). Frost sensitivity of the Pallas's squirrel is likely to reduce its establishment capacity in the coldest areas of the Ardennes, while the Dutch climate fully matches with the species requirements (Dijkstra & Dekker 2008).

C/ Habitat preferences[3]

Diurnal and arboreal, using tree hollows of the mid high canopy or building nests as red squirrels, the Pallas's squirrel occurs naturally in different forested habitat types as subtropical mountainous evergreen and broadleaved forests (Xu & Sheng 1992, Hori *et al.*2006), but it can also live in

[2] Organism's capacity to establish a self-sustaining population under Atlantic temperate conditions (Cfb Köppen-Geiger climate type) should be considered, with a focus on its potential to survive cold periods during the wintertime (e.g. plant hardiness) and to reproduce taking into account the limited amount of heat available during the summertime.

[3] Including host plant, soil conditions and other abiotic factors where appropriate.

subalpine coniferous forests or mixed forests of China above 3000 m (Smith & Xie 2008). In Taiwan, *C. erythraeus* takes profit of bamboo tropical forests and orchards (Chapuis 2011).

In introduced areas, due to their flexibility, they are also found in different forest types (Chapuis 2011, Dijkstra & Dekker 2008, Dijkstra *et al*. 2009) including deciduous, mixed and coniferous forest.

- France: mixed forests, oak woods, pinewoods, gardens;
- Belgium: wooded urban park, deciduous woods;
- The Netherlands: wooded urban park, deciduous and mixed forests (oak, elder, ash, birch, spruce, Douglas, poplar with blackberries and ferns), sometimes in riparian habitats;
- Italy: mixed broadleaved forest;
- Argentina: fragmented woods of mixed coniferous and broadleaved forests;
- Japan: temperate forests and fragmented woods in cultivated and suburban areas.

Duckworth & Robichaud (2005) consider this species as very flexible because it can also subsist in heavily degraded scrub landscapes containing small degraded forest patches. For example, in Argentina, where *C. erythraeus* was introduced in 1970, suitable habitats are greatly fragmented and wooded patches are dispersed in a rural-urban matrix (Bridgeman *et al.*2012). Despite that, the squirrel population has spread through ecological corridors while some small habitat gaps were present.

In the Netherlands Pallas' squirrels avoid monocultures of coniferous forests. Although it could be the case that this habitat is less preferred and will be occupied after deciduous and mixed forests are filled up (Dijkstra V., pers. com).

The composition of woodland habitats in Japan is partly characterized by the proportion of broadleaved evergreen trees of each area: this could explain their probability of use by *C. erythraeus* (Miyamoto *et al.* 2004, Tamura *et al*. 2004), as the global diversity of tree species could influence the habitat selection (Okubo *et al*. 2005a, Bertolino & Lurz 2011). In suburban areas, conifer plantations are an important habitat feature for the species, providing nesting sites and diverse materials for nest building (Okubo *et al.* 2005b).

In China, Yuan (2011) documented the main factors explaining the habitat selection of the red bellied tree squirrel (*Callosciurus flavimanus = C. erythraeus*) and showed that out of13 factors tested the most important ones seemed to be the high canopy density and high food richness. At a lower level, the shelter of wind, slope, slope orientation, distance to shrubs and altitude also partly explained the Pallas's squirrel habitat selection.

Using a CMR method, Yo *et al*. (1992) pointed out that habitat modifications such as weeding reduced the survival rates of squirrels but the individuals living close to natural forests use plantations as transitory habitats.

The spacing and sociality of *C. erythraeus* individuals can also change in habitats differing in food availability and predation pressure. Tamura *et al*. (1989) compared the social structure of two populations of *C. erythraeus thaiwanensis* (Formosan squirrel) in a native tropical habitat (Southern Formosa) and a temperate area of introduction (central Japan). The native habitat was rich in food during the whole year but counted several squirrel predators while the introduced area had less food to offer but also less predator species. The mating system (extensive multiple mating) was preserved in the new habitat but the second specificity of *C. erythraeus* social structure differed : in the native range, a spacing overlap was the rule among females home ranges while in the new recipient area, the female home ranges were separate (Tamura *et al.* 1989). We could therefore expect similar adaptations in the social structure pattern for *C. erythraeus* populations introduced in temperate regions.

The habitat use of *C. erythraeus* is influenced by the social structure pattern among individuals (Tamura *et al.* 1988, Yo *et al.* 1992) which influences the population density. Yo *et al*. (1992) also studied recruitment patterns in different areas in Taiwan: in a good quality habitat close to a natural forest, and in a poorer quality habitat further from the plantation margin. Adult squirrels were dominant in the first habitat while subadults were more frequent in the second habitat type, indicating a faster population turnover and a higher recruitment rate: subadults were more likely to remain in artificial forests for longer times. Thus, the effective *C. erythraeus* population regulation differs in favourable breeding habitats and poorer degraded habitats, showing once more the great adaptability of the species.

Thanks to the genetic structure study of the Pallas's squirrel populations in tree patches of artificial forests of the Sichuan Province (southern China), Guo *et al*. (2011) demonstrated that the population's historical demography was not affected by the forest fragmentation. This can be linked to the squirrel's adaptability to artificial forests in a way the species is able to change its diet composition according to the food resources availability. However, since 1950, new forestry practices, road-building and farming have considerably modified the forest structure in these native areas, leading to significant genetic differentiation within *C. erythraeus* populations of the different artificial forest patches. It clearly means that forest fragmentation induces a barrier to gene flow between populations. However, no population decline was reported whereas it normally occurs in rodent populations (Baratt *et al.* 1999, Lampila *et al.* 2009). The reason for this could be that the forest changes were also inauspicious for the Pallas's squirrel predators, reducing the pressure on *C. erythraeus* populations. Ran *et al. (*2006) reported that the food scarcity in artificial forest patches could however limit its population growth.

D/ Food habits[4]

In the natural range, the diet of *Callosciurus erythraeus* has been studied in Taiwan. This pointed out the sciurid eats numerous varied items but **mainly flowers and fruits or seeds** (90%) of around thirty different species, depending on the season. Animal consumption mainly concerns insects and is very low as it accounts for about 7% of the diet. In southern Formosa, the diet was composed of seeds and fruits during all seasons, reaching from 59 to 98% of the diet throughout the months (average:78%). In Vietnam, the diet of *C. erythraeus* includes tree flowers and leaves as well as seeds, fruit and tree sap (Koyabu *et al.* 2009, Bertolino & Lurz 2011).

[4] For animal species only.

In China (Sichouan Province), *C. erythraeus* can change its diet depending on the seasonal food availability (Ran *et al.* 2006). In summer and autumn, the food opportunities are varied but not in winter and spring, which induces a stronger **bark stripping** during these periods to satisfy the food requirements of the species (Ran *et al.* 2006, Dong *et al.* 2009). During the reproductive period (in spring), the extra need of energy is accentuated by the squirrel activity and thus the bark stripping. In artificial monocultures, where food availability is weaker than in natural forests, stripping bark could be an adaptive selection of *C. erythraeus* to maintain its population stability (Guo *et al.* 2011).

Although not always documented in the native range, it seems that the bark stripping behaviour is widely reported in new recipient areas as in Japan, Argentina and the Netherlands (Guichon *et al.*2005, 2009, Tamura & Ohara 2005, Bertolino & Lurz 2011). In countries of introduction, the species has been very flexible in habitats in which it formed new populations. In central Japan, according to Tamura *et al*. (1989), from July to November, 91% of the consumed items were fruits and seeds (31 different species). From December to June, these accounted for only 25% of the diet, the rest being replaced by flowers (especially *Camellia japonica*), bark or leaves. In France, the species has been observed eating tree bark, flowers, fruits and seeds. It was able to take profit of seasonal productions as pine nuts, acorns, olives, almonds, lemons and oranges... As in the native range and in Japan, it seems the animal part of the diet is low (around 5%) and mainly composed of insects (caterpillars). In many urban areas, leftover foods from humans can be an important food supply for *C. erythraeus* (Setoguchi 1990, Bertolino *et al*. 2004, Jessen *et al.* 2010, Bertolino & Lurz 2011), facilitating the winter survival for the species, especially during late winter and early spring when the food opportunities are low. In Italy, exotic squirrels mainly feed on seeds, fruits and flowers, and occasionally eat some insects, but they are quite able to modify their diet according to the season availability (Bertolino *et al.* 2004, Bertolino & Lurz 2011).

E/ Control agents

In the natural range, few studies have been done concerning predators, thus little information is available (Chapuis 2011). Nevertheless, in Taiwan (National Park of Ken-Ting), Tamura *et al*. (1989) identified two *C. erythraeus* (*thaiwanensis)* predators: the Crested Serpent Eagle (*Spilornis cheela*) and the Grey-faced Buzzard (*Butastur indicus*). The only terrestrial predators identified in this study were mainly feral cats, and some snakes like the pointed-scaled Pit viper (*Trimeresumus mucrosquamatus*) and the beauty snake (*Elaphe taeniura*).

In Japan, where *C. erythraeus* was introduced, the Black Kite (*Milvus migrans*) is considered as a potential predator (Tamura *et al*. 1989) but from the ground, as in Taiwan, feral catsare the main predators. The Japanese ratsnake (*Elaphe climacophora*) could also be a potential predator. In France and in the Netherlands, Pallas's squirrels killed by domestic cats and dogs have been reported (Chapuis 2011, Janssen R. com. pers.).

Concerning parasites, little information is available in the original range, except for ectoparasites (especially lice) (Chapuis2011). In areas of introduction of *C. erythraeus*, some information has been gathered. Two lice species (*Neohaematopinus callosciuri*, *Enderleinellus kumadai*), one flea species

(*Ceratophyllus anisus*), a tick (*Haemaphysalis flava*) and at least three nematodes (*Brevistriata callosciuri, Strongyloides callosciureus* and *Gongylonema neoplasticum*) have been registered for Japan (Kaneko 1954, Shinozaki *et al*. 2004a,b, Asakawa 2005, Sato *et al.* 2007). Among these parasites, *C. anisus* and *H. flava* are also known from other hosts in Japan but the other parasites may have been introduced in the country at the same time as the squirrels, although no information has been mentioned about pathogen pollution due to *C. erythraeus*(Shinozaki et al. 2004a).

In Belgium the lice species *E. kumadai, Hoplopleura erismata* and accidentally a nematode *(Mastophorus**sp.) have been identified (Dozières *et al.* 2010) in the Pallas's squirrel population. In the French population, the same researchers detected the louse *E. kumadai* as well as the flea *Nosopsyllus fasciatus**and the cestode *Hymenolepis sp*. (Dozières *et al.* 2010). The sublethal potential effects of these parasites have not been documented. This represents a small total of parasites but it is probably linked to the low number of mammals living in urban areas, where the Pallas's squirrel populations do live. At least, there is no evidence that under Belgian eco-climatic conditions, *C. erythraeus* would undergo any severe mortality linked to a parasite load or carry parasites that are a danger to native species.

In Argentina, the flea *Polygenis rimatus* and the mites *Androlaelaps fahrenholzi, Ornithonyssus* cf*. bacoti* and *Cheyletus sp.*native from the American continent, and larvae of the flies *Cuterebinae* have been detected as parasites of *C. erythraeus* (Benitez *et al*. 2010, Gozzi *et al*. 2012), but due to the low prevalence found for these parasites, *C. erythraeus* seems to be only an occasional host and the sanitary risks posed to native fauna in Argentina seem to be low at present (Gozzi *et al.* 2012).

F/ Establishment capacity in Belgium

The eco-ethology of *Callosciurus erythraeus* mainly explains its successful capacity of establishment and spread abilities in new areas of introduction. Its strong attractive appeal on humans also explains its ease to colonize urban habitats and can even induce economic benefits as tourist attractions (Bertolino & Lurz 2011). Pest or pet? It is somehow difficult to settle but the "magnetism" of squirrels is obvious and has to be taken into account for conservation purposes (Parrott *et al*. 2009, Guichón *et al*. 2005).

Even though, wild populations are still very rare. Established populations in Europe and South America originated from few animals (Wood *et al.* 2007, Bertolino 2009) (see Fig.3), thus proving the adaptability of *Callosciurus erythraeus* to new habitats, even if the colonization is slow and thus moderate (Dijkstra *et al*. 2009). Tree squirrels are generally considered as particularly adaptable because of their relatively **high reproductive potential**, **wide food habits**, and **plasticity to anthropogenic habitats** (Palmer *et al.* 2007, UNEP-WCMC 2010).). Thus, prompt actions are recommended in any case of suspected invasiveness leading to possible impacts (Stuyck *et al.* 2009).

Outside the native range, between 1935 and 2008, 28 introduction attempts of *C. erythraeus* have been recorded by Bertolino & Lurz (2011). Most of them were successful and reached a large population increase. Only some of them did not really raise (i.e. a self-regulating but localized population) with 4 failed attempts of establishment. *C. erythraeus* is thus considered to be a “good invader" due to its ability **to colonize new environments** (Novillo & Ojeda 2008, Bridgman *et al*. 2012). It is also able to colonize urban areas efficiently (Guichón *et al*., 2005).

Bertolino (2009) determined the likelihood ratio for a couple of different squirrel species to successfully establish in a new area of introduction. This ratio is very important for the *Callosciurus* species with a value of 0.73. Moreover, if a minimum of 4 individuals are released, this likelihood ratio even reaches 0.90 while 14 individuals of *Sciurus* species would be necessary to attain the same level of establishment success. **It means that *Callosciurus* species have a very high probability of establishment in introduction range after accidental escape or deliberate release into the wild; the likelihood that the release of one pair of *Callosciurus* species would establish a new population is higher than 70%.**

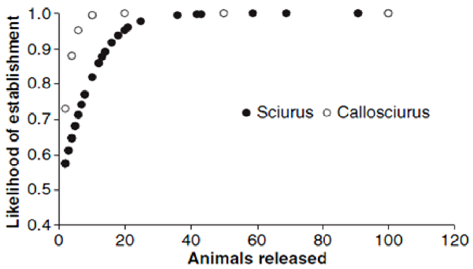

Fig 3. Likelihood of *Sciurus* and *Callosciurus* establishment as a function of the number of animals released (from Bertolino *et al.* 2009)

In Argentina, the presence of exotic tree plantations for commercial and ornamental purposes also facilitated the success of *C. erythraeus* (Guichon & Doncaster 2008) because they consist of nesting and feeding habitats for the species. Therefore, human activities often cause environmental modifications that may generate positive interactions between introduced species (Mack *et al.*2000, Grosholz 2005).

Finally, in Belgium, populations of *Callosciurus erythraeus* can easily establish because they meet good eco-climatic conditions in terms of climate and suitable forested habitats (deciduous, mixed and coniferous woodlands) as well as urban parks and gardens that are all convenient for the species and can provide numerous food items usable by the Pallas's squirrel.

G/ Endangered areas in Belgium

All the wooded areas found in Belgium consist of optimal habitat for the development of the Pallas's squirrel, where it could form dense populations. Urban parks and other small patches of wooded habitats, urban matrix as well as more natural areas may be interesting for this squirrel which can be really adaptive. It may also occur in wooded habitats of the maritime region although the forest fragmentation could be a natural factor of containment of emerging populations. Due to harsh winter conditions (mean temperature of coldest months < -2.0°C), Pallas's squirrel may face some difficulties to establish in the Haute-Ardennes as well. Thus, it seems that the Pallas's squirrel could occur nearly everywhere in Belgium.

Establishment capacity in the Belgian geographic districts:

Districts in Belgium	Environmental conditions for species establishment[5]
Maritime	Suboptimal
Flandrian	Optimal
Brabant	Optimal
Kempen	Optimal
Meuse	Optimal
Ardennes	Optimal
Lorraine	Optimal

ESTABLISHMENT CAPACITY AND ENDANGERED AREAS IN BELGIUM

Callosciurus erythraeus **can successfully establish viable feral populations from a few individuals only. It is likely to establish self-sustaining populations in Belgium and neighbouring areas if introduced because of a high invasive capability and adaptive potential and because suitable climatic conditions, habitats and food supplies are met.**

2.1.5 Dispersion capacity

Specify what is the rate of dispersal once the species is released or disperses into a new area. When available, data on mean expansion rate in introduced territories can be specified. For natural dispersion, provide information about frequency and range of long-distance movements (i.e. species capacity to colonise remote areas) and potential barriers for spread, both in native and in introduced areas, and specify if the species is considered as rather sedentary or mobile. For human-assisted dispersion, specify the likelihood and the frequency of intentional and accidental movements, considering especially the transport to areas from which the species may easily colonise unintended habitats with a high conservation value.

A/ Natural spread

Home range

The density of Pallas's squirrel populations differs regarding habitats and seasons(normally lower in early spring). The highest ones, reaching 5 to 7 adults/ha, were reported in temperate mixed forests of Japan as well as in the tropical native range (Tamura *et al.*, 1989) and in these areas, they didn't vary annually during the study period. Nevertheless, the density of adult females was significantly lower in a recipient area than in the natural range. The lowest densities are given for plantation of Japanese fir (*Cryptomeria japonica*) in Taiwan (Lin & Yo 1981), with an average of 2 to 3 individuals/ha. In France, different data were collected: in the Bois de la Garoupe (Cap d'Antibes), the density was 8 individuals/ha in May 2010 while it reached only 3 to 3.5 squirrels/ha in the Bois des Encourdoules (Vallauris, France) for the seasons 2009 and 2010 (Chapuis 2011). In Flanders, the

[5] For each district, choose one of the following options : optimal, suboptimal or inadequate.

densities vary from 0,1 red squirrels/ha in isolated woods to 2,2 red squirrels/ha in biggest forests (Verbeylen et al. 2003) as found in other studies (Wauters & Dhondt 1990 ; Wauters & Lens 1995).

Male home ranges respectively attain 1.4 to 2.2 ha in Taiwan and Japan (Tamura *et al*. 1989) and are larger than those of females (ranging from 0.28 to 0.46 ha) for the same respective areas (Tamura *et al.*1989). In Taiwan, according to Yo *et al*. (1992), these values can reach 3.8 ha for males and 0.5 to 0.7 ha for females. **In comparison, the home ranges of male and female red squirrels are larger with estimates of 4 to 9 ha for males and 3.4 to 8 ha for females in different forest types** (Wauters & Dhondt 1992, Lurz *et al.* 1997).Home ranges of 2 to 5 ha are found in coniferous forests where the food resources are evenly distributed and until 10 ha in deciduous forests where food supplies are highly variable and unevenly distributed (Wauters & Dhondt 1998). But, as for the red squirrel, in an introduced temperate area, home range overlaps between males among themselves and between both sexes are higher than those observed between females. In the native area, these overlaps also exist among females. An average of 8 adult males can overlap one adult female home range, corresponding to a carrying capacity of 7 to 9 sexually mature squirrels per hectare (Tamura *et al.*1989). This mating system is the same in the new recipient temperate areas. Thus, we expect the same situation for new Pallas's squirrel populations developing in Belgium.

According to Tamura *et al*. (1989), most of the males leave their natal area at one year old in Taiwan (native tropical area) and central Japan (temperate introduced area) while fewer females do (only 35% disappear from the natal area after one year). In the introduced area, 35% of young females settle close to the maternal home range without overlapping it, but in Taiwan they overlap it in 35% of the cases (even during the reproductive season), probably because of a higher food availability and for a better avoidance of predators by co-defence (alarm calls), a phenomenon which is also seen in ground squirrel species (Sherman 1981). Therefore, we could expect similar adaptations of the social structure patterns in Belgium.

Dispersal distance

Few studies of dispersal distances are available for this squirrel species, but it is usually considered that the **maximum dispersal distance rarely exceeds 5 km** (Lin & Yo 1981, Guichon & Doncaster 2008).

The Pallas’s squirrel can potentially cross small habitat gaps, while dispersal over long distances without connectivity is less likely. This can lead to a more accurate prediction of the invasive potential of the Pallas's squirrel and give keys for management methods limiting their expansion in new recipient areas. According to Bridgman *et al*. (2012), the colonization of an urban matrix by *C. erythraeus* depends on its perceptual range which is defined as "the distance from which a particular landscape element can be perceived or detected as a potential habitat by a given animal" (Lima & Zollner 1996). On that basis, Bridgeman *et al*. (2012) consider C*. erythraeus* as able to cross some habitat gaps if the distance without connectivity is smaller than 100m. If upper, there would be no colonization of potential habitats. It means that *C. erythraeus* ability to disperse at distances higher than 100m are unlikely to happen. In Japan, Miyamoto *et al*. (2004) estimated this perceptual range at 163m because it was the largest home range width of a female that could be crossed (Tamura *et* *al.*1987). This value was higher in the study of Lin & Yo (1981) with **maximum daily movements of respectively 326m to 484m for adult and juvenile females**, but these results were collected in contiguous wooded areas and could be lower in fragmented woods (Guichon & Doncaster 2008) which seems to be confirmed by the results of Bridgman *et al*. (2012).

The connectivity potential could increase with stepping-stones, as cables, bushes, isolated trees, hedgerows and high vegetation as scrubs along open fields and rivers (Guichon *et al.* 2005, Guichon & Doncaster 2008) as it does for *Sciurus vulgaris* and *S. carolinensis* (Fitzgibbon 1993, van Apeldoorn *et al*. 1994, Wauters *et al*. 1994, Selonen & Hanski 2004). In urban areas, it can occupy small fragmented forest sites (Miyamoto *et al.* 2004).

Expansion rate

Data about average observed areal dispersion rates are available from studies performed in Japan (Tamura 2004)and Argentina (Guichon *et al*. 2005) which generally fits with growth curves characterized by an initial lag phase of 10–20 years and a successive exponential increase (Bertolino 2009). Within 52 years, *C. erythraeus* colonized an area of 300 km² in Japan which corresponds to a dispersal rate of **5.8 km²/year**. In Argentina, the Pallas's squirrel population in Buenos Aires spread at a higher rate of **21.9 km²/year** over a period of 31 years. Other results are available for the Netherlands where, the Pallas's squirrels spread to maximum 12 km from the escape point within 15 years, corresponding to an areal dispersion rate of **3.6 km²/year** (Dijkstra *et al*. 2009, Dijkstra *et al*.2011).

Those results indicate that the Pallas's squirrel has a substantial dispersal capacity, which is however lower than this of the grey squirrel. The latter is characterized by an average observed areal dispersion rate of 18 km²/year that can reach 250 km²/year during the phase of exponential increase (see figure 4) (Bertolino *et al.* 2008, Bertolino 2009).

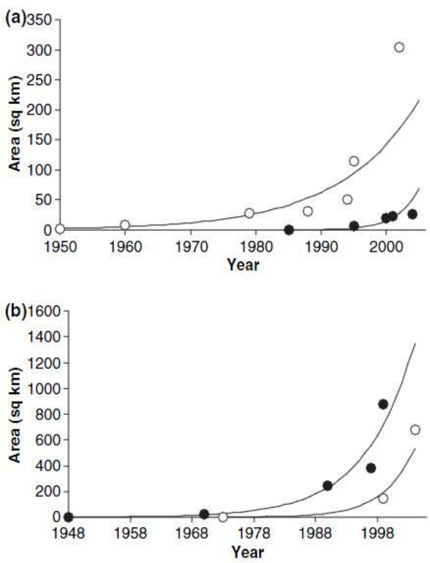

Fig 4. Spread of some squirrel populations in areas of introduction (from Bertolino 2009).
(a) *Callosciurus erythraeus* at Kanagawa, Japan (white dots, model fitting: $R2 = 0.93$, $F1,5 = 64.93$, $P < 0.001$) (black dots corresponds to *Callosciurus finlaysonii* at Maratea, Italy) ;
(b) *Sciurus carolinensis* at Turin, Italy (black dots, $R2 = 0.99$, $F1,3 = 294.2$, $P < 0.001$) and *C. erythraeus* at Buenos Aires, Argentina (white dots, model fitting: $R2 = 0.99$, $F1,1 = 168.8$, $P < 0.05$)

B/ Human assistance

Most of the Pallas's squirrel establishments out of their native range are the result of deliberate or non intentional introductions by humans (Bertolino & Lurz 2011), while only few are linked to the dispersal of individuals coming from an area of introduction (e.g. from The Netherlands to the Belgian border, Dijkstra *et al.*2009). In some cases, the species has been introduced in the wild for ornamental reasons and generally the population established from a few individuals, like in France (Chapuis 2011). In other situations, animals have been released by pet handlers (or at least we could have a strong suspicion about this) or they sometimes escaped from private enclosures before founding new populations in the wild (Aprile & Chicco 1999, Okubo *et al*. 2005b, Dijkstra *et al.*2009, Gerriet 2009, Stuyck *et al.*2009).

As explained by Bertolino & Lurz (2011), the strong appeal of squirrels to humans makes the situation even more complex to manage because it may lead to additional introductions by translocation of individuals from a source population to new areas not yet colonized, helping the species to overcome ecological barriers and thus increasing the expansion rate of *C. erythraeus*. Human assistance plays therefore an important role in the invasion dynamics of this species.

DISPERSAL CAPACITY

The Pallas's squirrel can spread from introduction places to new areas by using different elements of its perceptive range. The dispersal capacity of juveniles away from their natal home range is considered to be lower than 5 km/year. The mean areal expansion rate observed in Japan and Argentina varies between 6 and 22 km²/year and is known to increase after the establishment phase. Human assistance may also amplify the potential of expansion of *C. erythraeus* by translocation.

2.2 EFFECTS OF ESTABLISHMENT

Consider the potential of the non-native organism to cause direct and indirect environmental, economic and social damage as a result of establishment. Information should be obtained from areas where the pest occurs naturally or has been introduced, preferably within Belgium and neighbouring areas or in other areas with similar eco-climatic conditions. Compare this information with the situation in the risk analysis area. Invasion histories concerning comparable organisms can usefully be considered. The magnitude of those effects should be also compared with those caused by their closest native relatives.

2.2.1 Environmental impacts

Specify if competition, predation (or herbivory), pathogen pollution and genetic effects is likely to cause a strong, widespread and persistent decline of the populations of native species and if those mechanisms are likely to affect common or threatened species. Document also the effects (intensity, frequency and persistency) the non-native species may have on habitat peculiarities and ecosystem functions, including physical modification of the habitat, change to nutrient cycling and availability, alteration of natural successions and disruption of trophic and mutualistic interactions. Specify what kind of ecosystems are especially at risk.

In areas of introduction, Bertolino & Lurz (2011) recently reported that the most evident damage caused by *Callosciurus* sp. in many areas is bark stripping. It can be intense and significantly impact trees and timber plantations, which is supposed to be even worse when squirrel densities are high (up to 18 individuals/ha as mentioned in Argentina by Benitez *et al*. 2010). Negative impacts to native species are reported but not quantified. The Pallas's squirrel could also convey parasites to native species.

A/ Competition

Data on negative impacts to indigenous species, and especially to *Sciurus vulgaris** (by possible exclusion), are sometimes reported but have not yet been properly quantified (Dijkstra *et al.* 2009, Chapuis *et al*. 2011). However, *C. erythraeus* was considered to pose a potential threat to native *Sciurus vulgaris* because it inhabits similar habitats and feeds on similar resources (Lange *et al.* 1994, Helin *et al*. 1999, Dijkstra & Dekker 2008, Smith & Xie 2008, Dijkstra *et al*. 2009, Stuyck *et al*. 2009, Dijkstra 2010, Chapuis *et al.* 2011).

B/ Predation

Some potential problems of predation on native fauna have been mentioned in areas where *C. erythraeus* has been introduced, but these don't seem to be very important. In Argentina, Pereira *et al.*(2003) observed occasional predation on eggs and Guichon *et al*. (2005, 2009) also reported the consumption of eggs in bird rearing farms. In Japan, according to Azuma (1998), egg predation was observed once in a nest of Japanese white-eye (*Zosterops japonica*). As the Pallas's squirrel diet is mainly vegetarian and the animal consumption is mainly based on insects, these observations were quite rare.

C/ Herbivory

The Pallas's squirrel is omnivorous, but almost all of its food consists of vegetable matter (Tamura 1996, Suzuki *et al.* 2006).

In its native area, even when it is easily frightened by humans, *C. erythraeus* is considered as a tropical crop pest (Hill 2008). It causes damages in fruit trees and crop plantations, especially in oil palm, papaya and cocoa trees, eating and spoiling the fruits which are eaten as well as the green parts of coveted plants.

In the new recipient areas, the most evident damage caused by this species is also bark stripping, especially where and when food availability is weak (Guo 2011): it can be really important as reported in France (Jouanin 1986), Argentina and Japan (Tamura & Ohara 2005). However most of the data are qualitative (Bertolino & Lurz 2011). Another impact of *C. erythraeus* may be linked to the use of leaves, branches and bark to build its nests. In Japan, the chemical composition of bark was studied to understand the pattern of damage among different tree species, but the results were unconvincing although the sugar content of phloem and the concentrations of certain secondary compounds (e.g. flavanols) could explain a part of this bark-stripping behaviour (Tamura & Ohara 2005).

In France, the species is now considered as a pest by part of the citizens who even name it "Korean rat" (Chapuis 2011) because of damages caused in gardens and plantations (bark stripping of trees and shrubs, fruit consumption especially in olive and citrus plantations and in orchards). Similar problems also occur in Argentina (Guichon *et al*. 2005, 2009), where the consumption of cereals in storage silos is also reported (district of Lujan; Guichon 2009, Bertolino & Lurz 2011).

D/ Genetic effects and hybridization

In Belgium and neighbouring countries no hybridization can happen because of the genetic distance between the native species and the Pallas's squirrel.

E/ Pathogen pollution

C. erythraeus can carry parasites from its native range into new recipient habitats, leading to the introduction of new parasite species in recipient ecosystems and thus, to a possible pathogen transmission to native host species (Barton 1997, Bertolino & Lurz 2011). On the other hand, when a parasite species reaches new areas, it has to adapt to new parasite communities (Torchin & Mitchell 2004, Bertolino & Lurz 2011).This can sometimes lead to the development of new host-parasite cycles (Esch *et al*. 1990).

However, the transmission of diseases through *Callosciurus* sp. is not well documented. In introduced areas of Pallas's squirrels, pathogen pollution of native wildlife species or even humans is possible, but nothing is known about it. Bertolino & Lurz (2011) pointed out diseases like the monkey pox virus that could be transmitted by squirrels as it has been documented in Zaire for the species *Funisciurus anerythrus* (Khodakevich *et al*. 1986), but no evidence of such a risk is currently recognized for *C. erythraeus*.

F/ Effects on ecosystem functions

Chung & Corlett (2006) studied the rodent diversity in highly degraded tropical landscapes in Hong Kong to better understand the role played by different rodents on such ecosystems. These authors conclude that *C. erythraeus* is a strong selective seed consumer previous to the dispersion of the seeds. Thus, the presence of *C. erythraeus*, recently introduced, should lead to a positive restoration of a natural process because this species and other tree squirrels must have occurred in Hong Kong in the past.

ENVIRONMENTAL IMPACTS

It is likely that the establishment of the Pallas's squirrel in Belgium and neighbouring areas will induce problems of herbivory, particularly because of its bark stripping behaviour in woodland areas, but also because of potential depredation in plantations and orchards. The predation on native fauna is expected to be very low and the transmission of pathogens could likely cause a risk but, currently, it is not documented enough. Competition with native species like *Sciurus vulgaris* has been mentioned but not proven as yet. As other squirrels, *C. erythraeus* has a potential positive effect on seed dispersal.

2.2.2 Other impacts

A/ Economic impacts

Describe the expected or observed direct costs of the introduced species on sectorial activities (e.g. damages to crops, forests, livestock, aquaculture, tourism or infrastructures).

The bark stripping behaviour of *C. erythraeus* has been previously discussed. It can damage timber but it can also lead to trees dying. Significant economic impacts due to the Pallas's squirrel have been pointed out in many publications both in the native range (especially on conifer plantations; Lin & Yo 1981, Kuo 1982, Tsui *et al.* 1982) and in new recipient areas where introductions have occurred (Japan, Argentina and France). Hill (2008) compares the damages of *C. erythraeus* on oil palm trees to those of rats. In Taiwan, because of bark-stripping, a severe economic impact is known in some coniferous plantations like *Cryptomeria japonica*, *Cunninghamia lanceolata*, *Pinus luchuensis* and *Pinus elliottii* (Lin & Yo 1981, Kuo 1982, Tsui et al. 1982, Tamura 1996, Bertolino & Lurz 2011).

However, most data available are qualitative and don't enable us to assess the quantitative losses caused by the Pallas's squirrel (Bertolino & Lurz 2011).

B/ Social impacts

Describe the expected or observed effects of the introduced species on human health and well-being, recreation activities and aesthetic values

Studies on *C. erythraeus* mainly mention environmental and economic impacts, but their presence can also include negative social effects for humans. The Formosan squirrel can sometimes annoy people by building nests in private gardens (Suzuki *et al*. 2006). In France, the species, seen as a pest, is not welcome anymore for many people (Chapuis 2011) even if it was appreciated (appeal and behaviour) at first. Its popularity clearly decreased because of the damage it sometimes causes to infrastructures like telephonic cables, sprinkler systems, etc. In Argentina, such problems of deterioration of lighting, television and telephonic cables have also been reported (Guichon 2005, 2009). Thus, nowadays, in France some people even try to catch and get rid of this species by poisoning or shooting, which also implies high risks for non target species. According to Chapuis *et al*. (2011), the consequences of *C. erythraeus* introductions could be close to the consequences of the Grey squirrel introductions in terms of damages to trees and shrubs by bark stripping and fruit consumption in cultures but also in private gardens and properties (here, these authors also consider a strong potential impact on red squirrel populations).

STAGE 3 : RISK MANAGEMENT

The decision to be made in the risk management process will be based on the information collected during the two preceding stages, e.g. reason for initiating the process, estimation of probability of introduction and evaluation of potential consequences of introduction in Belgium. If the risk is found to be unacceptable, then possible preventive and control actions should be identified to mitigate the impact of the non-native organism and reduce the risk below an acceptable level. Specify the efficiency of potential measures for risk reduction.

3.1 RELATIVE IMPORTANCE OF PATHWAYS FOR INVASIVE SPECIES ENTRY IN BELGIUM

The relative importance of intentional and unintentional introduction pathways mediated by human activities should be compared with the natural spread of the organism. Make use e.g. of information used to answer to question 2.1.3.

Two introduction pathways have been acknowledged for *Callosciurus erythraeus* in Belgium. The first few individuals (10 to 12) at the origin of the Dadizele population have been reported as escaped/released from an animal trader. Therefore, the import of exotic squirrels through pet shops has to be considered as a clear potential problem for introduction. Because of the plasticity of the species in the wild and because escape already led to wild populations in and very close to our country, the import of Pallas's squirrels has to be considered as a serious threat. Nevertheless, only little information about *C. erythraeus* sales by pet retailers is available for Europe. Thus the level of risk is difficult to assess.

The second pathway of introduction could result in a possible natural colonization, in particular from the border with the Netherlands where a population was present but where an eradication effort is in progress and almost achieved (Voskamp P., pers. com.).

3.2 PREVENTIVE ACTIONS

Which preventive measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially (i) the restrictions on importation and trade and (ii) the use of specific holding conditions and effect of prohibition of organism introduction into the wild.

(i) Prohibition of organism importation, trade and holding

A general wildlife management strategy in continental Europe is absolutely needed because all countries don't invest the same energy to prevent introductions of exotic species on their territory (Genovesi 2005). Moreover, the continuous increase of animal trade during the last decades has been a main cause of species introductions (Westphal *et al.*2008). Squirrels are still being traded and sold as pets, thus further introductions of *C. erythraeus* may be expected. Therefore, Bertolino (2009) and Bertolino & Lurz (2011) already suggested trade recommendations and interdictions as a global strategy on introduced species.

It is forbidden to release exotic animals in the wild in many neighbouring countries as in Belgium. In our country, holding possibilities are indeed limited: *C. erythraeus* is not included in the short positive list of mammal species that may be held by private people. This list has been established in the framework of the animal welfare regulation (Royal Decree of 16th July 2009). However, the European Union still lacks a proactive approach to better control and prevent the introduction of invasive alien species (Bertolino & Lurz 2011). Such a control for squirrels is even more advisable if they can be sold in pet shops. State authorities generally banned the import of such species only after a successful establishment in their country. For example, in France, since 2007 work has been done by scientists and the Ministry of Ecology to prohibit the import and sale of Sciuridae (Tillon *et al.*2007). In the Netherlands, Dijkstra *et al*. (2009, 2011) also recommended a ban on trading and keeping *C. erythraeus* and other harmful exotic squirrels, resulting in prohibition of trading and keeping *C. erythraeus, S. carolinensis* and *S. niger* in this country since July 2012. However, to develop an efficient policy, such interdictions have to be taken at a global level and not dispersedly in the European Union, especially when a risk on fauna, flora or/and ecosystems caused by such species has been pointed out in at least one European country.

In most cases, people responsible of such releases were not aware of the consecutive risks of establishment of *C. erythraeus*. Some natural or artificial barriers to expansion may be present, like in Cap d'Antibes thanks to existing roads and sea belt (Le Louarn & Quéré 2003), but these are often only temporary and can only slightly slow down the species progression.

Besides a strong European policy, there could be a better control through the World Trade Organization for signatory states for sanitary or phytosanitary reasons.

Finally, a third way to prohibit the import of this alien species and to avoid its keeping and potential release is the implementation of the European Union list of the Annex B of European Community Regulation no. 338/97 (the European Union Wildlife Trade Regulation that puts into effect the CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora- within the European Union). The species belonging to that list present threats to native species (Shine 2006). Fortunately, *Callosciurus erythraeus* three has been proposed (Bertolino & Lurz 2011) and recently added to this list as well as *Sciurus niger* and *Sciurus carolinensis* (UNEP/CBD/AHTEG-IAS 2011).

Bertolino & Lurz (2011) also suggest a more proactive approach concerning animal species traded when their invasiveness is a potential risk. In Japan, for example, three lists exist:

- one for highly invasive species in the country or elsewhere (including *C. erythraeus*),
- another one for closely related species for which a risk assessment procedure has to be done before import (as all the species of the genus *Callosciurus*),
- a third one during the import, imposing the certification of the species identity. All the Sciuridae species not considered by the two first lists are belonging to this group, especially because of taxonomy problems and confusions that often occur among squirrel species.

Preventive actions to inform a wide public (private citizens but also state departments, local authorities, associations, etc.) on the risks linked to the presence of *C. erythraeus* are also included and necessary (Chapuis *et al*. 2011). In urban areas, exotic squirrel populations are often fed by private people: a good awareness is thus essential to strengthen *C. erythraeus* population control where they appear.

When a population is locally known, Chapuis *et al*. (2011) also advise to control peripheral areas regularly to ensure that the Pallas's squirrel is still absent; otherwise new trapping actions need to be launched in these areas.

(ii) Use of specific holding conditions and effect of prohibition of organism introduction into the wild

Squirrels imported by the way of pet shops, private citizens and zoos are at risk of releases or escapes (Bertolino 2009). Use of stricter rules on import and possession is therefore the most efficient approach to avoid risky introductions of *Callosciurus erythraeus* in the wild, followed by eradication actions or long-term containment or control (Shine *et al.* 2008, Bertolino 2009, Dijkstra 2011).

3.3 CONTROL AND ERADICATION ACTIONS

Which management measures have been identified to reduce the risk of introduction of the organism? Do they reduce the risk to an acceptable level and are they considered as cost-effective? Specify if the proposed measures have undesirable social or environmental consequences. Consider especially the following questions.

(i) Can the species be easily detected at early stages of invasion (early detection)?

In tropical forests of the native range, Hill (2008) considers the species as easy to control because of the weak reproductive potential of *C. erythraeus*.

In recipient areas, recent introductions may not have led to population establishment because, meanwhile, they had no time enough to set up (Bertolino & Genovesi 2005, Bertolino 2009). But in Belgium and neighbouring countries, eradication campaigns enlightened the difficulty to have a good population estimate even in urban habitats where the individuals should be rather easily spotted. The eradication campaign of Dadizele (Belgium) demonstrates that even in a heavily urbanized area, the settlement of an exotic species may not be rapidly detected and considered as problematic (Stuyck *et al*. 2009). The same conclusions were made in the Netherlands about the underestimation of the population size despite field studies and the necessity to remove the species as soon as the first individuals are detected (Dijkstra 2011).

In spite of this, wild populations of *C. erythraeus* are still very rare. The dispersal potential of the species seems to be very limited, but it is also clear that established populations in Europe and South America originated from few animals (Wood *et al.* 2007, Bertolino 2009) (see Fig.3), thus proving the adaptability of *Callosciurus erythraeus* to new habitats, even if the colonization is slow and thus moderate (Dijkstra *et al*. 2009). Tree squirrels are generally considered as particularly adaptable because of their relatively **high reproductive potential**, **wide food habits**, and **plasticity to anthropogenic habitats** (Palmer *et al.* 2007, UNEP-WCMC 2010). Thus, prompt actions are recommended in any case of suspected invasiveness leading to possible impacts (Stuyck *et al.* 2009).

(ii) Are they some best practices available for organism local eradication?

In their risk assessment for *C. erythraeus* presence in the Netherlands, Dijkstra & Dekker (2008) rapidly advised the removal of individuals in the localities concerned. They started trapping operations from October 2011 to May 2012. A bit more than 200 individuals of *C. erythraeus* were caught, with a variable trapping success appearing partly linked to the weather conditions.

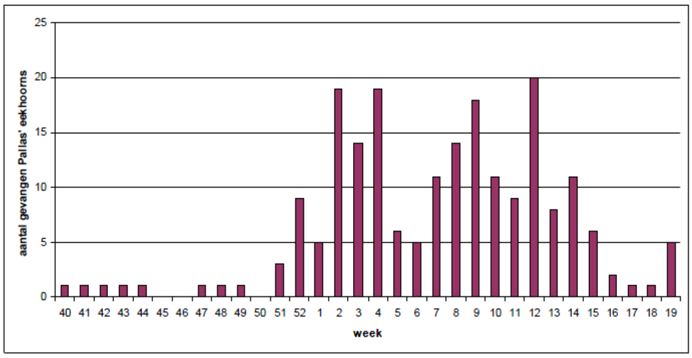

Fig 5. Numbers of Pallas's squirrels caught per week in the southern Netherlands between October 2011 and May 2012 (Dijkstra 2012).

The trapping operation gave encouraging results but as the Pallas's squirrel population was underestimated, a new trapping operation was operated between December 2012 and April 2013 (Voskamp P., pers. com). It was alreaday planned before the first trapping operation to ensure a whole eradication of the population Dijkstra & Dekker 2008). It led to an additional remove of 46 (32?) individuals (Janssen R., pers. com).

Live-traps baited with banana and peanuts are successfully used to capture squirrels in different countries (Tamura *et al.* 1989). Peanut butter is also efficient and has been used in the live-traps placed in the Netherlands (Voskamp P., pers. com) but because of side effects (capture of many different species) it was replaced by walnuts (still causing some red squirrel and great spotted woodpecker captures) (Dijkstra pers. com.). The capture pressure needs to fit the expected population level and the traps have to be checked daily.

Intensive trapping operations have been led in Belgium in 2008 (and 2010) and apparently led to the eradication of the local population of Dadizele (Shine *et al*. 2008, Stuyck *et al.* 2009). Some countries did not apply euthanasia after capture because of ethical questions, like in Flanders where the government got some pressure from animal right associations and decided to sterilize caught individuals and to send them in zoos (G. Verbeylen, pers. comm.). In Italy, in the area of Brezzo di Bedero, after a monitoring effort to define the species abundance with the use of hair tubes, trapping sessions were launched and the individuals of *C. erythraeus* which were caught were transported to a certificated laboratory to be euthanized through an excess of CO_2.
In the National French Plan developed to strive against Pallas's squirrels, different levels of actions have been proposed (Chapuis *et al*. 2012). First, it is advised to remove *C. erythraeus* in the main sectors at risk (south of the A8 highway and Vallauris in Cap d'Antibes). In urban areas, trapping will be organized in areas with high densities of *C. erythraeus,* based on agreements with the landowners. Intensive trapping in these areas is expected to have a sink effect.

(iii) Do eradication and control actions cause undesirable consequences on non-target species and on ecosystem services?

Dijkstra *et al*. (2009) suggest live-trapping as an appropriate method to ensure that non native squirrels (*Sciurus vulgaris**) would be unintentionally killed. The trapping operations should be done between September and December as *S. vulgaris** rears its young between January and September and red squirrel females could be trapped leading to potential negative effects on their offspring. But, checking the traps two times a day is a good method to reduce such a problem at the lowest level. By the way, the fact that Pallas's squirrels were not euthanized in the Netherlands encouraged private citizens to assist the capture operations (especially in private gardens).

(iv) Could the species be effectively eradicated at early stage of invasion?

Because of the difficulty to estimate sizes of newly detected populations of*C. erythraeus*, sometimes the removal of individuals by eradication campaigns has to be performed in different stages as it was experimented in Dadizele (Belgium) (Stuyck*et al.*2009, Bertolino & Lurz 2011) or inWeert (the Netherlands) (Dijkstra2012).

The likelihood to easily eradicate the Pallas's squirrel at early stage of invasion in the Netherlands (Weert) was stated by Dijkstra & Dekker (2008) according the expected spread slowness for this species. If it is important to monitor precisely the population before eradication (e.g. with camera or hair traps), scientists advice to rapidly start eradication campaigns, even if the number of individuals is not accurately known because the longer eradication actions are postponed the faster the Pallas's squirrel population may grow (Janssen R., pers. com.). The Netherlands also advised the Belgian government to launch trapping operations close to the border where the Pallas's squirrel was present.

In Cap d'Antibes (France), Chapuis & Menigaux (2010) reported that some citizens were shooting, trapping and poisoning the species (whilst others were feeding it), and that an action plan was urgently needed to limit the species before the last geographical barrier would be crossed (A8 motorway). They also noted that non-intervention in the early years, followed by marked expansion in the population, meant that interventions would now be more difficult and expensive. To accomplish this eradication, Chapuis *et al*. (2011) estimated the different costs at 100.000 € for the first year of actions planned in 2011, then 90.000 € for 2012 and 60.000 € for 2013 and 2014 each. In this budget, preventive actions to inform a broad public and improve its awareness on the risks posed by the Pallas's squirrel are also included and necessary.

(v) If widely widespread, can the species be easily contained in a given area or limited under an acceptable population level?

If active measures are not taken from early stages of introduction and if no serious monitoring is carried out since the arrival of *C. erythraeus* in a new area of introduction, it can become really difficult to manage the eradication, like in France (Chapuis & Menigaux 2010, Chapuis2011). Due to the expected increase in the *C. erythraeus* population size and range, Dijkstra *et al*. (2009) also advice fast eradication actions to minimize the management costs. The UNEP-WCMC report (2010) also recommends a constant monitoring effort to allow a complete removal of the existing populations (e.g. in the Netherlands and Belgium). In the Netherlands, the difference between the estimated population of Pallas's squirrel before the first attempt of eradication and the eradication campaign itself showed how the population size can be underestimated (Stuyck*et al.* 2009 ; Dijkstra 2012). It is important to notice that despite the awareness campaign developed by the operators, private citizens did not always collaborate, especially at the beginning, which had an underestimating effect of the Pallas's squirrel population level. Thus it will take additional efforts to enhance the eradication measures; the situation is still not completely solved actually.

CONCLUSION OF THE RISK MANAGEMENT SECTION

An important problem concerning the dispersal capacity of *C. erythraeus* is its possible undetection at first stages of invasion which may increase the risk of imperceptible diffusion.

Establishment of Pallas's squirrel in Belgium is likely to occur either due to escape/release from captivity or from a natural expansion of the population established in the Netherlands near the Belgian border, where eradication actions are currently undertaken. The prohibition of Pallas's squirrel import, trade and keepingcould be considered as an efficient measure for reducing the risk of entry to an acceptable level. As a transitional measure, drastic security rules including ear-tagging and systematic sterilization combined with an official surveillance system and the obligation to rapidly report any escape should be imposed for Pallas's squirrels already kept in captivity.
Those preventive measures, linked to a good citizens' awareness, have to be preferred over early detection and population control as the Pallas's squirrel may easily establish feral populations after escape. Eradication actions are only feasible at the very beginning of the invasion process and are difficult to implement because of the species' low detection rate at low densities, rapid expansion from the release site when suitable ecological conditions are met and strong public opposition towards killing actions. Beside that, it is necessary to have a good overview of the food supply available for the species to prevent the species expansion.

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Cellule interdepartementale
Espèces invasives

La CiEi est chargée depuis novembre 2009 de coordonner les actions visant à limiter les dommages causés par les espèces invasives en Wallonie. Ses activités se fondent sur l'engagement du Gouvernement wallon à prévenir l'installation de nouvelles espèces invasives et de lutter contre celles dont la prolifération pose problème

http://biodiversite.wallonie.be/invasives
Email : invasives@spw.wallonie.be

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