PLURIFOR PROJECT
EMERGING PESTS AND DISEASES WORKSHOP:
TOWARDS EARLY WARNING DETECTION METHODS

# Eradication of forest pests

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Oeiras, 25 January 2018

# Questions

- Is it feasible?
- Reasons of failure or success?
- What about eradication tools?
- Is it cost-effective?
- Is it relevant to involve citizens?
- What about when eradication is no longer a possibility?

# Is it feasible?

*"FOR MANY ERADICATION IS NOT BELIEVED TO BE FEASIBLE"*
SIMBERLOFF, 2003

# Feasible? **YES!**

Global Eradication and Response Database (GERDA) – arthropod eradication programs and the factors that influence eradication success (Kean et al., 2018)

Out of 672 arthropod eradication programs, **59%** were considered to be successful!

Yet, targeted species are repeated.

3 species *L. dispar*, *C. capitata*, and *B. dorsalis*, collectively accounted for 169 programs!

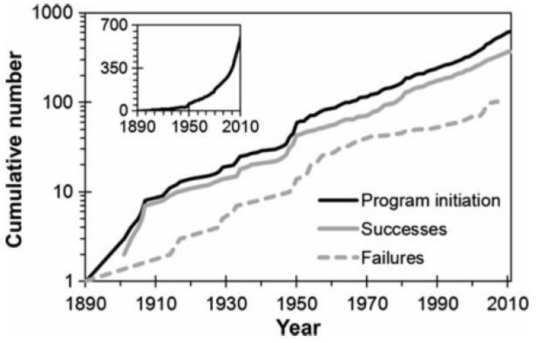


**Fig. 2** Cumulative number of initiated eradication programs, and when programs were declared to be either successful or a failure (excluding programs in progress or if the outcome was not known), 1890–2010. The *insert* graph represents the total number of initiated programs on a non-transformed scale

**Gerda · global eradication and response database** · www.b3nz.org/gerda
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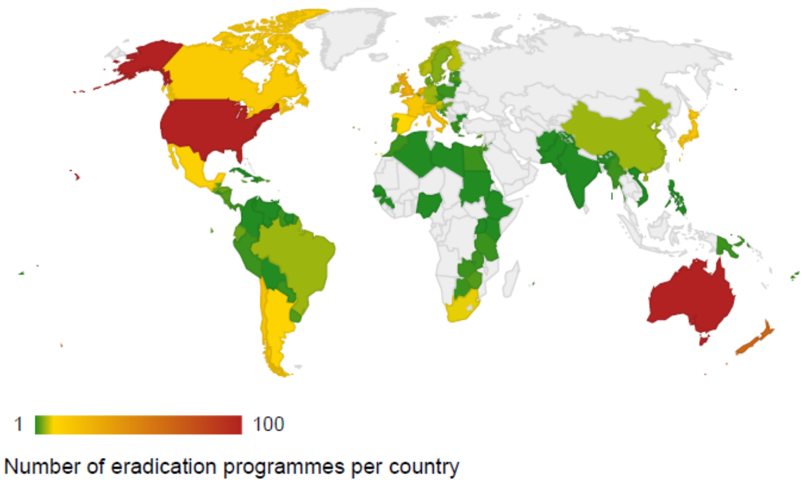
**Gerda · global eradication and response database**

This database summarises incursion response and eradication programmes from around the world.

The scope of the database is terrestrial arthropod pests and plant pathogens. Weeds, vertebrate pests, aquatic pests, and animal diseases are not currently included. Read more about the scope and purposes of the database in the **frequently asked questions (FAQ)** section.



# But …

**Whereas in some eradication has been a success!**

- For the Asian longhorned beetle *Anoplophora chinensis* (Col: Cerambycidae) detected in Europe since 2003, several eradication programs started in Europe, in France was declared eradicated in 2006!
- The ALB was also eradicated in several states of US.

**In others cases eradication has been a failure!**

- The emerald ash borer, *Agrilus planipennis* (Col: Buprestidae) introduced in the 1990s in US, despite many quarantines and eradication attempts, continued spreading to other states and Canada.

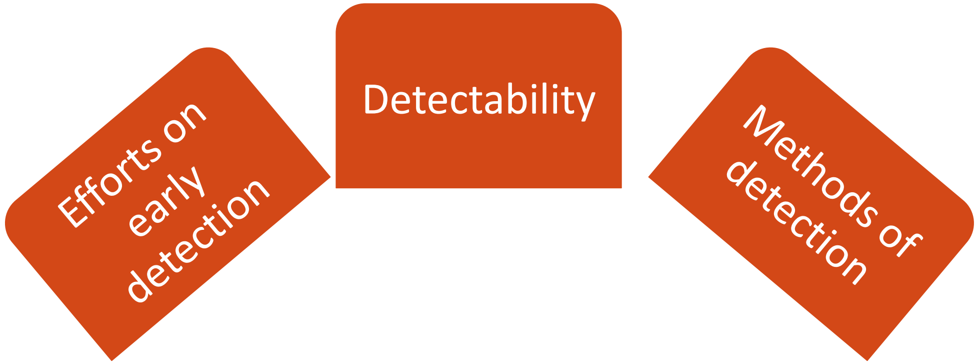
# Reasons of failure or success?

*"SKEPTICISM REFLECTS THE HISTORICAL LACK OF SCIENTIFIC THEORY BEHIND ERADICATION"* LIEBHOLD ET AL. 2016

# Important components of successful eradication!

## QUICKNESS!

- Time elapsed since establishment
- Relative detectability
- Methods of detection available



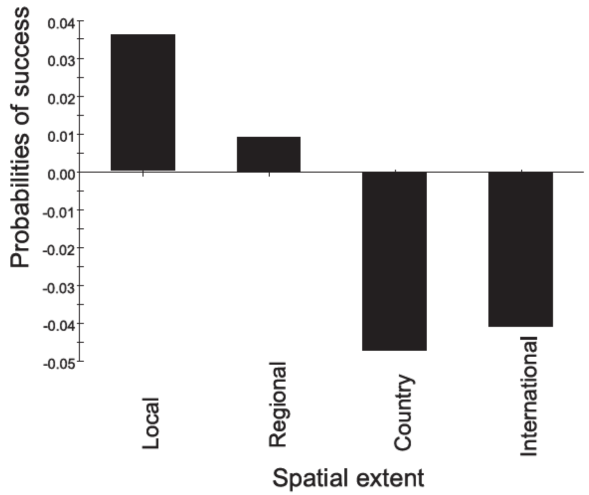

"If the action is taken within **four years** since the start of the invasion …, eradication is likely; later, chances rapidly decrease." Pluess et al., 2012 PLoS ONE 7(10): e48157.

# Important components of successful eradication!

**CONFINEMENT!**

- Size of the infested area
- Time elapsed since establishment

**“Very small-scale eradication need not** require enormous resources”



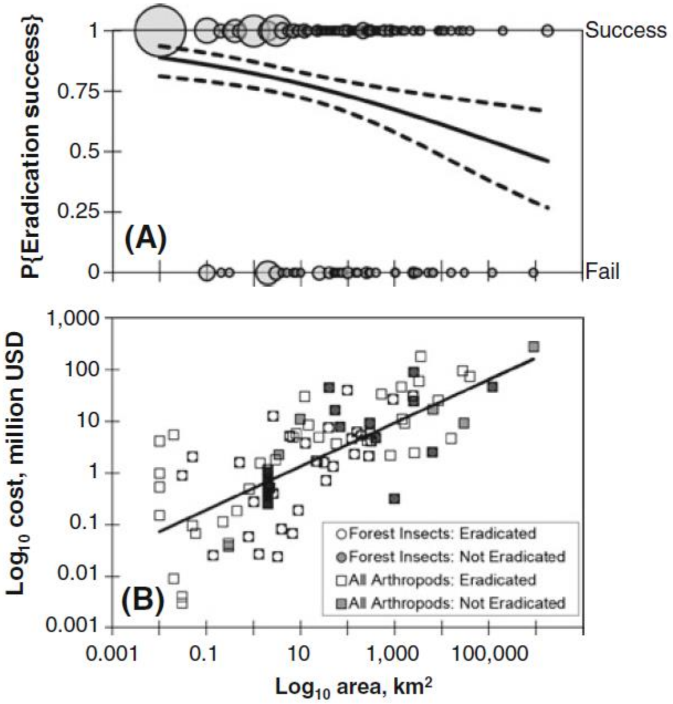




**Fig. 3** Relationship between area of the infestation and the probability of eradication success (**a**), and the program costs (**b**). In **a**, the size of the circle reflects the number of cases, while the *solid* and *dashed lines* are the predicted probabilities and 95 % confidence intervals from logistic regression, respectively. In **b**, the *solid line* is the least squares regression fit to all arthropod data

Eradication campaigns were more successful in **man-made habitats**, e.g. greenhouses, where 91.7% of campaigns resulted in eradication (Pluess et al. (2012)? PLoS ONE 7(10): e48157.

# Important components of successful eradication!

## TARGET SPECIES TRAITS

- Rate of reproduction;
- Easy detection at low population density (e.g. via visual identification or traps);
- Host range;
- Dispersal ability

Citrus canker (caused by Xanthomonas axonopodis pathovar citri), eradicated in the southeastern US in the early 20th century, had a highly restricted host range (Merrill 1989).

# Important components of successful eradication!

**Dispersal ability**

The rate of spread of an organism affects the likelihood of delimitation

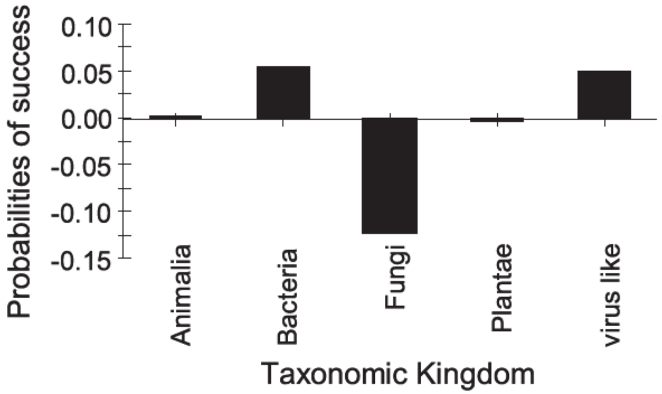
Dispersal can result in populations establishing at long distance from the main infestation.

Some organism may disperse quickly by
- their own - e.g. *Leptoglossus occidentalis*
- wind dispersal – e.g. larvae of *L. dispar*
- anthropogenic transport, e.g. transport of infested material

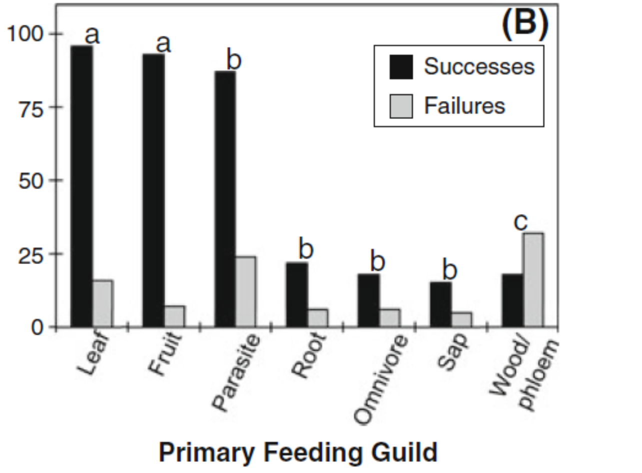
# Important components of successful eradication!

## Feeding guild and size of organism

Among large groups, fungi have the lowest probability of eradication and bacteria the highest, insects are in the midway (Pluess et al., 2012)




Among insects, bark and wood borers seem to have the lowest rate of eradication success! (Tobin et al, 2014).




Data may be biased by target groups for which more eradication programs were undertaken

# Important components of successful eradication!

**Availability of eradication tools**

The availability of taxon-specific monitoring and control tools increase the **probability of eradication success**
e.g. pheromone traps

Surveillance tools are crucial for **detecting and delimiting** the presence of **small** newly founded populations.

Eradication relies on the existence of efficient control tools with a **minimum effect on non-target species**.

# Important components of successful eradication!

**Propagule pressure**

Eradication is difficult if there is a continuous introductions of new invaders

Repeated eradication

- May increase costs and reduce benefits

# What about eradication tools?

*"…ERADICATION PROGRAMS INCREASED DRAMATICALLY OVER TIME, PERHAPS BECAUSE SCIENTISTS HAVE DEVELOPED MORE EFFECTIVE AND EFFICIENT TOOLS …"* LIEBHOLD ET AL. 2016

# Detection and surveillance tools

Eradication relies on a efficient monitoring system: detection, delimitation, evaluation of treatments and confirmation of eradication

- Pheromone traps - most sensitive to small populations (e.g. *Lymantria dispar*)
- Feeding baits (e.g. *Vespa velutina*)
- Tree visual surveys (e.g. PWN)
- Aerial images  (drones, ….)

A program to eradicate ALB from Chicago depending on tree visual surveys, was cumbersome, expensive, and not accurate!
Treatments were applied to all host trees within 200 - 800m of every infested tree!
The ALB was ultimately eradicated from Chicago.

New **molecular tools** are relevant to identify the source of infestation, and allowing higher accuracy of correct species identification.

New **technological tools** (e.g. drones, electronic nose) may bring new improvements to eaely detection.

**Citizens science** – reports by citizens facilitated may help to detect new cases

# Control tools

Taxon-specific control tools increase the probability of eradication

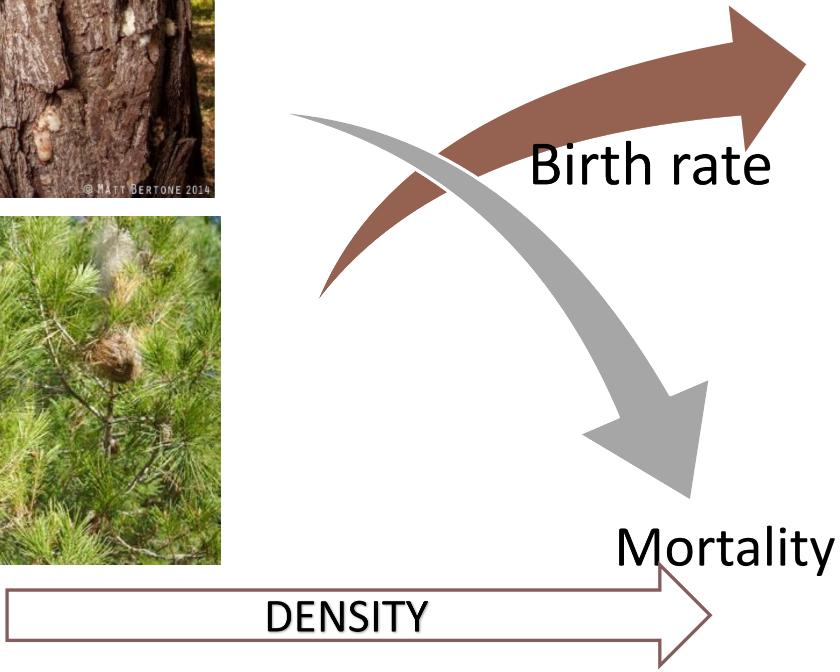
- Release of sterile males (sterile insect technique SIT) (e.g. fruit flies);
- Spraying with microbial insecticides (e.g. *Bt* for tree defoliators);
- Systemic insecticides (wood borers);
- Bait attractants (mass trapping);
- Host tree removal (e.g. wood borers, pathogenic fungi);
- Mating disruption with sex pheromones;
- Host traps (mass trapping);
- Quarantine regulations.

For species for which mating disruption or SIE were developed eradication become almost routine in some regions.

# Tools exploring Allee effect

*The positive relationship between individual fitness and population numbers or density*

- **Cooperation** (e.g. ability to over come host defenses, thermoregulation)
- **Defense** (e.g. repel or avoid natural enemies)
- **Reproduction** (e.g. probability to locate a mate)
- **Inbreeding depression**

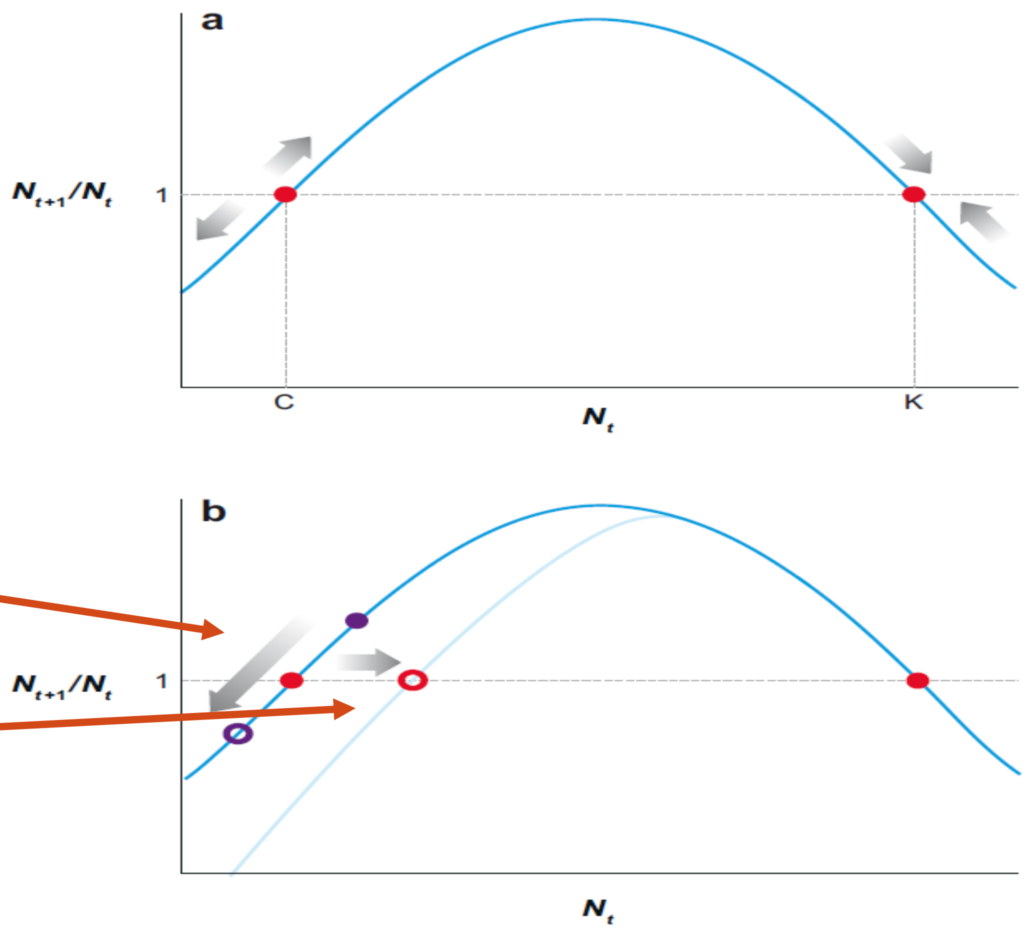

Eradication does not imply:
… *the seemingly impossible feat of eliminating every individual in a population!* Liebhold et al, 2016

# Tools exploring Allee effect

Control tools can be used to intensify Allee effects.

- Pushing populations to levels below Allee threshold
- Increase Allee thresholds;

- e.g. Release of sterile males or mating disruption increase Allee effects related with reproduction.




Liebhold & Tobin, 2008

Many successful eradication programs have combined two or more tactics, particularly combining density-independent treatment (e.g.,pesticides) with a density-dependent treatment (e.g., mating disruption).

# Is it cost-effective?

"… IT MAY BE COSTLY, AND IT MAY ENTAIL COLLATERAL DAMAGE…"

SIMBERLOFF 2003, WEED SCIENCE 51(2):247-253.

# When is eradication the best management option?

Decisions should be based on benefit-cost analyses

Benefits

**Avoidance of**

- Trade restrictions on potentially contaminated goods
- Yield losses
- Permanent treatments costs of established populations
- Societal implications (e.g. unemployment)
- Ecological impacts (e.g. biodiversity conservation)
- Land use land cover changes

*Although the cost-benefit analysis is conceptually simple, conducting a rigorous analysis is extremely difficult because identifying and comparing the costs and benefits of all actions and inactions becomes increasingly unmanageable,* Myers et al. Annu. Rev. Entomol. 1998. 43:471–91

# When is eradication the best management option?

Costs

- Eradication costs
- Ecological impacts (non-target species)
- Human health impacts (e.g spraying insecticides)
- Economical impacts of quarantine restrictions
- …

An infamous failure was (...) to eradicate the imported fire ant (*Solenopsis invicta*) in the US…, a fiasco in terms of collateral damage (including to human health and nontarget insects) and expense (over $200 million) termed ‘‘the Vietnam of entomology’’ by E. O. Wilson (Brody 1975).
This campaign probably exacerbated the fire ant invasion by **causing greater mortality for its natural enemies than for the fire ant itself.**

# There are only a few cost-benefit analyses studies!

In studies from NZ benefits are in general expected to surpass the costs!

TABLE 1: Costs and averted economic impacts associated with actual and planned eradication of forest insect pests in New Zealand. Costs are derived from unpublished New Zealand Ministry of Agriculture and Forestry reports and are shown in New Zealand dollar value current at the end of each campaign.

| Organism | Eradication Period | Eradication cost (NZ$ million) | Estimated economic impact over 20 years (NZ$ million) | Approximate averted cost (economic impact less cost of eradication, NZ$ million) | Reference(s) |
|---|---|---|---|---|---|
| White-spotted tussock moth, (*Orgyia thyellina*) | 1996 – 1998 | 12 | 25 – 177 | 13 – 165 | MoF (1997); Horgan (1997); Myers and Hosking (2002). |
| Gum leaf skeletoniser (1), (*Uraba lugens*) | 1997 – 1998 | 4 | 101 – 142 | 97 – 138 | Journeaux (2003); J. Bain, Scion, pers. comm. |
| Painted apple moth, (*Teia anartoides*) | 1999 – 2006 | 65^ | 58 – 356 | -7 – 291 | MAF (2002); Anderton (2006); Suckling et al. (2007a). |
| Fall webworm, (*Hyphantria cunea*) | 2003 – 2006 | 7 | 19 – 83 | 12 – 76 | Anderton (2006). |
| Gum leaf skeletoniser (2)* | 2003 | 120† | 101 – 142 | -19 – 22† | Journeaux (2003); Ross (2003a, 2003b). |
| Hokkaido gypsy moth, (*Lymantria umbrosa*) | 2003 – 2005 | 6 | 3 – 291# | -3 – 285 | Sutton (2005); Harris Consulting (2003). |

* Eradication was not attempted due to an unfavourable cost–benefit analysis.
^ Budgeted figure was >$90M, but eradication was achieved for less.
† Eradication cost estimate based on Ross (2003b) (mean value of the estimated range of $90–$150 million).
# Value calculated according to Harris Consulting (2003).

But :
*Cost-benefit analyses of eradication programs tend to underestimate the costs and overestimate the benefits.*
Myers et al. 1998

Brockerhoff et al.: New Zealand Journal of Forestry Science 40. (2010) S117-S135

# Cost-benefit analyses

Cost increase with area affected!

Cost increase when populations become low!

ESCALATING COSTS FOR KILLING THE LAST INDIVIDUALS
Eliminating the last 1–10% of the population may demand equal expenditures of time, energy, and money to that required for the first 90–99% and therefore be more expensive per insect killed.

Myers, et al (1998). *Annual review of entomology*, *43*(1), 471-491

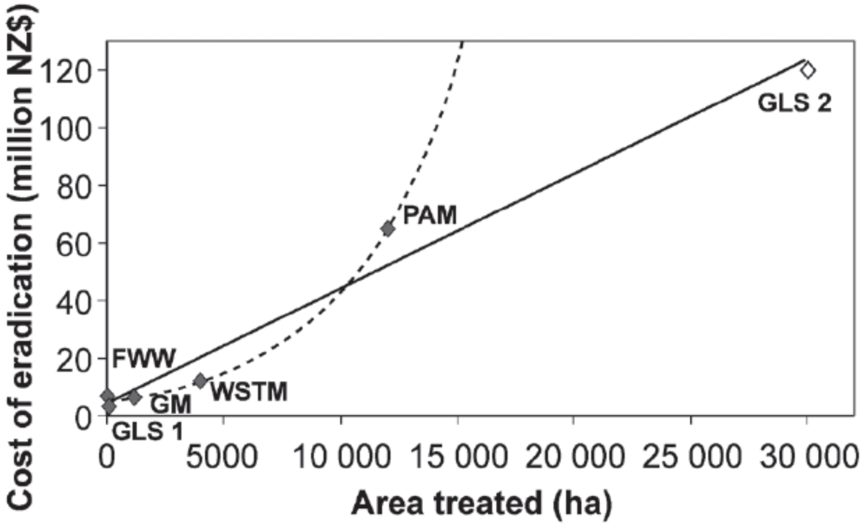



FIGURE 1: Relationships between the area affected by incursions (treated area or known affected area) and cost of recent eradication campaigns against defoliating Lepidoptera in New Zealand (NZ$ value current at end of campaign). Filled diamonds represent successful eradication campaigns; the single open diamond (GLS 2) represents an incursion for which eradication was not attempted. The linear relationship includes

Brockerhoff et al.: New Zealand Journal of Forestry Science 40. (2010) S117-S135

# Is it relevant to involve citizens?

"CONTROL OF BIOLOGICAL INVASIONS DEPENDS ON THE COLLECTIVE DECISIONS OF RESOURCE MANAGERS."

EPANCHIN-NIELL ET AL, 2010.

# Communication, Education, Involvement
must be a part of eradication programs

**Non acceptance** of society of the eradication programs and the **lack of consensus** and participative collaboration may hinder eradication efforts!

Especially when suppressive measures collide with human safety, economical concerns, cultural values or welfare.

Inversely, the collaboration of the society may be extremely important to guarantee successful results.

Example: New colonies may easily start by human activities if citizens are not aware, do not care or even oppose to the eradication efforts.

# Communication, Education, Involvement must be a part of eradication programs

**Examples**

Aerial application over urban areas, may cause public health concern.

Misinformed public may not recognize the difference between chemical insecticide treatments and semiochemical based eradication treatments, such as mating disruption.

Removal of host trees may face opposition by local residents.

People may be not aware of the consequences when moving firewood from one region to another.

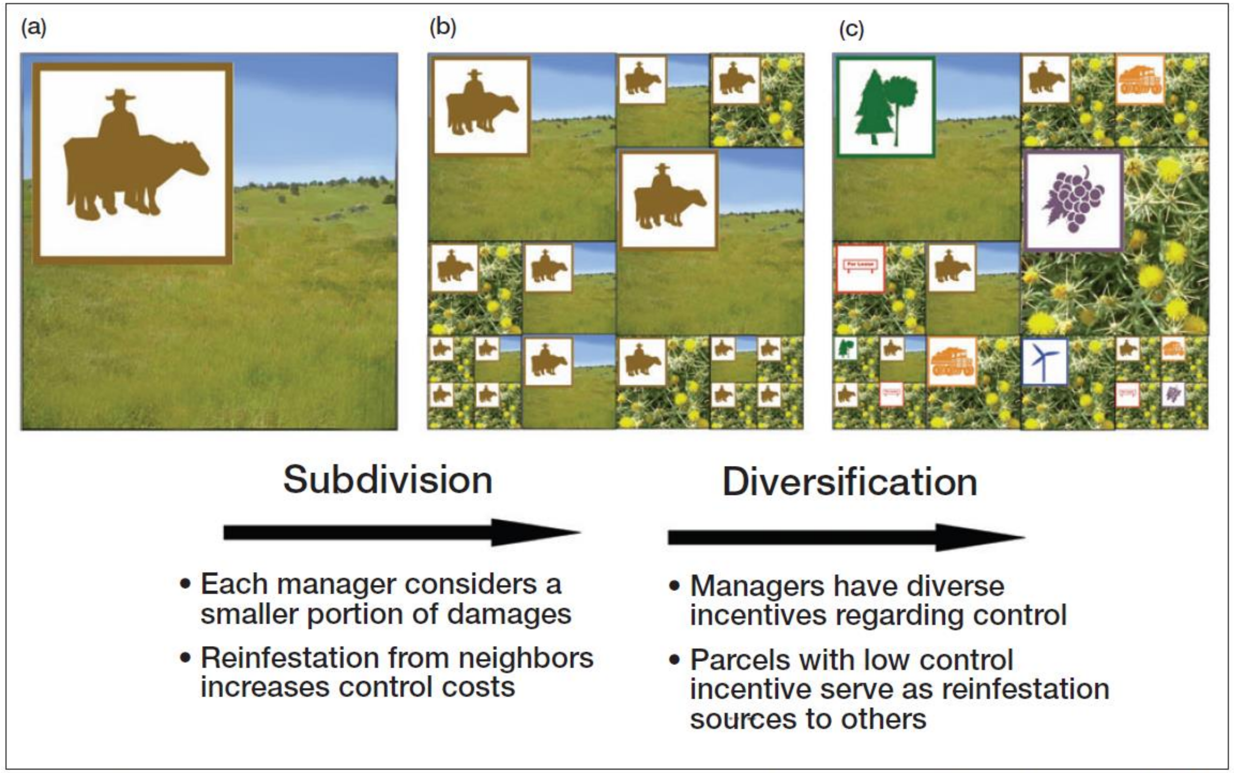



**Figure 1.** *The complexity of a management mosaic (a) increases as it is subdivided into more and smaller parcels (b) and as land use diversifies (c). Increasing complexity of this social landscape can reduce managers' incentives to control invasions, leading to over-invasion of the landscape.*

More fragmented landscapes with large number of ownerships imply more efforts on the engagement of variated stakeholders and citizens and pose more challenges!

Epanchin-Niell et al, 2010. Frontiers in Ecology and the Environment, 8(4), 210-216.

More need for action coordination at governmental level

As land becomes increasingly subdivided, each manager assumes responsibility for a smaller portion of the total; the incentive to control invasives is therefore diminished.

Coordination may be facilitated by top-down and middle-out approaches that promote education, regulation, incentives, and increased communication among all stakeholders

# What about when eradication is no longer a possibility?

"… I HAVE DODGED THE MATTER OF WHETHER ERADICATION IS AN APPROPRIATE STRATEGY EVEN IF IT IS FEASIBLE …"

SIMBERLOFF 2003, WEED SCIENCE 51(2):247-253.

In principle, eradication should be carried out when **long-term costs of damage and/or control exceed short-term costs** of successful and permanent elimination.

Myers et al. Annu. Rev. Entomol. 1998. 43:471–91

Ultimately

Eradication is not necessarily more efficient than ongoing lower-level control efforts

Then, other strategies may be used!

# Slowing the spread

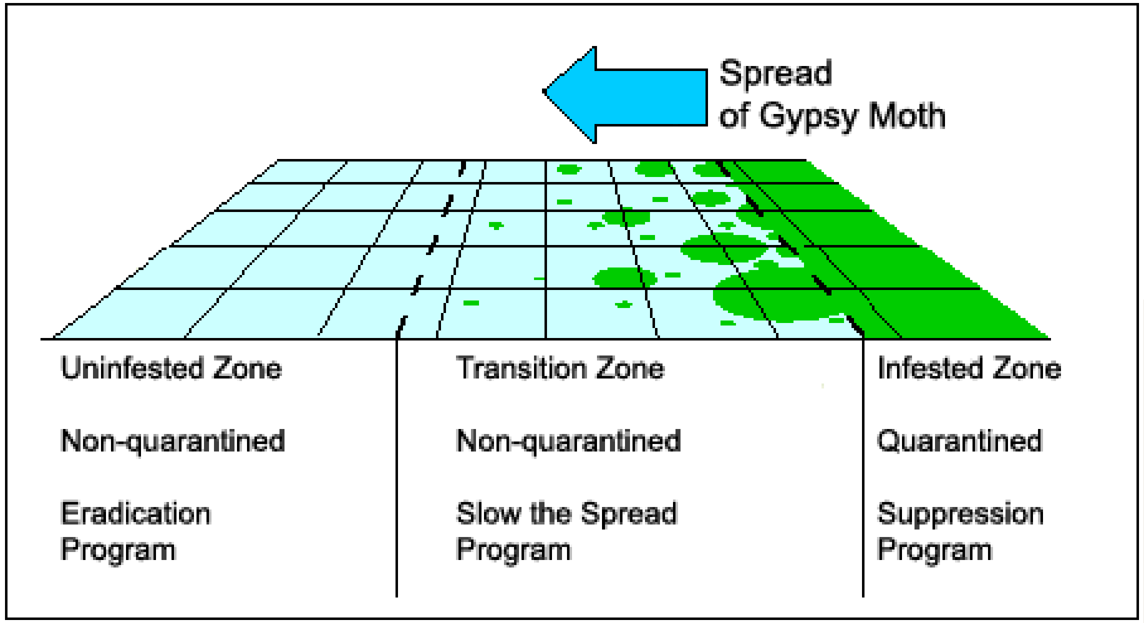



*Diagram provided by the STS Decision Support System*

GYPSY MOTH IN NORTH AMERICA The gypsy moth was first targeted by organized eradication efforts in the United States in the late 1800s. However, despite these efforts, the pest has continued to spread and is now perhaps the most notorious forest pest in North America. Eradication has been abandoned in the infested areas of the northeastern United States and Ontario, Canada. ... But many states at the edges of the spreading invasion have continued to pursue eradication and carry out programs designed to slow the spread of gypsy moth

# Area wide suppression

Area-wide pest management -  targeting in simultaneous entire pest populations at large scale to keep it at low levels

Pest populations are contained at low levels for longer periods – IPM methods can be used

Use of ecological and environmental sustainable strategies: SIT, mating disruption avoiding the use of pesticides

# Classical biological control

***Anaphes nitens***

*Psyllaephagus bliteus*

Thank you
Obrigada
Merci
Gracias