



CPM *10th Session*

Commission on Phytosanitary Measures
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Agenda Item 18: Special Topics

New treatment technologies for phytosanitary applications

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Science and Technology

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OUTLINE

- 1. Introduction**
- 2. New Treatments**
- 3. New Paradigms**



Introduction

- 1. Treatments and the IPPC**
- 2. Treatments and USDA APHIS**



The IPPC and Treatments

Article VII.1 of the IPPC 1997 states:

Contracting parties shall have sovereign authority to regulate, ...the entry of plants and plant products and ..., may:
(a) prescribe and adopt phytosanitary measures concerning the importation of plants, plant products and other regulated articles, including, for example, **inspection, prohibition ..., and treatment**.

Top 3 Phytosanitary Measures

- **Inspection (2% vs risk-based)**
 - ISPM Nos. 23 & 31
- **Treatment (probit 9 vs risk-based)**
 - ISPM Nos. 18 & 28
- **Prohibition (not authorized vs prohibited)**
 - ISPM No. 20 (Sec. 4.2.3)

Treatment is a measure...And therefore:

Must be technically justified -- IPPC Article VII.2(a)

Subject to equivalence -- ISPM 24

Appropriate for the strength of measures -- “**Least restrictive measure**” [Article 5 of the SPS Agreement and Article VII.2g of the IPPC]

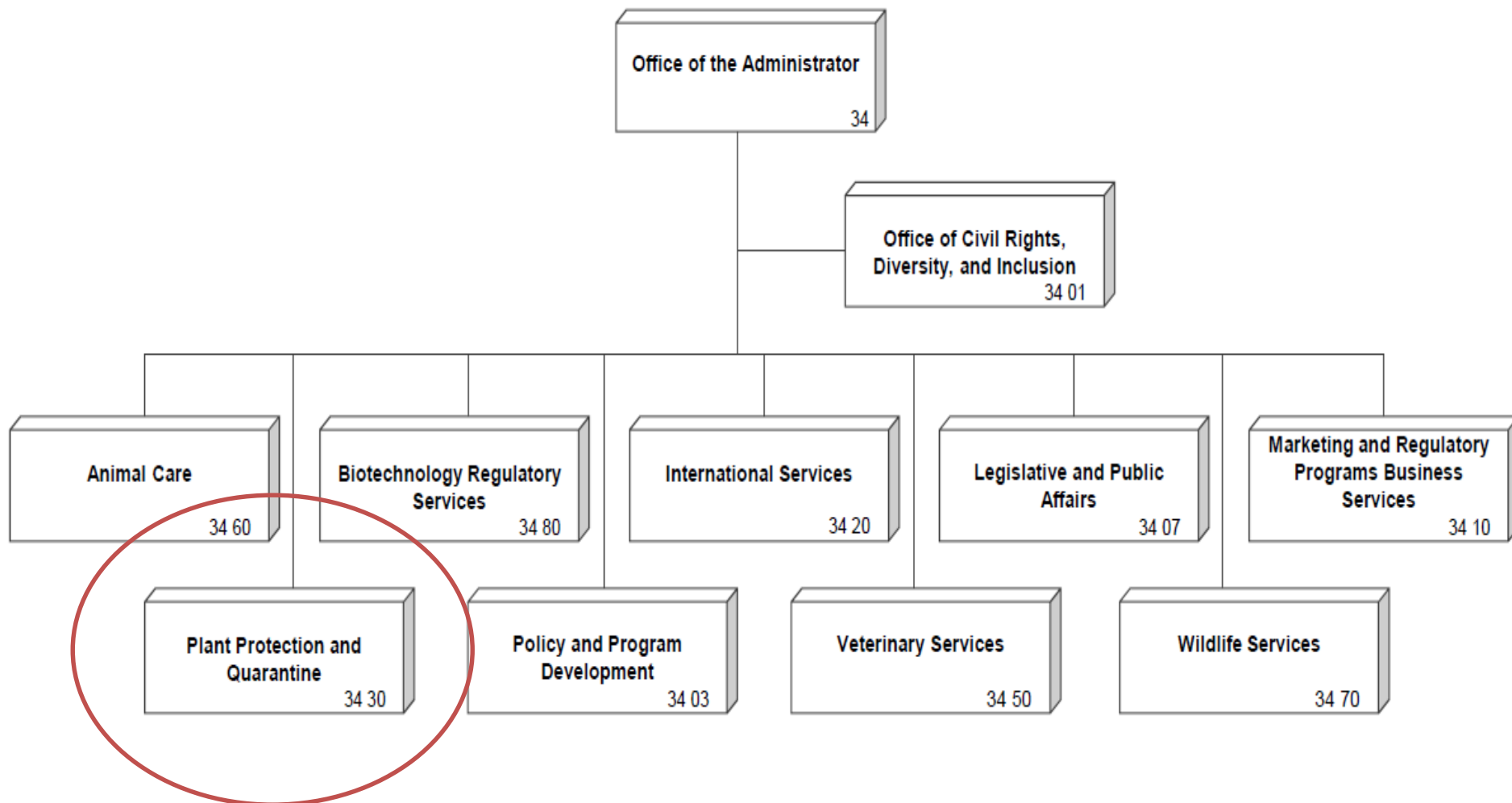
Strength of measures

PRA: The process of evaluating biological or other scientific and economic evidence to determine whether an **organism** is a **pest**, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it [Article II and ISPM 5]



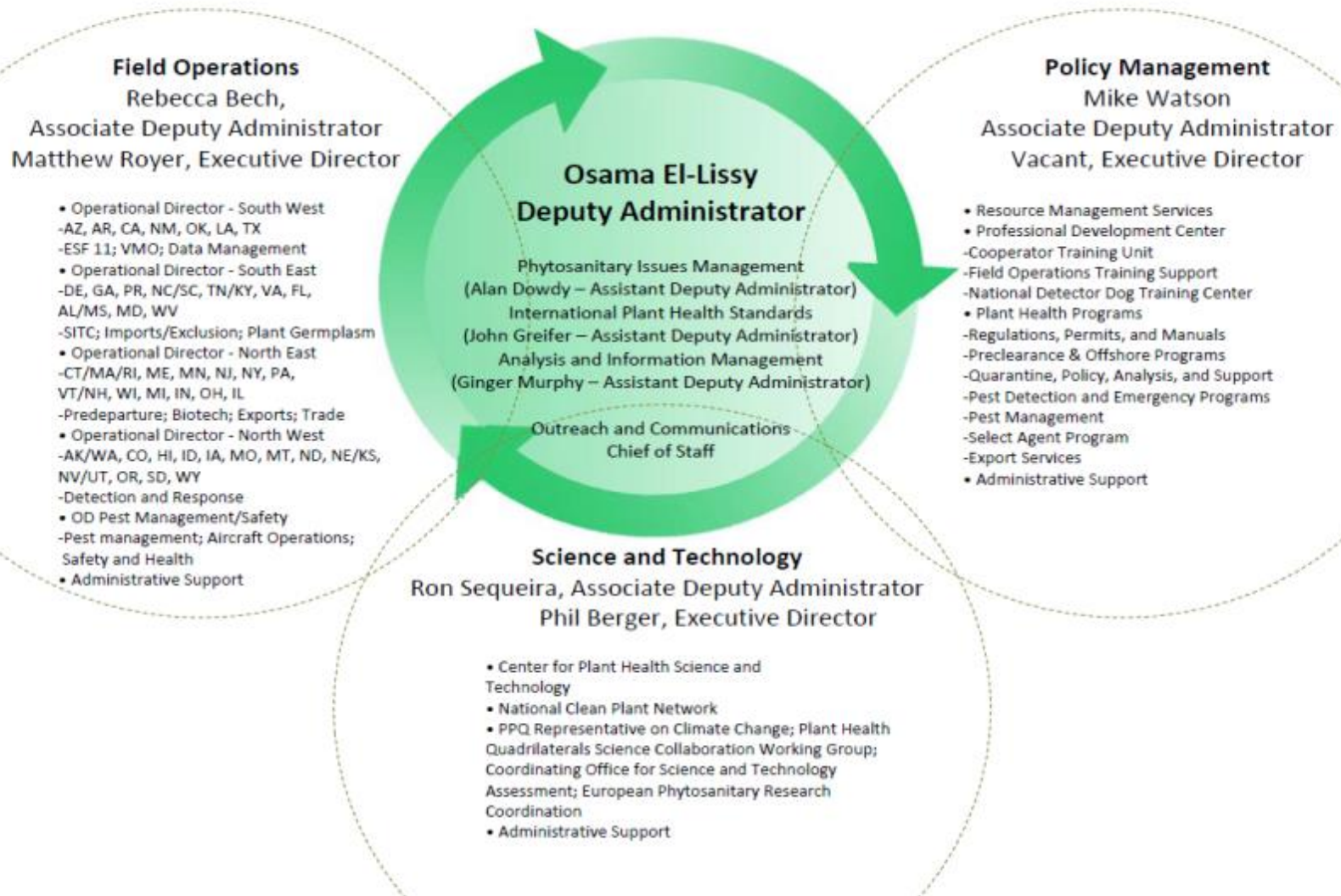
ANIMAL AND PLANT HEALTH INSPECTION SERVICE

The mission of the Animal and Plant Health Inspection Service is to protect the health and value of American agriculture and natural resources.



Plant Protection and Quarantine Organizational Structure

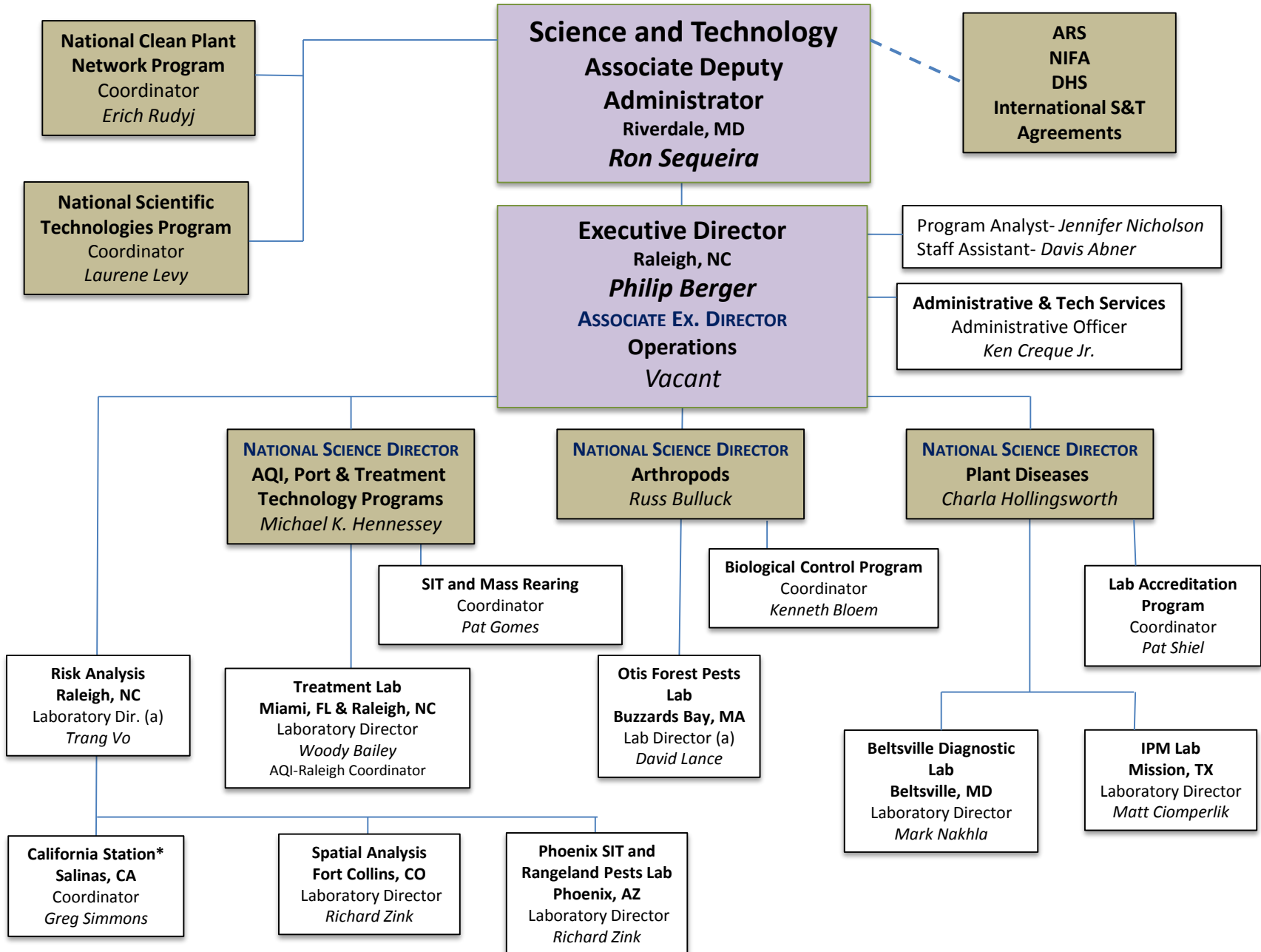
Current as of January 2015



“1. We Safeguard American Agriculture
2. We facilitate Safe Trade “



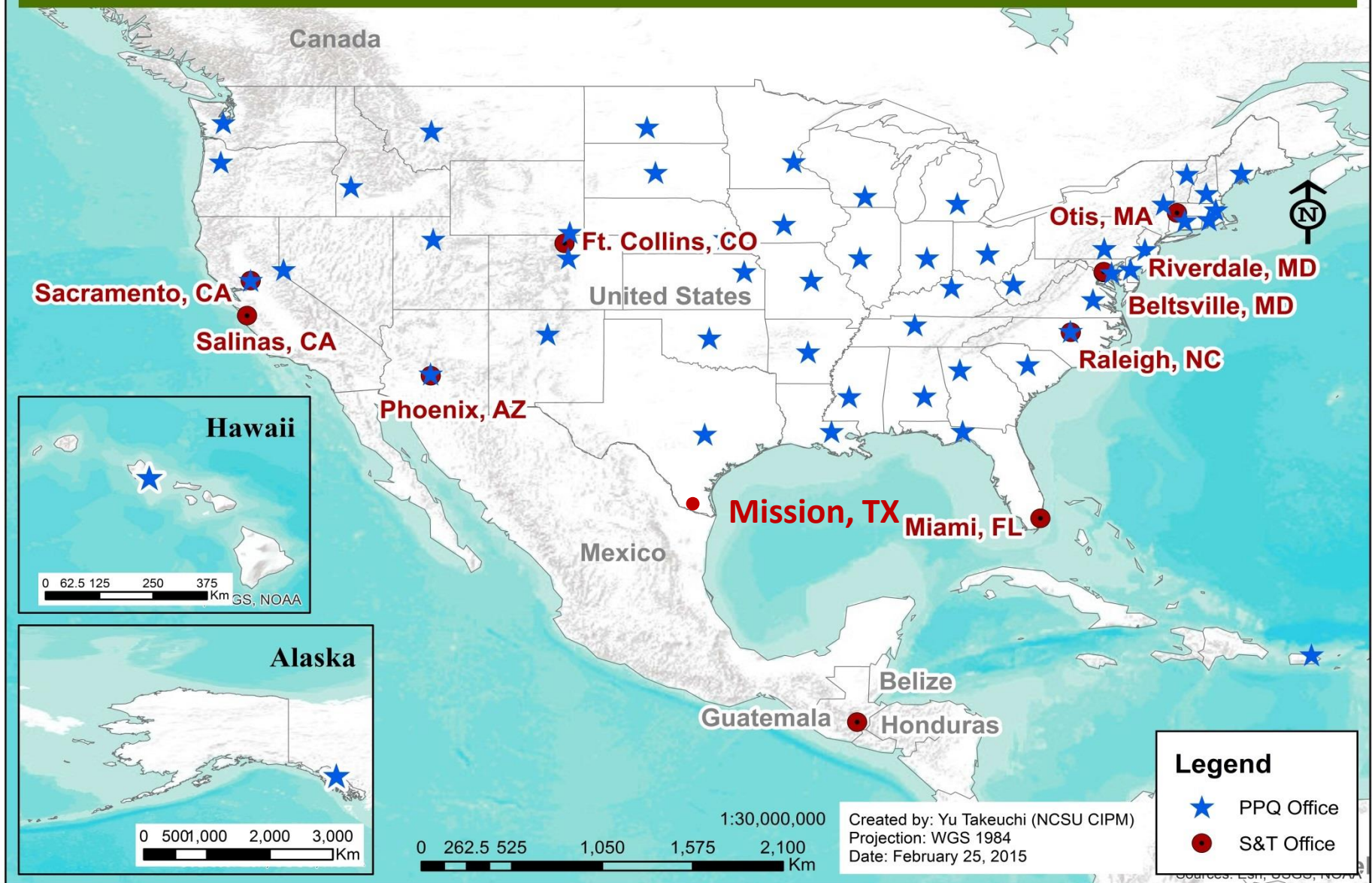
Science and Technology in USDA APHIS PPQ



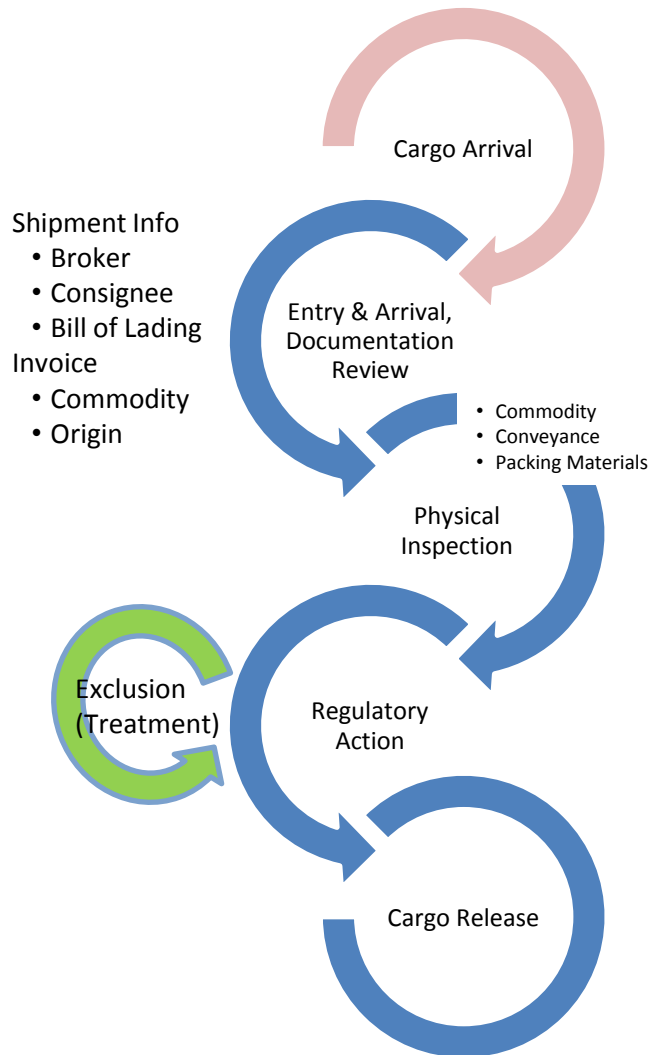
USDA APHIS PPQ Science & Technology Office Locations



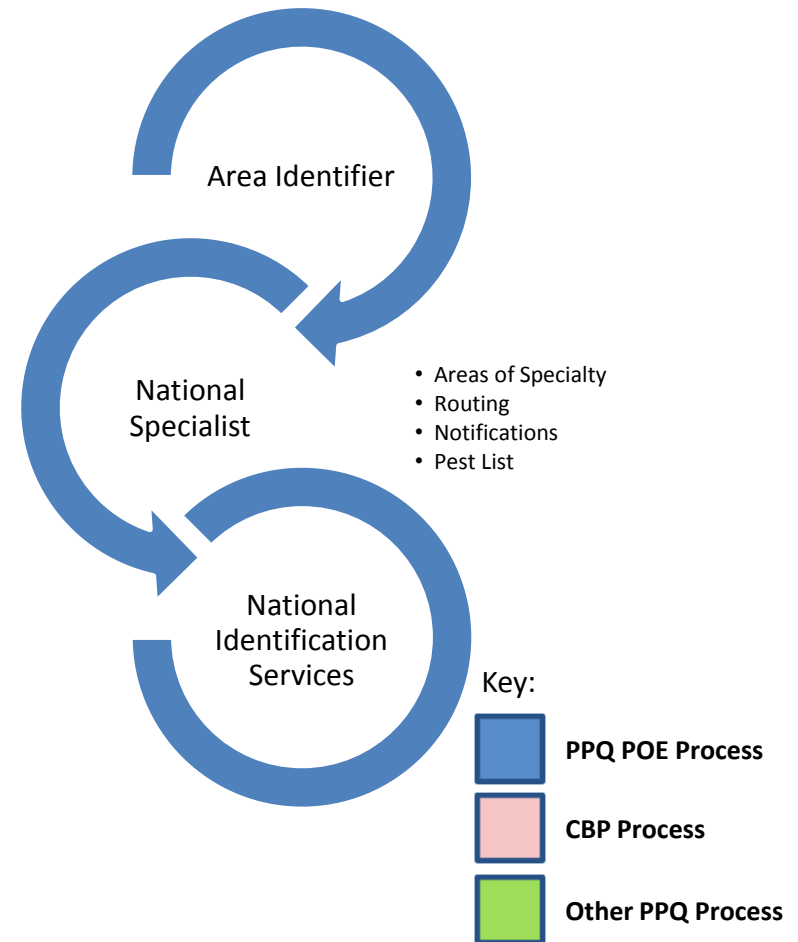
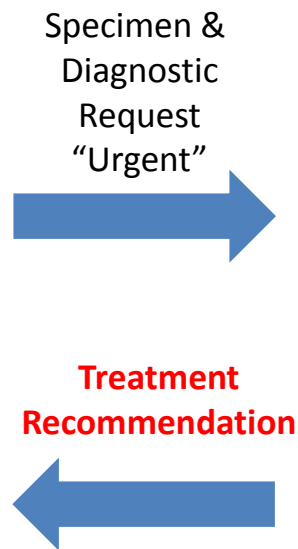
USDA APHIS PPQ offices and S&T offices



Trade Flow



Hazard confirmation (Pest Identification)





PART 1. NEW TECHNOLOGIES FOR TREATMENT





Tools for treatment, decontamination & detection

Treatment Development

- Irradiation
- Cryogenic
- Cold Treatment
- Steam Treatment
- Treatments for fruit flies, Methyl bromide alternatives, Khapra Beetle

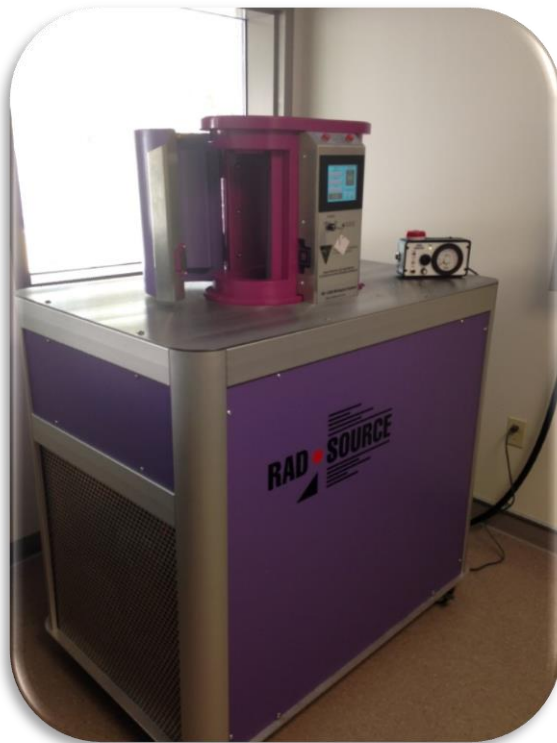
Decontamination

- Air cargo
- Gasifier Incineration
- Steamer-shredder

Detection

- Fruit fly lures and traps
- Imaging
 - X-rays
 - Hyperspectral
- Volatile organic compound detection
 - Portable
 - Z-Nose
 - Colorimetric Sensing Arrays
- Diagnostics
 - Current methods
 - New - CANARY

Treatment Development: Irradiation – generic doses



Development of additional generic phytosanitary irradiation doses

Current Generic Doses

- 150 Gy tephritid fruit flies
- 400 Gy All Insects other than lepidopteran adult/pupa

Deliverable

- Development of generic doses for Lepidoptera, scales, and mites.
- Collaborator: Guy Hallman, IAEA

Treatment Development: Irradiation - O₂ concentration

Effects of modified atmospheres on phytosanitary irradiation treatment efficacy



- Most Modified Atmosphere Packaging (MAP) create low O₂ environment
- Irradiation industry wants to use MAP to extend shelf life of product
- Anoxic environments can reduce efficacy of phytosanitary irradiation
- Current policy requires a minimum concentration of 18% O₂ (very conservative) in MAP
- Partnering with University of Florida, Gainesville

Deliverable

- Determine the lowest concentration for O₂ that will result in a successful irradiation treatment in Lepidoptera (including additional studies for CO₂ concentration)
- Determine metric to establish threshold for other pest Orders
- Establish less conservative policy for MAP O₂ requirements



Treatment Development: Irradiation - citrus

Effect of phytosanitary irradiation on the quality and shelf-life of citrus

- There are concerns with the proposed cold treatment for the impending Chinese citrus exports to the US
- Determine whether or not phytosanitary irradiation is a feasible treatment for Chinese citrus imports
- Following an irradiation treatment, fruit will be evaluated for changes in quality and shelf-life indicators
- Partnering with Chapman University, Orange CA

Deliverable

- Determine quality and shelf-life results for 2 varieties of Chinese citrus; if possible, Chinese cooperator will use the same methodology to test an additional variety in China

Treatment Development: Cryogenic

Cryogenic freeze treatment for non-perishable commodities



- Targeting non-perishable commodities such as tile and logs as well as WPM
- Will mitigate all tropical and temperate pests
- Cost of proposed treatment is comparable with methyl bromide fumigations
- Results using computer modeling are completed; currently building full scale prototype
- Partnering with KB Enterprises

Deliverables

- Develop a mobile cryogenic freeze container to treat non-perishable commodities; mobile unit will be stationed in locations where fumigations cannot be performed (i.e. low temperature areas, <40F)



Treatment Development: Cold Treatment Verification

Improved monitoring of in-transit cold treatment containers and vessels

- CPHST is reviewing 4 international industry submissions that propose improved monitoring of in-transit container cold treatments.
- While the equipment and procedures differ in each proposal they generally will ensure that:
 - in-transit cold treatment data is uploaded using a modem
 - data is electronically available via industry server and can be sent to PPQ 556 database.
- Deliverable: Technologies/procedures for cold treatments that can be verified early so that the commodity can be cleared before it arrives at the port.

Treatment Development: Steam Treatment

Vacuum steam treatments for US hardwood veneer log exports

Phase 1 Objectives

- Determine the total time to achieve 56°C / 30 min to the geometric center of logs
- Measure the effect of vacuum steam treatment on log quality
- Measure the energy consumed to achieve 56°C / 30 minutes to geometric center of logs

Phase 1 Results

- Sapwood of treated black cherry, tulip poplar and hickory slightly darker than controls
- Cherry heartwood slightly darker in treated veneer vs control
- Overall veneer grading judged no negative effect on veneer value and yield



Treated red oak veneer



Control red oak veneer

Treatment Development: Fruit Flies

Develop generic phytosanitary treatments for exotic fruit flies using colonies at Seibersdorf IAEA Laboratory

- Cold Treatment*. *Bactrocera invadens* and *B. zonata*. Determine relative cold tolerances & most tolerant life stage.
- Fumigation & Hot water*. Comparative studies to determine relative tolerance for three fruit fly species.
- Influence of citrus fruit and cultivar on cold treatment efficacy and differences in populations.



Treatment Development: Methyl Bromide Alternatives

Alternatives for wood fungal pathogens and pine wood nematode

• Sulfuryl fluoride and phosphine

- *In vitro* screening of 30+ fungi cultures and pine wood nematode
 - Phosphine: effective on pine wood nematode but not on pathogens
 - Sulfuryl Fluoride: *Ceratocystis fagacearum* and *Geosmithia morbida* consistently most tolerant
 - 100% efficacy @ 240 mgL⁻¹ 72h / 20°C



Control  240 mgL⁻¹



- Additional work to characterize fumigant penetration in logs

Treatment Development: Khapra beetle

Khapra beetle treatment development

Colonies at Otis Laboratory Quarantine

- Field and lab strains to evaluate for insecticide resistance
- *T. variable*: two strains to use as surrogate spp.

Research areas

- *Fumigation*: Sulfuryl fluoride schedule development, schedule review, efficacy / diapause / temp interactions.
- *Insecticides*: Treatment efficacy and residual control
- *Irradiation*: Future work for quarantine shipments



Decontamination Development: Air Cargo Containers

Caribbean fruit fly airplane disinfestation

- Cargo container at CPHST Miami tarped to regulate temperature of container
- 1 Shot Aircraft Insecticide (2.0% d-Phenothrin and 2.0% Permethrin)
 - 100% kill at label rates (1.4 oz per 1000 cubic feet)
 - Preliminary Test: 300 adult flies
 - Additional tests: 1500 adult flies



Decontamination Development: Waste Disposal

Waste disposal for regulated garbage project

- Evaluate existing disposal technologies for use with Regulated Garbage
 - Example: Mobile Gasifier alternative to incineration that is mobile, cleanly incinerates to ash, is powered by natural gas and limited emissions



Decontamination Development: Steamer-shredder

Shredding and Steaming Disposal System for Plant Pest Material

- Successfully used to decontaminate medical waste on-site at hospitals
- Significant reduction in waste volume
- Portable versions can be developed



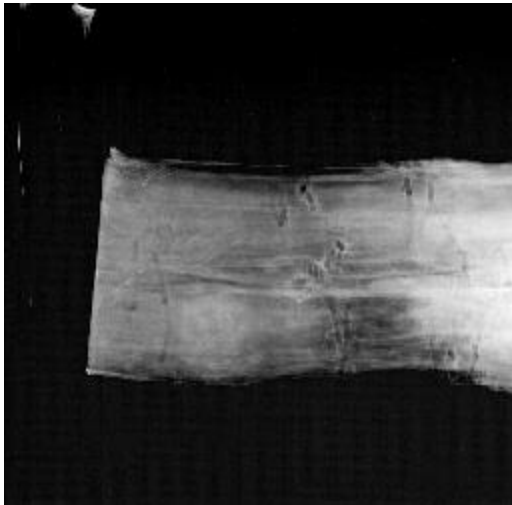
Pest Detection: Fruit Fly Lures and Traps

Efficacy testing of these lures against fruit fly species in China



Pest Detection: Imaging

X-Ray Imaging as an Agricultural Screening Tool to detect infested plant materials



Ambrosia beetle galleries in wood



Pest Detection: Imaging

Hyperspectral Imaging as an Agricultural Screening Tool

Non-Destructive Inspection of Citrus for Fruit Fly Infestation



Pest Detection: Volatile Compound Detection

Portable Gas Chromatography as an Agricultural Screening Tool

- Utilization of Portable Gas Chromatography for Sampling and Analysis of Volatile Organic Compounds (VOCs) within shipping container.
- Possible uses could be:
 - to detect treatment compounds
 - To detect non-manifested commodities or prohibited commodities such as citrus
 - To detect invasive pests and pathogens.



Pest Detection: Volatile Compound Detection

Z-nose Portable Gas Chromatograph for Detection of Plant Pest VOCs

- Used to identify crop threats
- Recently used to identify prohibited citrus species



Pest Detection: Volatile Compound Detection

Improving Techniques for Detection of Prohibited Plants and Invasive Pests at Ports of Entry



- Identify signature volatile compounds as a means of distinguishing between non-infested and infested wood packing material.
- Volatiles are collected and analyzed by GC/MS and identified against NIST library.
- GC/MS methodology selected as primary calibration model and used to validate developed zNOSE methodology.

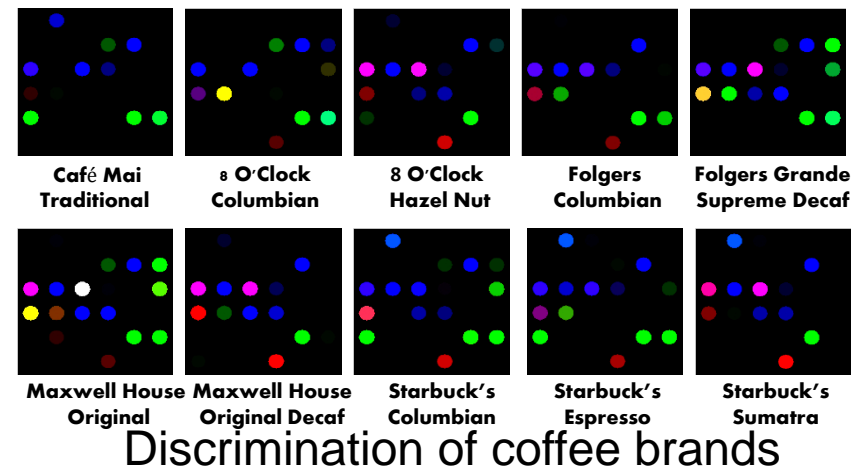
PROJECT DELIVERABLE: A Library of identified volatiles unique to wood-boring pests to use as a reference in the selection of commercial instrumentation as agricultural screening tool for inspectors.



Pest Detection: Volatile Compound Detection

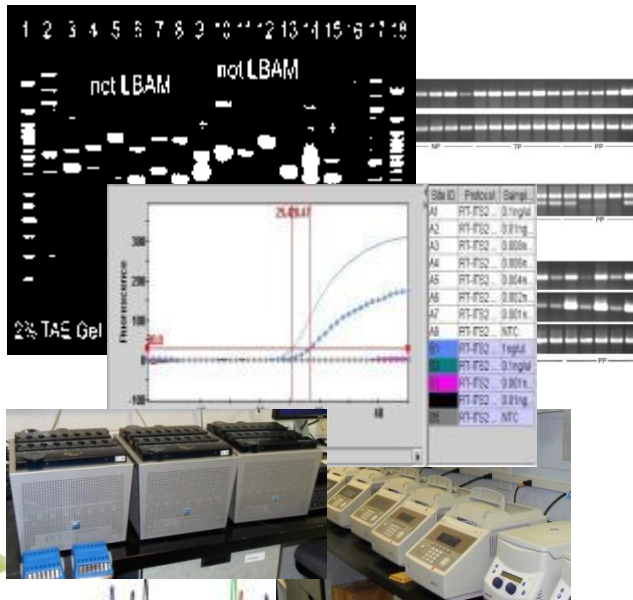
Improving techniques for detection of prohibitive plants and invasive pests at ports of entry

- Colorimetric Sensing Arrays (CSAs):
 - Chemoresponsive pigments and dyes
 - High sensitivity ~ppb range
 - Ability to discriminate among similar analytes (e.g. types of coffee, beer etc.) based on array patterns
 - Evaluation for port detection:
 - Warehouse and Khapra beetle colonies, *Trogoderma* pheromones, Wood borers and pathogens (*Ralstonia solanacearum*)



Pest Detection: Diagnostic Detection-current methods

Conventional and real-time PCR ; DNA sequencing

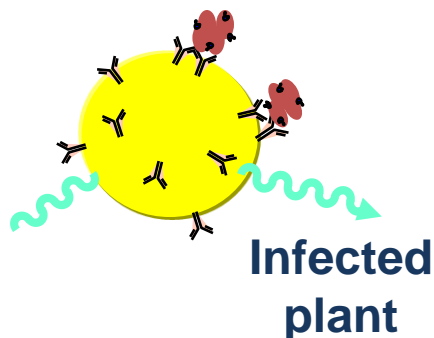


ELISA and serological flow devices

E.g. DNA analysis of pest gastropods and nematodes supports surveys

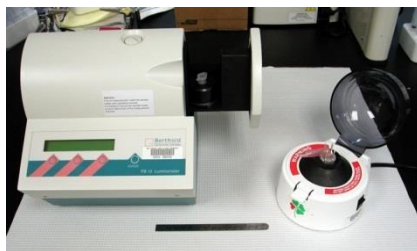


Pest Detection: Diagnostic Detection - CANARY

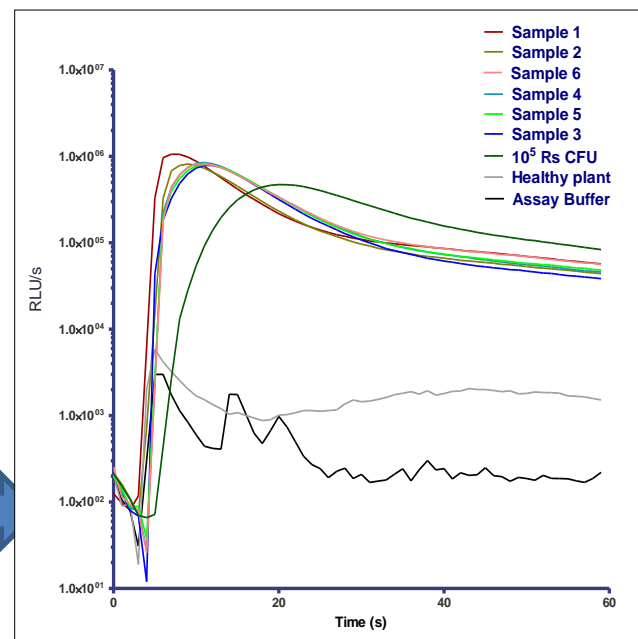


Soak in
assay buffer
5 min

Add CANARY
cells to sample
and measure
light output



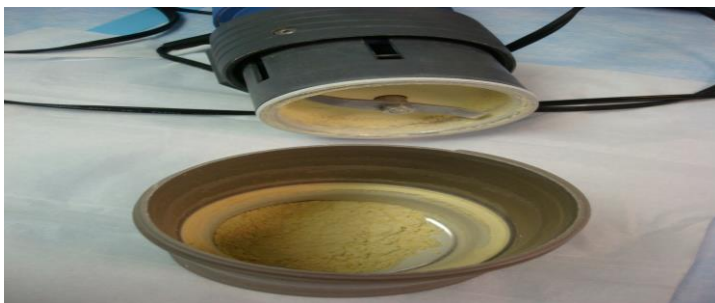
CANARY use on
diagnostic samples



10 minutes or less are required for sample preparation and sample testing for *Ralstonia solanacearum*.

Trace Elemental Signature of Seized Illegal Fruit for Trace Back to Place of Origin

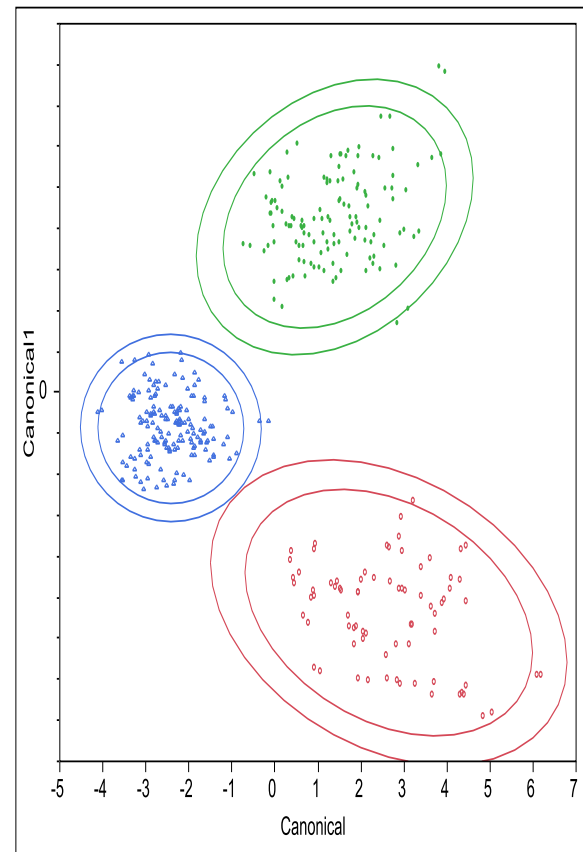
DRIED SAMPLE GROUND INTO POWDER



POWDERED SAMPLE ACID DIGESTED INTO “EXTRACT” FOR ICP/MS ANALYSIS



- **SAMPLE PREPARATION PHASE OF ANALYSIS COMPLETED**





PART 2. NEW PARADIGMS FOR TREATMENTS



Phytosanitary Hazard Analysis and Critical Control Point System

P-HACCP

- a concept borrowed from food safety
- adapted to the phytosanitary challenge of standardizing risk management operations

P-HACCP is a systematic approach to identify, evaluate and control quarantine species



P-HACCP

ROLES

- Conduct risk assessment **Industry/NPPO**
- Determine the critical control points (CCPs) **Industry/NPPO**
- Establish critical limits **Industry/NPPO**
- Establish monitoring procedures **Industry**
- Establish corrective actions **Industry**
- Establish verification procedures **Industry/NPPO**
- Establish record-keeping and documentation procedures **Industry/NPPO**

P-HACCP

- **Step 2. Determine the critical control points (CCPs)**



Where are the biological bottlenecks?



Where can phytosanitary measures be most effectively applied (in terms of costs and killing power)



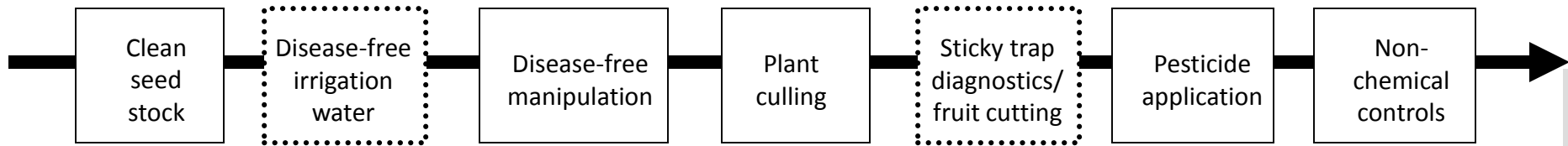
Traditionally: quarantine treatments



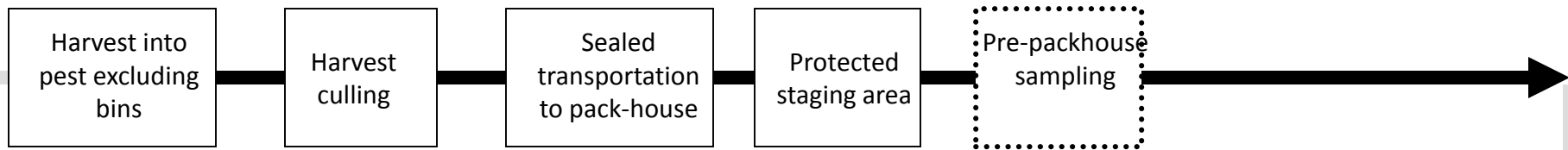
Challenge: field to fork



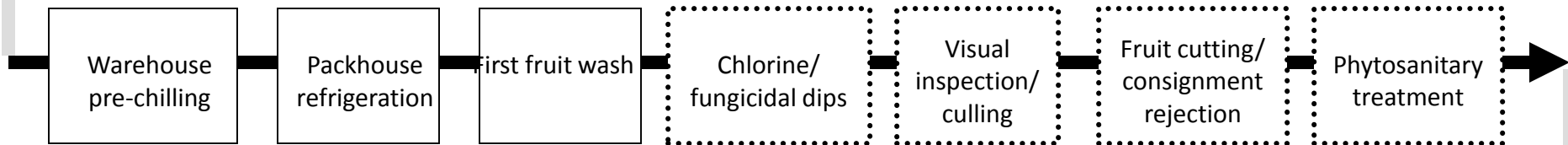
FIELD MEASURES



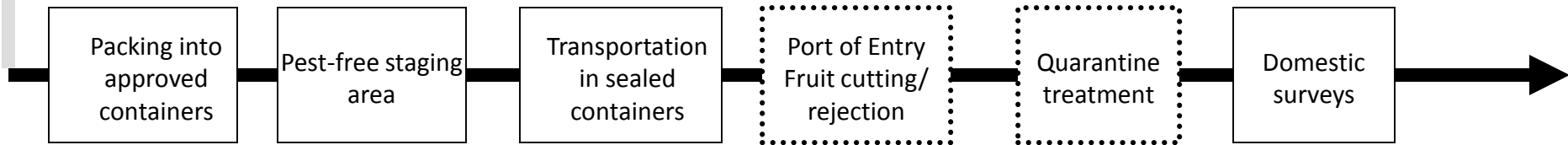
HARVEST MEASURES



PACKHOUSE MEASURES

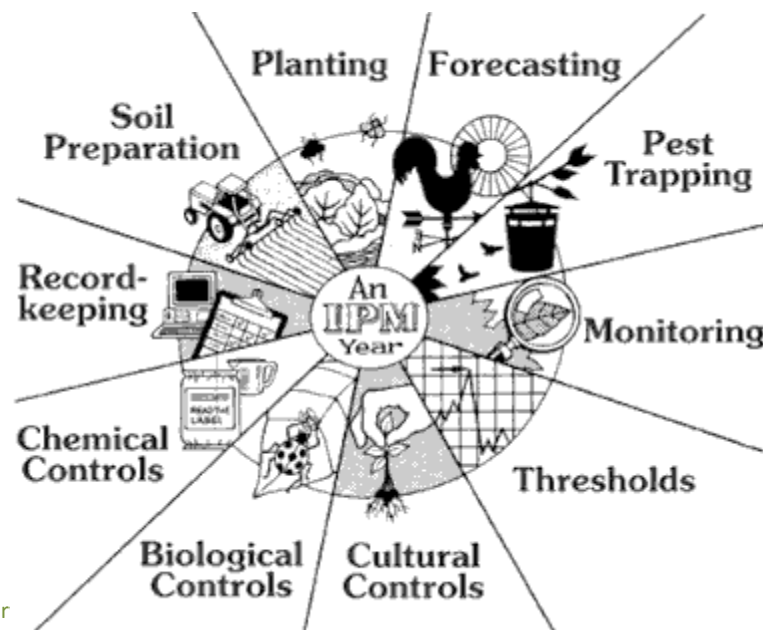


PORT AND TRANSPORTATION MEASURES



Remember IPM?

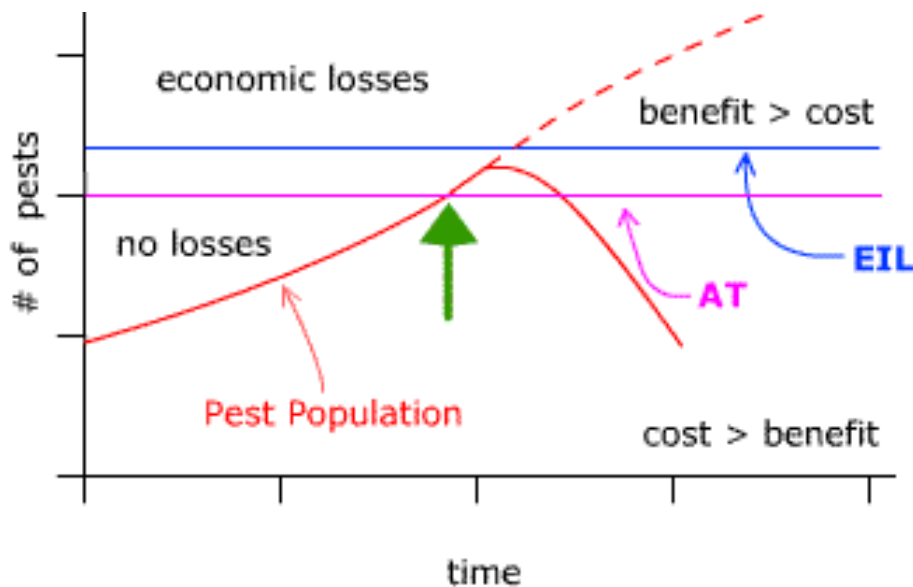
- Economic Threshold
- Economic Injury Level



•Economic Threshold

“the population density at which control action should be determined (initiated) to prevent an increasing pest population (injury) from reaching the economic injury level”

Stern et al. 1959



•Phytosanitary Threshold

the population density at which phytosanitary measure(s) should be initiated to prevent a pest population from being introduced

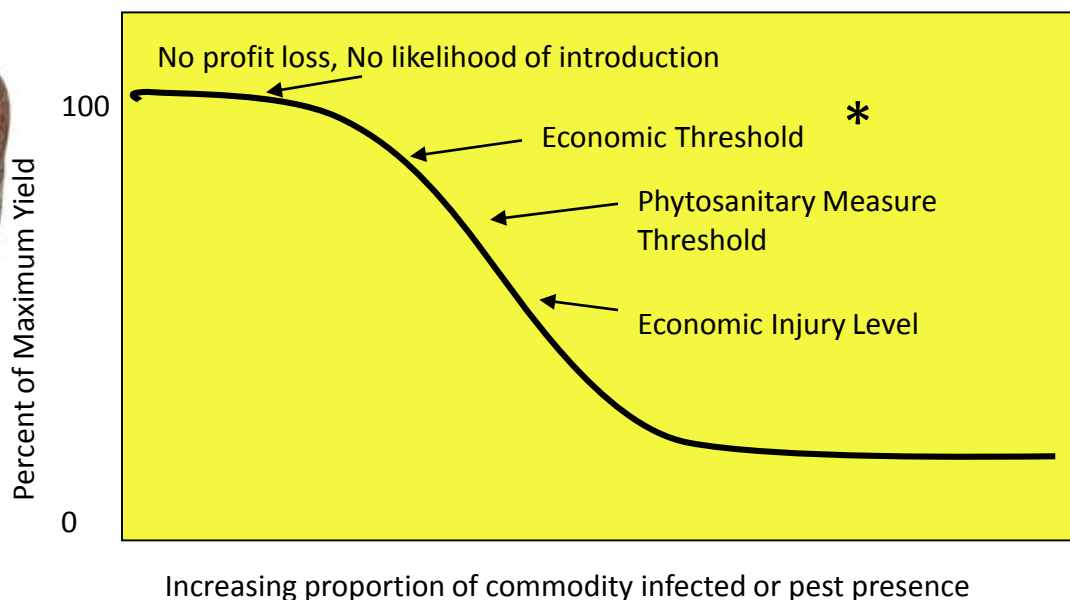
(Takeuchi 2006)



•Phytosanitary Threshold

Phytosanitary Measure Threshold =

$$\frac{\min [\text{Pest density that leads to introduction; Pest density that leads to economic damage}]}{\text{cost of treatment or maintenance of all CCLs}} > 1$$



**The location of the ET relative to the PT will depend on actual monetary cost of a phytosanitary measure. In some cases the ET may be the same or lower than the PT.*

The phytosanitary measure threshold (PMT) in relation to yield and the proportion of the commodity that is associated with quarantine species. The PMT is the level of a quarantine species in a commodity that will not lead to an introduction.

**The location of the ET relative to the PT will depend on actual monetary cost of a phytosanitary measure. In some cases the ET may be the same or lower than the PT. The EIL denotes levels of pests that cause more damage than the combined costs of all phytosanitary treatments.*

A great idea for a Critical Control Limit for field and other CCPs!

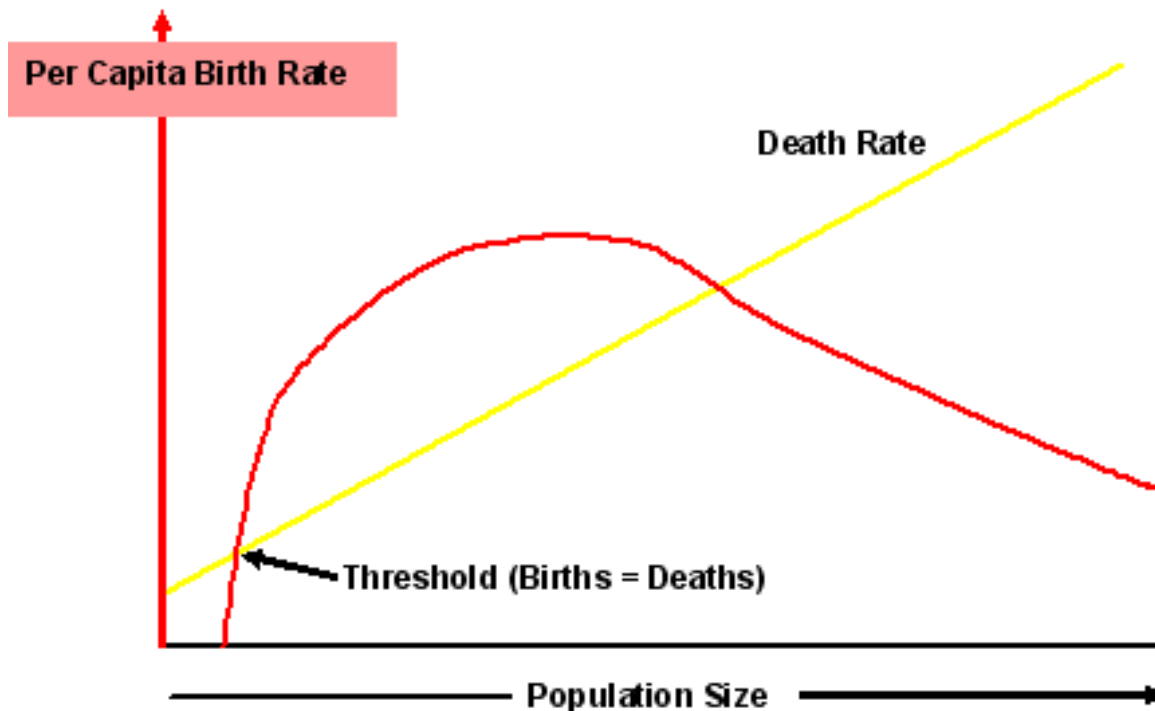
The **Allee effect**

The **Allee effect** is a phenomenon in biology characterized by a correlation between population size or density and the mean individual fitness (often measured as per capita population growth rate) of a population or species.

Allee, W. C. 1931. Animal Aggregations

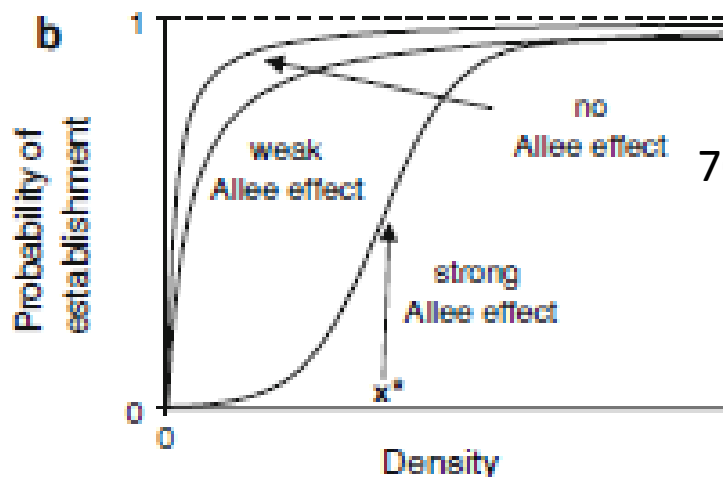


The Allee effect



Smaller populations are more subject to stochastic events. Therefore both drops in the overall population and increased fragmentation of the population may result in extinctions.

The Allee effect



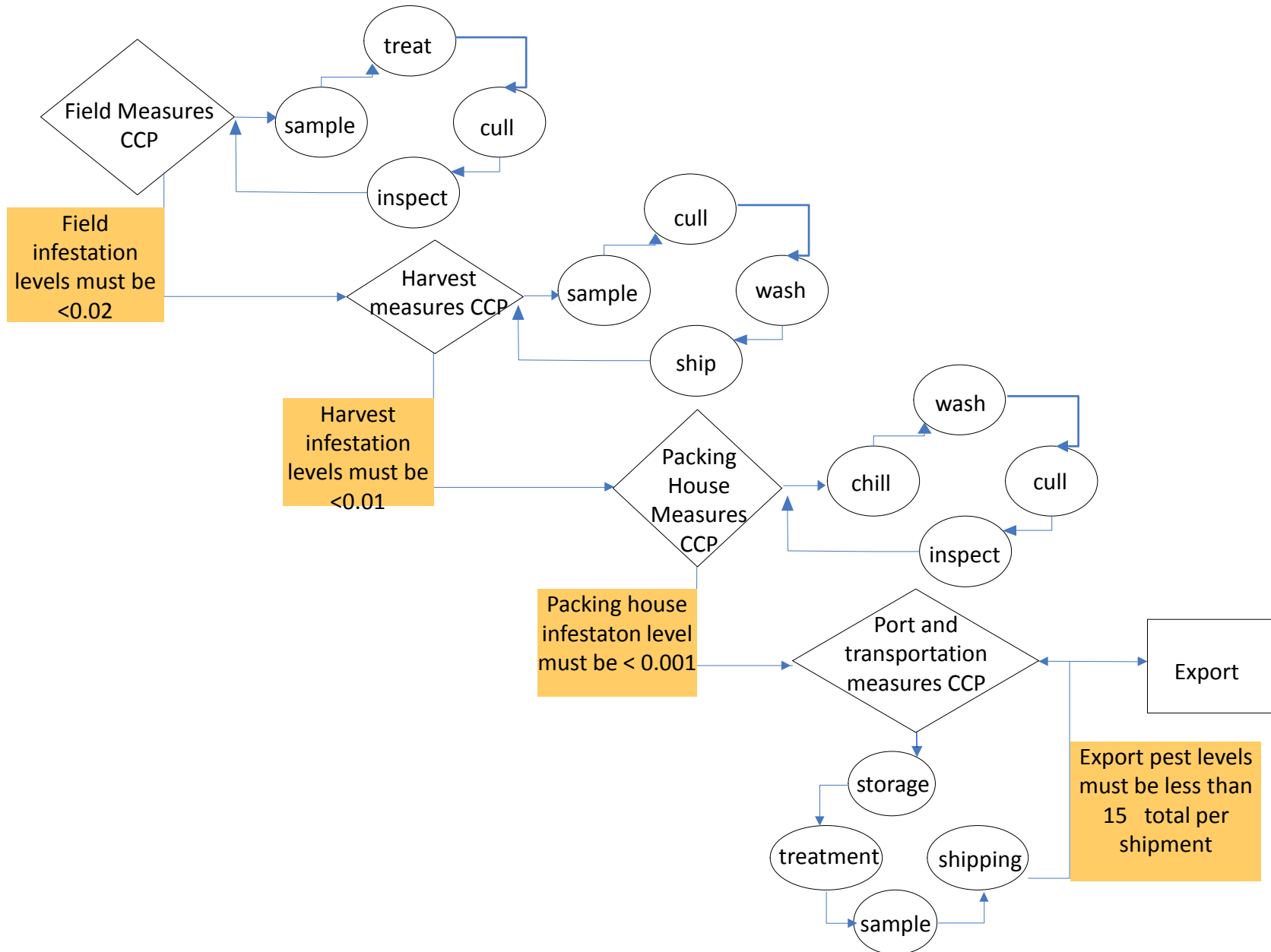
70% of all studies detect *Allee* effects

Brockerhoff, E.G., M. Kimberley, A.M. Liebhold, R.A. Haack and J.F. Cavey. 2014. Predicting how altering propagule pressure changes establishment rates of biological invaders across species pools. *Ecology* 95: 594-601

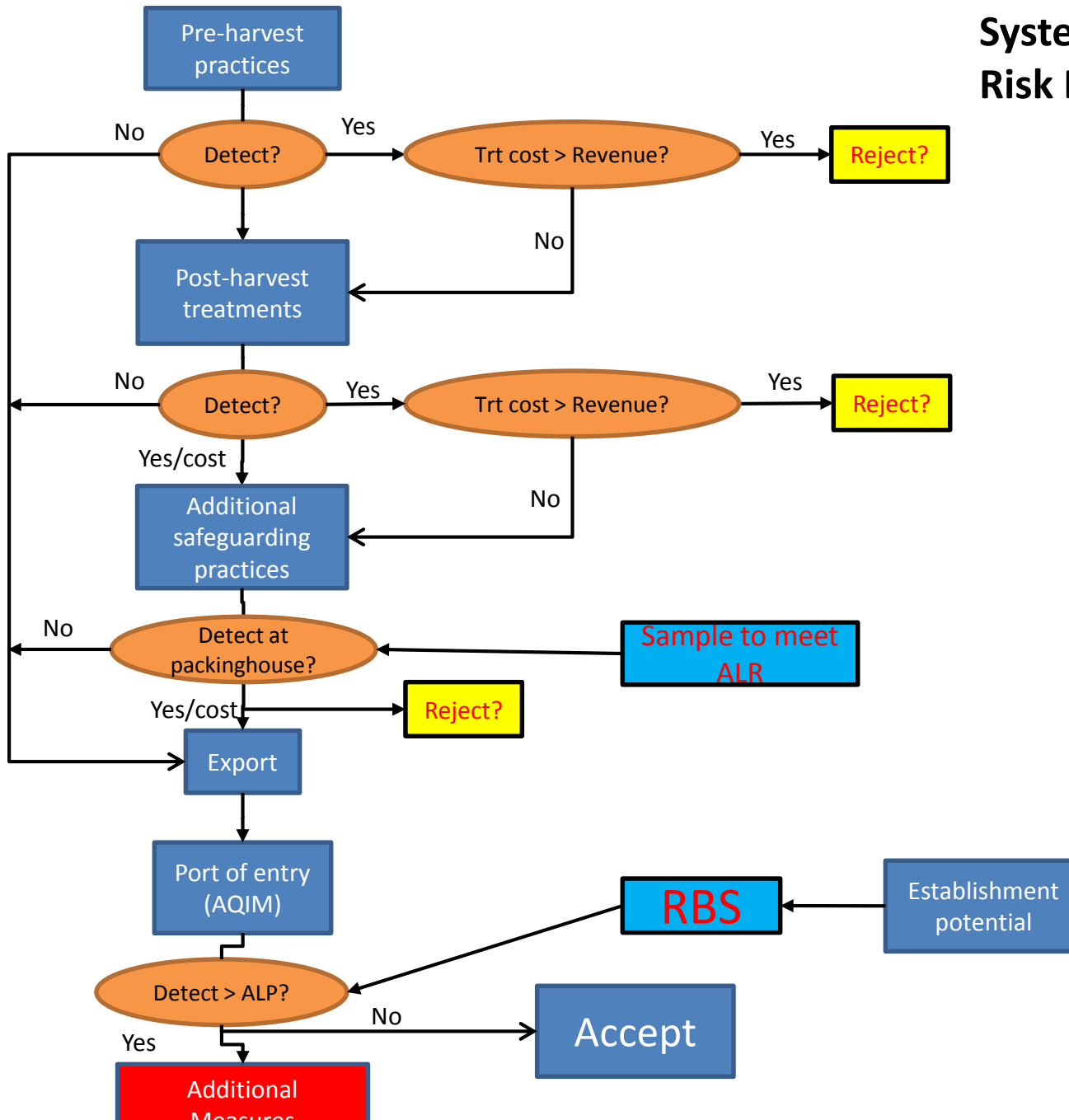
Tobin, P.C., L. Berec and A.M. Liebhold. 2011. Exploiting Allee effects for managing biological invasions. *Ecology Letters* 14: 615

Kramer, A.M., B. Dennis, A.M. Liebhold and J.M. Drake. 2009. The evidence for Allee effects. *Population Ecology* 51: 341-354





Systems Approach with Risk Based Sampling Plan



Steps towards integrated phytosanitary measures

1. Adopt ALP/ALR that is linked to risk in terms of likelihood of introduction and impact
 - From mortality-based treatments to focus on viability&impact of survivors
2. Shift from focus on a single post-harvest treatment to integrated measures
 - Systems approaches or combination of interdependent measures
3. Consider field and pre-harvest conditions that incorporate the concept of phytosanitary threshold
 - Infection or infestation level that is not likely to lead to successful introductions combines concept of allee effects with management
4. Consider documentation/quality systems based on common paradigms such as HACCP
 - P-HACCP
5. Consider using a generic, consistent evaluation framework
 - Include evaluation of efficacy, uncertainty, failure rate and corrective actions

