Informing Efficient Strategies to Reduce Pest Risk from Live Plant Imports

Rebecca Epanchin-Niell, Resources for the Future

International Symposium for Risk-Based Sampling

June 28, 2017

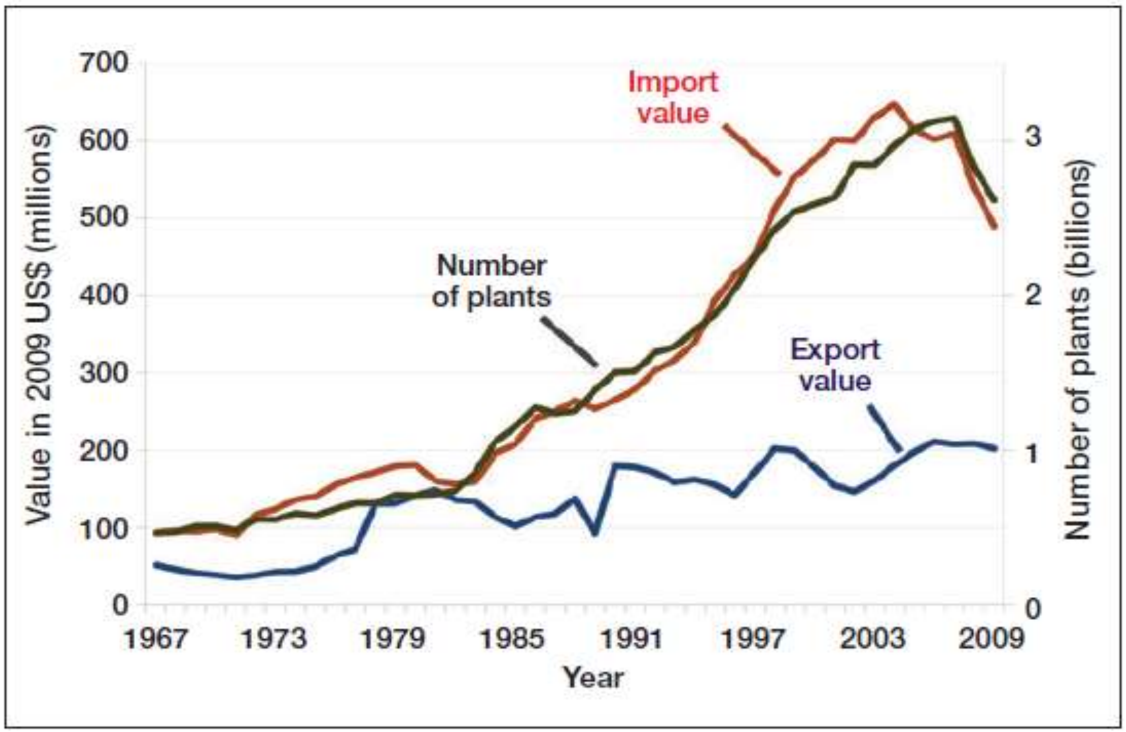
RESOURCES FOR THE FUTURE

Hemilia sp.

Schefflera sp.

Hemlock wooly adelgid

Live Plant Imports a Key Input to U.S. Horticultural Industry



Liebhold et al. *Front Ecol Environ* 2012; 10(3): 135–143.

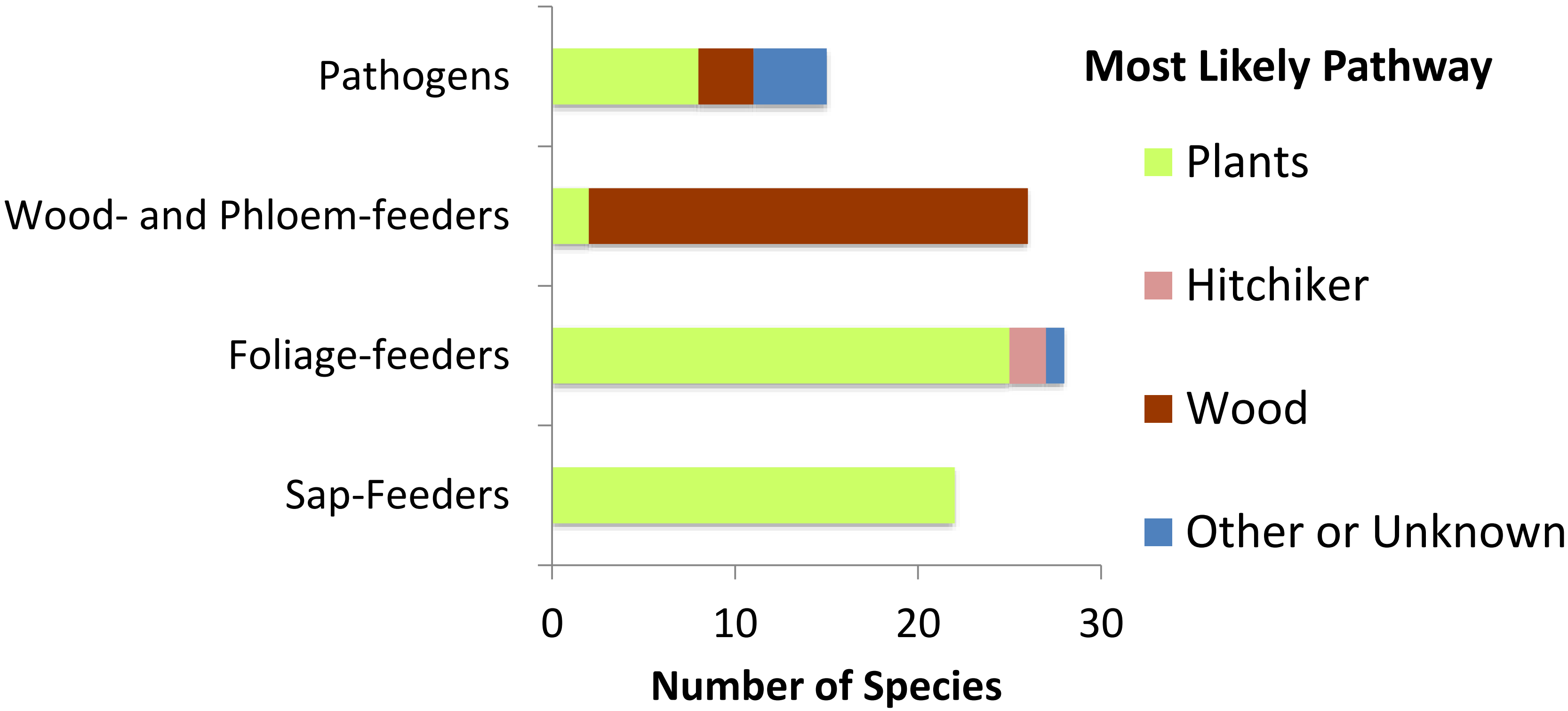
> 2.5 billion live plants imported annually

Off-shore production of ornamental bare-root and cuttings (Central and South America, and Africa)

- Climate at off-shore locations is more favorable for production
- No supplemental heating needed for greenhouses
- Lower labor rates

Most Likely Invasion Pathways

Non-Native Forest Pests Established in US



Liebhold A.M., Brockerhoff E.G., Garrett L.J., Parke J.L. and Britton K.O. 2012. Live Plant Imports: the Major Pathway for Forest Insect and Pathogen Invasions of the United States. Frontiers in Ecology and the Environment 10: 135-143

Live Plant Imports

Legal trade of plants

- Seeds
- Cuttings
- Bare root
- Rooted in media
- Tissue culture

Illegal and not authorized

- Plant smuggling in cargo
- Passenger baggage
- Plants in mail

Live Plant Imports a Primary Pathway

Primary pathway for forest pest introduction

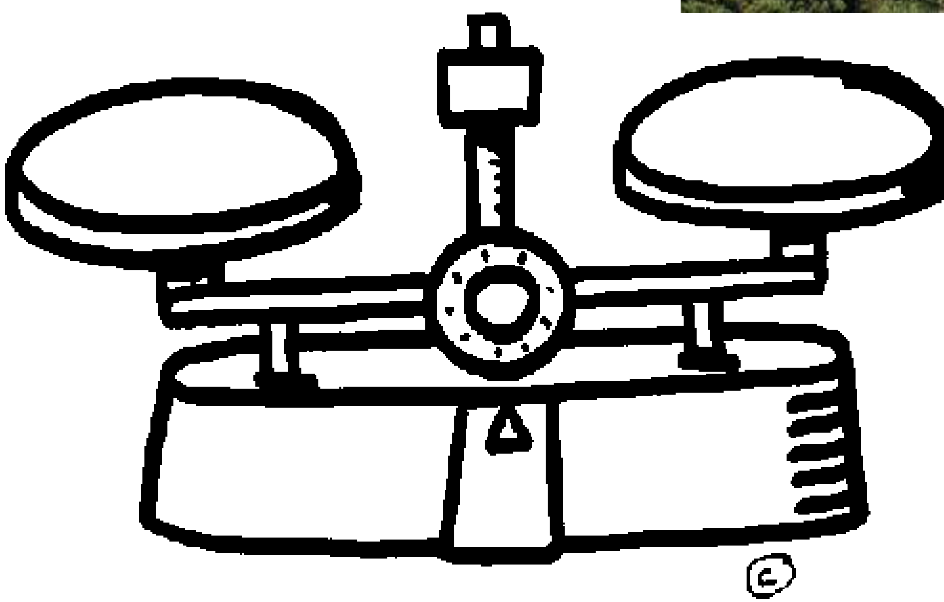
White pine blister rust

Citrus longhorned beetle

Sudden oak death

Light brown apple moth

Benefits from Imports



Harm from Imports

Informing efficient strategies for reducing non-native pest invasion risk

Co-PI: Sandy Liebhold, USFS

National Socio-Environmental Synthesis center (SESYNC) working group

Evaluate Policies

How design policies to achieve the "biggest bang for the buck"?

Needed for evaluation:

- Effectiveness at reducing pest risk
- Costs of implementing policies
- Benefits from reduced pest introduction

Long History of Tension Between Plant Imports and Pests

O-3

The Legacy of Charles Marlatt and Efforts to Limit Plant Pest Invasions

ANDREW M. LIEBHOLD AND ROBERT L. GRIFFIN

2016 American Entomologist 62(4)

History of Plant Quarantine in the USA

Long History of Tension Between Plant Imports and Pests

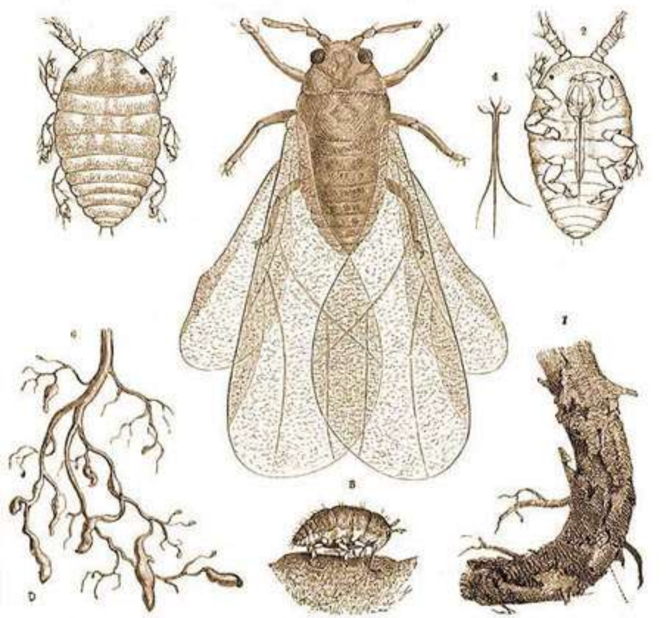
- < 1870, little recognition that species movement harmful
  - 1800s – Acclimatization Societies: add to mother nature

  - late 1800s – USDA Office of Seed and Plant Introduction to diversify domestic agriculture

"Plant explorers"

The Grape Phylloxera

Introduced to Europe from US in 1864 → Massive damage to viticulture industry



Led to 1878 “International Convention on Measures … against *Phylloxera vastatrix*”

1. Exporting countries certify pest-free plants
2. Importing countries can inspect and reject contaminated material
3. International body to monitor implementation

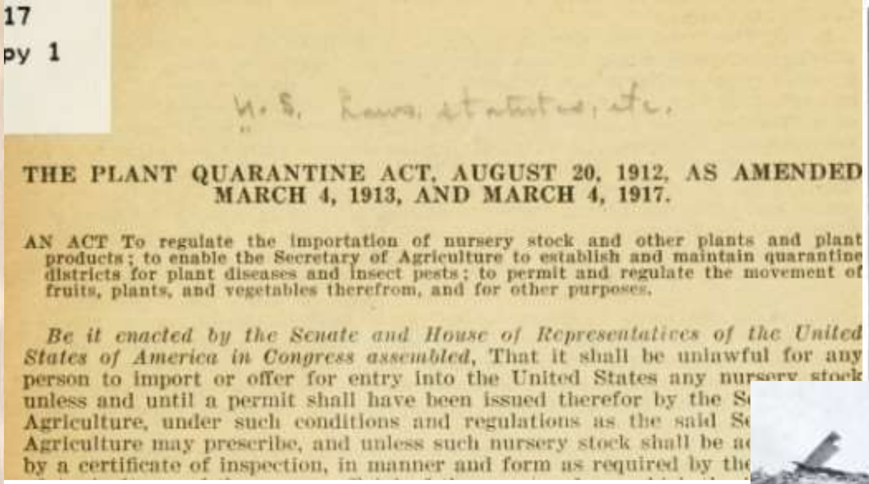
1882 map of grape phylloxera distribution in France

~1870 - San Jose scale, *Quadraspidiotus perniciosus*, introduced to San Jose, California, on trees from China

1881-,California Legislature passes “An Act to Promote and Protect the Horticultural Interests of the State”

Many Failed Attempts to Pass Legislation in US in late 1800s

- …Despite increasing concern
- Many European countries banned US live plant imports
- 1905, Congress passed Insect Pest Act
  - Prohibited pests but not plants; little impact



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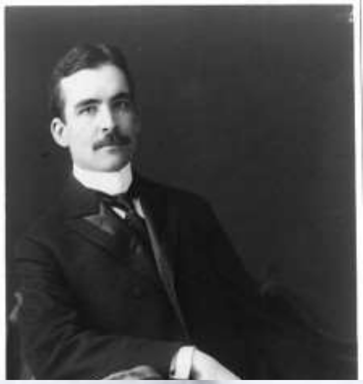
py 1

THE PLANT QUARANTINE ACT, AUGUST 20, 1912, AS AMENDED MARCH 4, 1913, AND MARCH 4, 1917.

AN ACT To regulate the importation of nursery stock and other plants and plant products; to enable the Secretary of Agriculture to establish and maintain quarantine districts for plant diseases and insect pests; to permit and regulate the movement of fruits, plants, and vegetables therefrom, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That it shall be unlawful for any person to import or offer for entry into the United States any nursery stock unless and until a permit shall have been issued therefor by the S[illegible] Agriculture, under such conditions and regulations as the said S[illegible] Agriculture may prescribe, and unless such nursery stock shall be a[illegible] by a certificate of inspection, in manner and form as required by th[illegible]

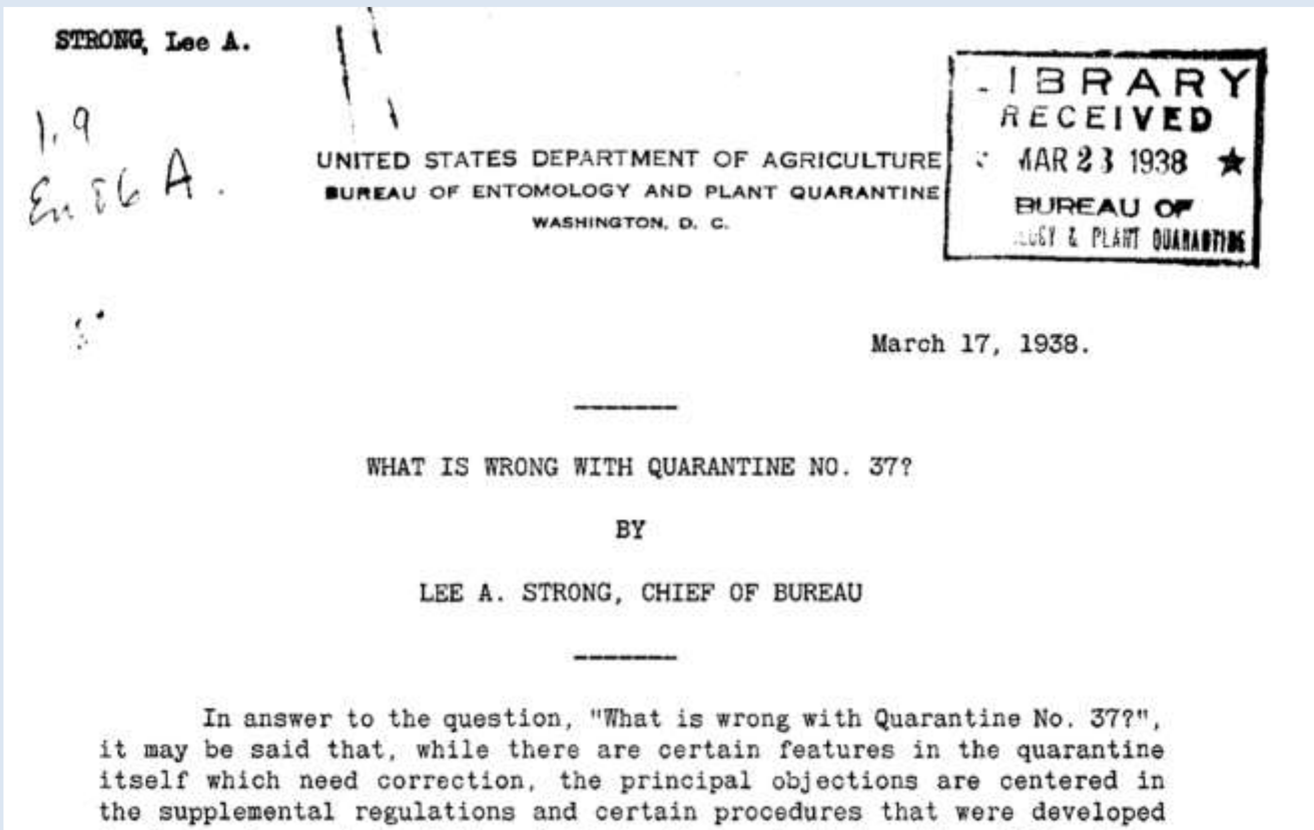


Quarantine 37 (1918)

- Required
  - Small Shipments
  - Shipments mainly breeding material plant stock
  - Inspection
  - Treatments for potential hosts of plant pests (fumigation, quarantine observation)

Quarantine 37 was later relaxed regarding:

- size of shipments
- mandatory fumigation
- post-entry quarantine procedures.


STRONG, Lee A.

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE
WASHINGTON, D. C.

March 17, 1938.

WHAT IS WRONG WITH QUARANTINE NO. 37?

BY

LEE A. STRONG, CHIEF OF BUREAU

In answer to the question, "What is wrong with Quarantine No. 37?", it may be said that, while there are certain features in the quarantine itself which need correction, the principal objections are centered in the supplemental regulations and certain procedures that were developed

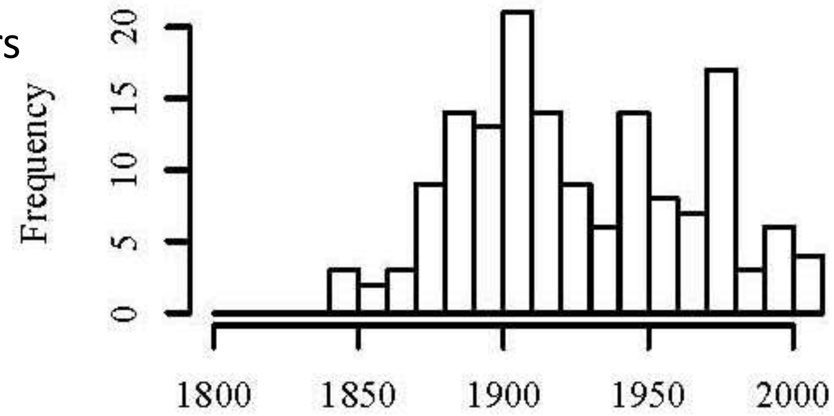
The Move Toward Free Trade

- 1945 - Bretton Woods Conference
- 1945- GATT Agreement
- 1995 – WTO formed
- 1995 – SPS (Sanitary and Phytosanitary Measures) Agreement signed

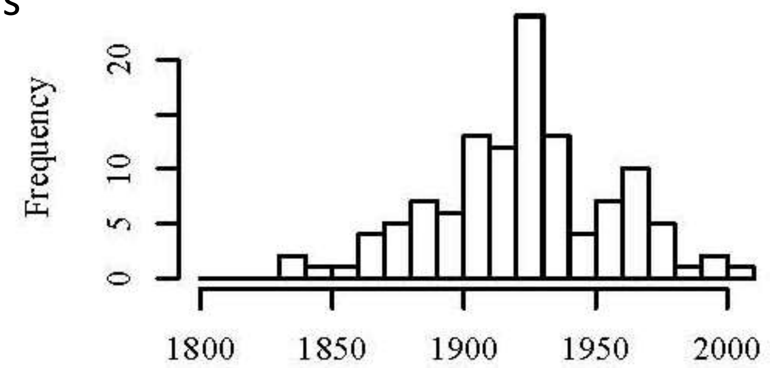
Harry White and John Maynard Keynes at the Bretton Woods Conference.

Nonnative Forest Species Detections by Decade

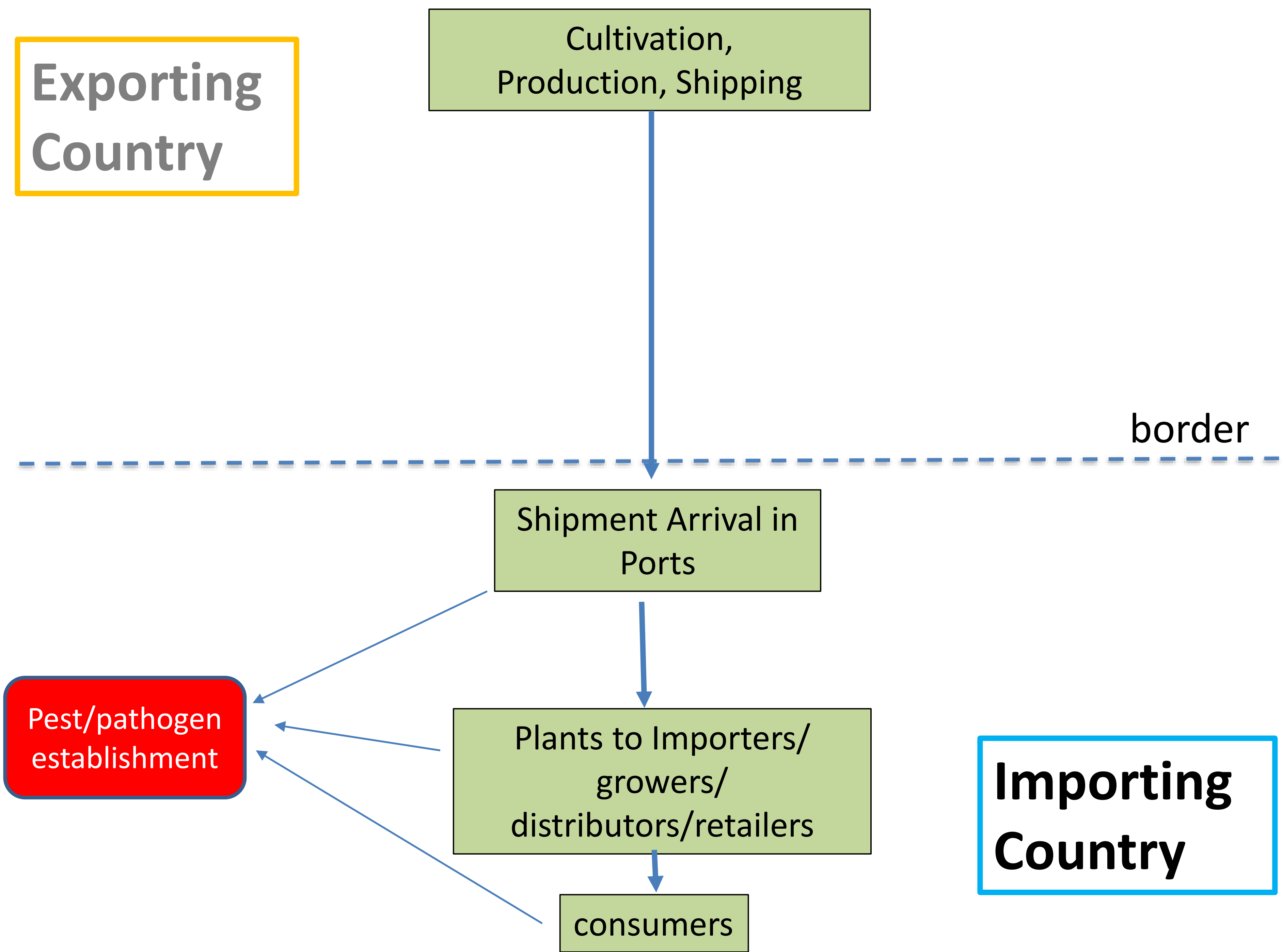
Sap-Feeders



Foliage-Feeders



Aukema, J.E., D.G. McCullough, B. Von Holle, A.M. Liebhold, K. Britton and S.J. Frankel. 2010. Historical Accumulation of Nonindigenous Forest Pests in the Continental US. Bioscience 60: 886-897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Shipment Arrival in Ports
Pest/pathogen establishment
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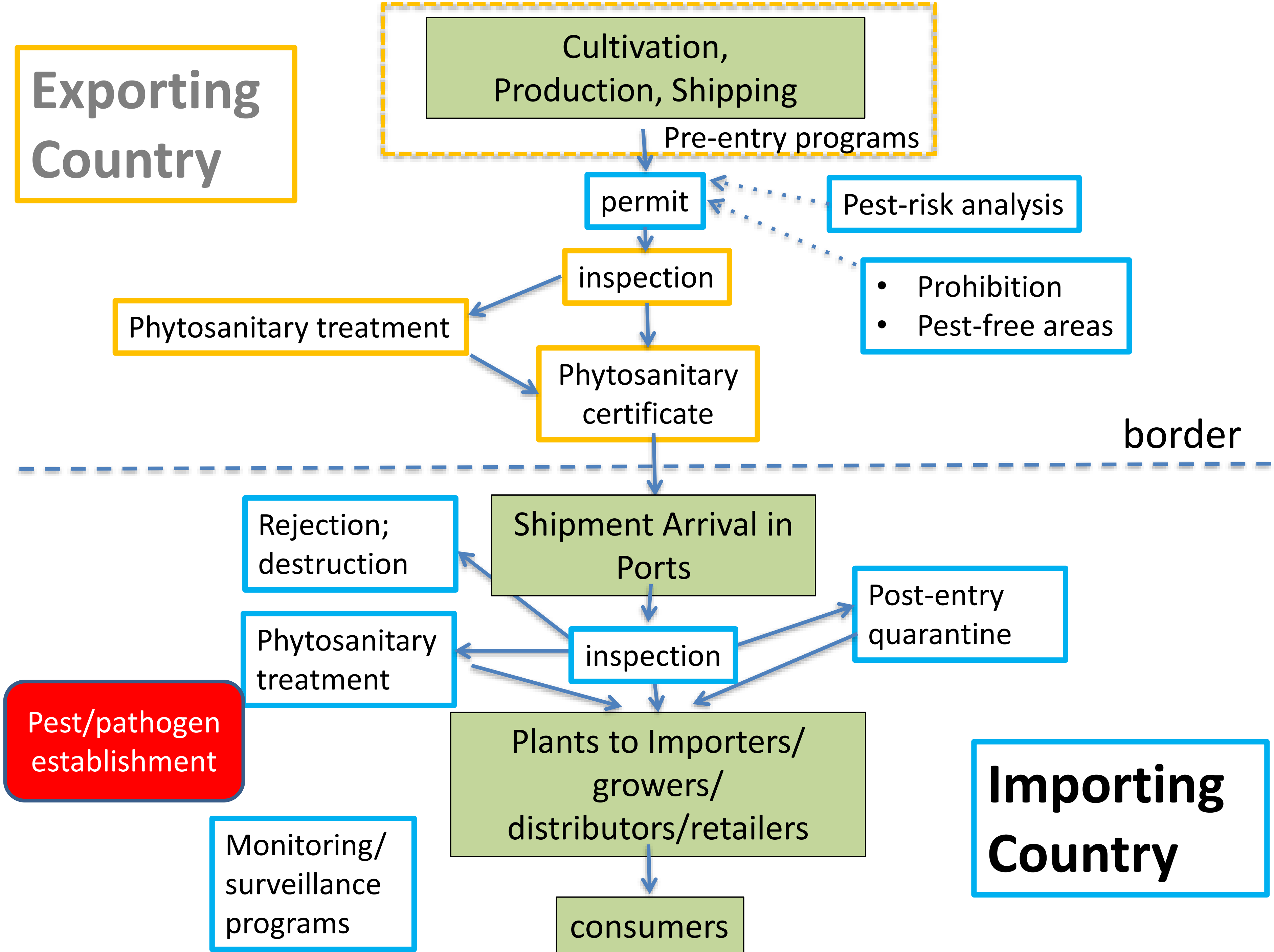
Importing Country
consumers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ENVIRONMENTAL SCIENCE & POLICY 51 (2015) 228–237

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Review

International variation in phytosanitary legislation and regulations governing importation of plants for planting

CrossMark

R. Eschen[a,*], K. Britton[b], E. Brockerhoff[c], T. Burgess[d], V. Dalley[e], R.S. Epanchin-Niell[f], K. Gupta[g], G. Hardy[d], Y. Huang[h], M. Kenis[a], E. Kimani[i], H.-M. Li[j,k], S. Olsen[e], R. Ormrod[l], W. Otieno[m], C. Sadof[n], E. Tadeu[o], M. Theyse[p]

[a] CABI, Rue des grillons 1, 2800 Delémont, Switzerland

- Overviews measures to limit pest introduction
- Describes differences among countries
- Evidence of effectiveness

Key measures

Phytosanitary certificate
Import permit
Import inspections
Pathway risk analysis

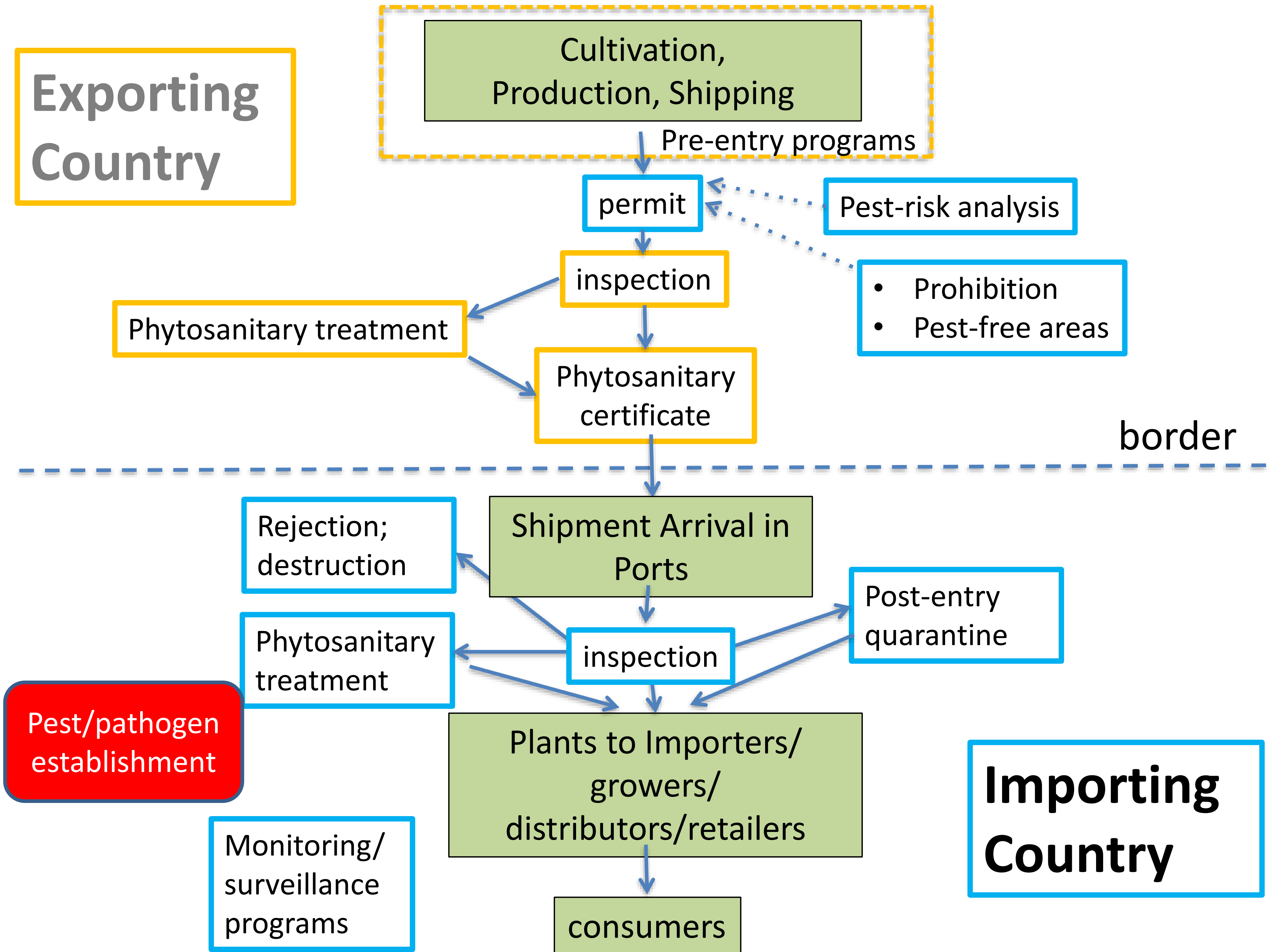
No contaminants/soil
Pre-export treatments
Pest free area
Pest free production site
Shipping in specific season
Post-entry quarantine

	New Zealand	Australia	USA	Canada	India	China	Brazil	Kenya	South Africa	EU
Phytosanitary certificate	+	+	+	+	+	+	+	+	+	+
Import permit	+	+	+	+	+	+	+	+	+	–
Import inspections	+	+	+	+	+	+	+	+	+	+
Pathway risk analysis	+	+	#	+	+	+	+	#	#	–
No contaminants/soil	#	#	#	+	#	+	+	+	#	#
Pre-export treatments	+	+	#	#	#	#	+	#	#	#
Pest free area	#	#	#	#	#	#	#	#	#	#
Pest free production site	#	#	#	#	#	#	#	#	#	#
Shipping in specific season	#	+	#	#	–	–	–	–	–	#
Post-entry quarantine	+	+	#	#	#	#	+	#	#	#

Great heterogeneity among countries

Effectiveness

- Difficult to assess effectiveness
  - Most countries lack inspection data (esp. on negative outcomes) and import data
    - Data on imports and detections would allow to assess risks, trends, measure effectiveness
- Specific measures
  - New Zealand → 14% of consignments in quarantine infested (mostly with pathogens)
    - Inspections and treatments not fully effective



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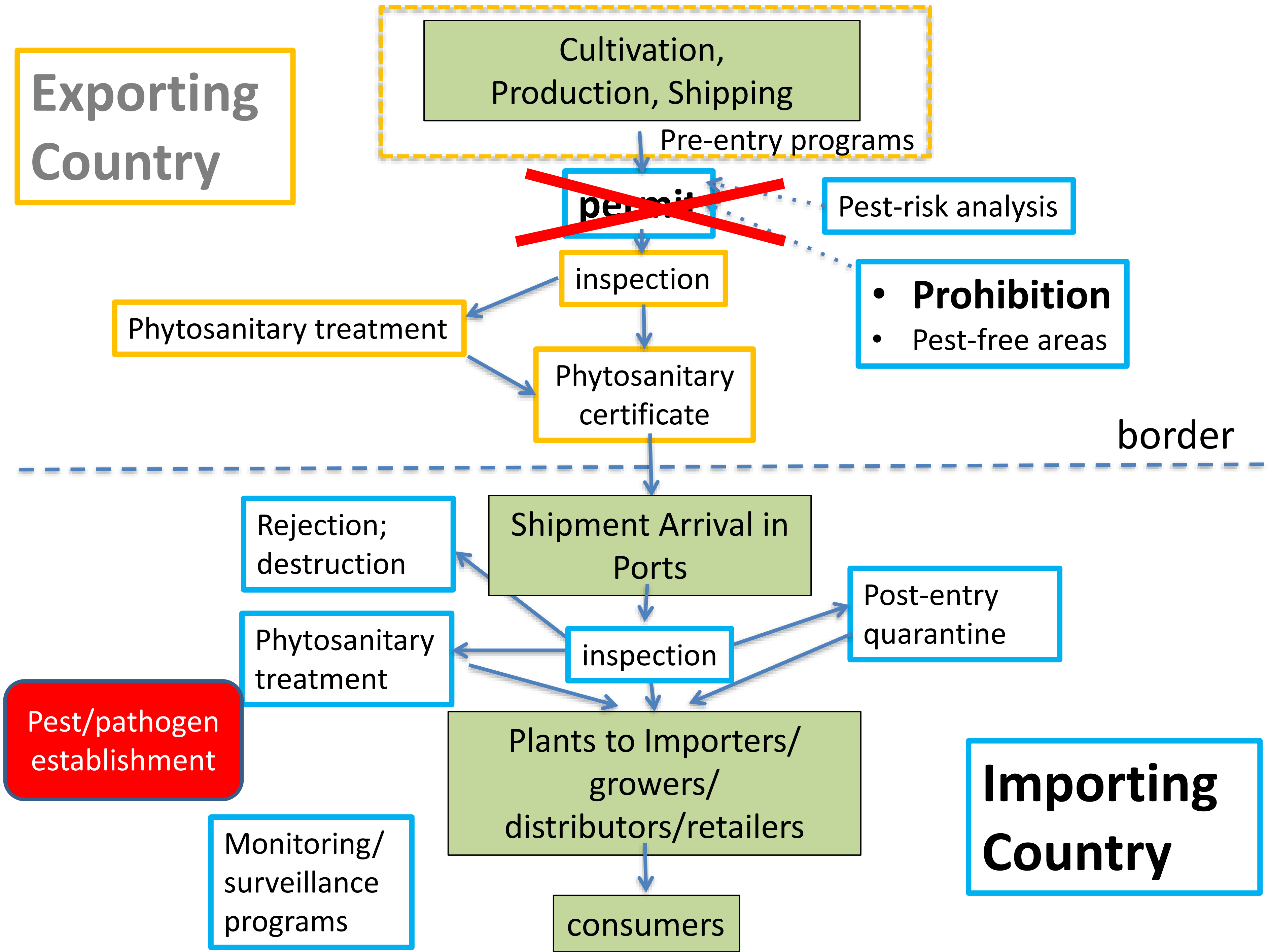
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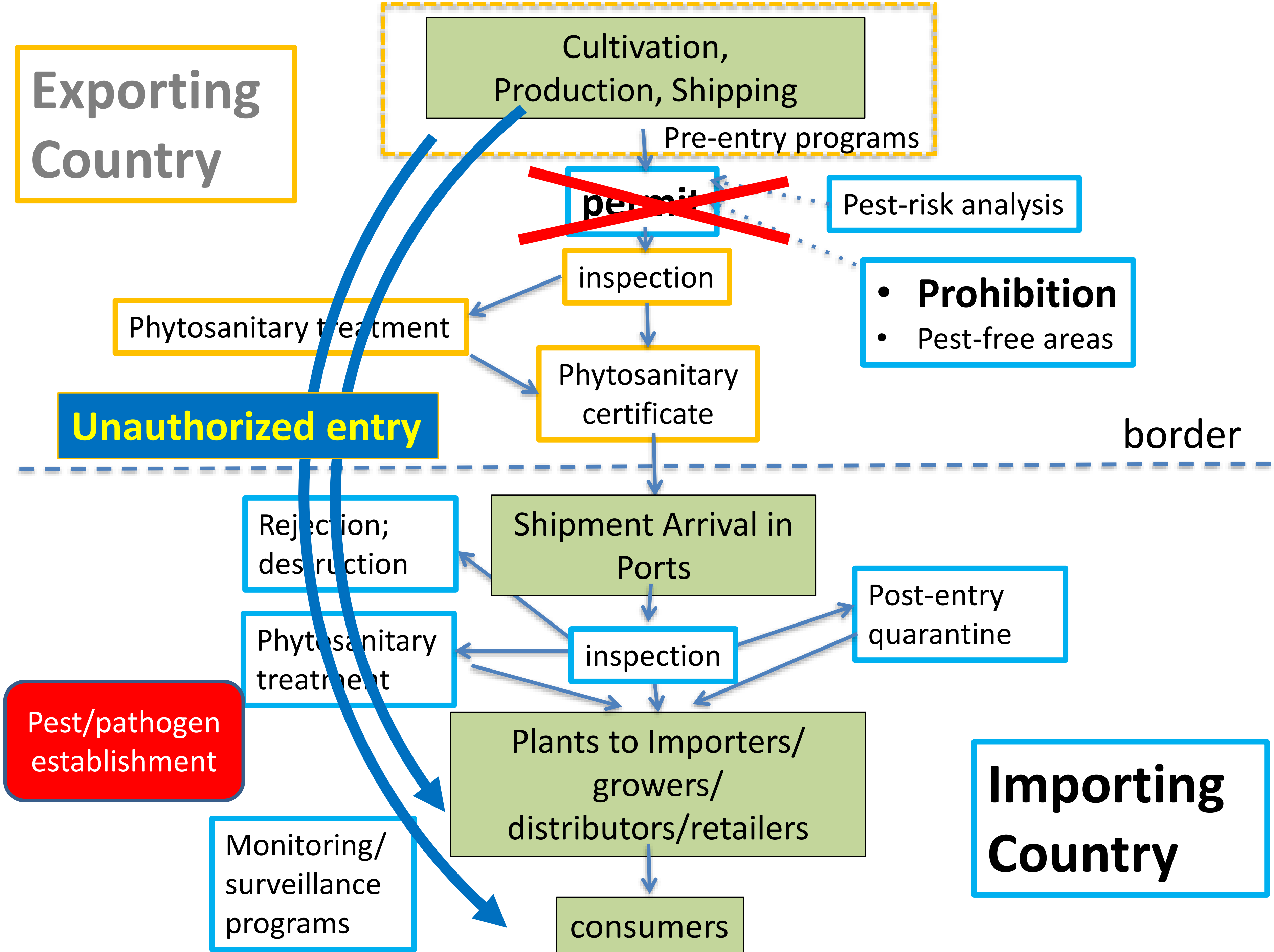
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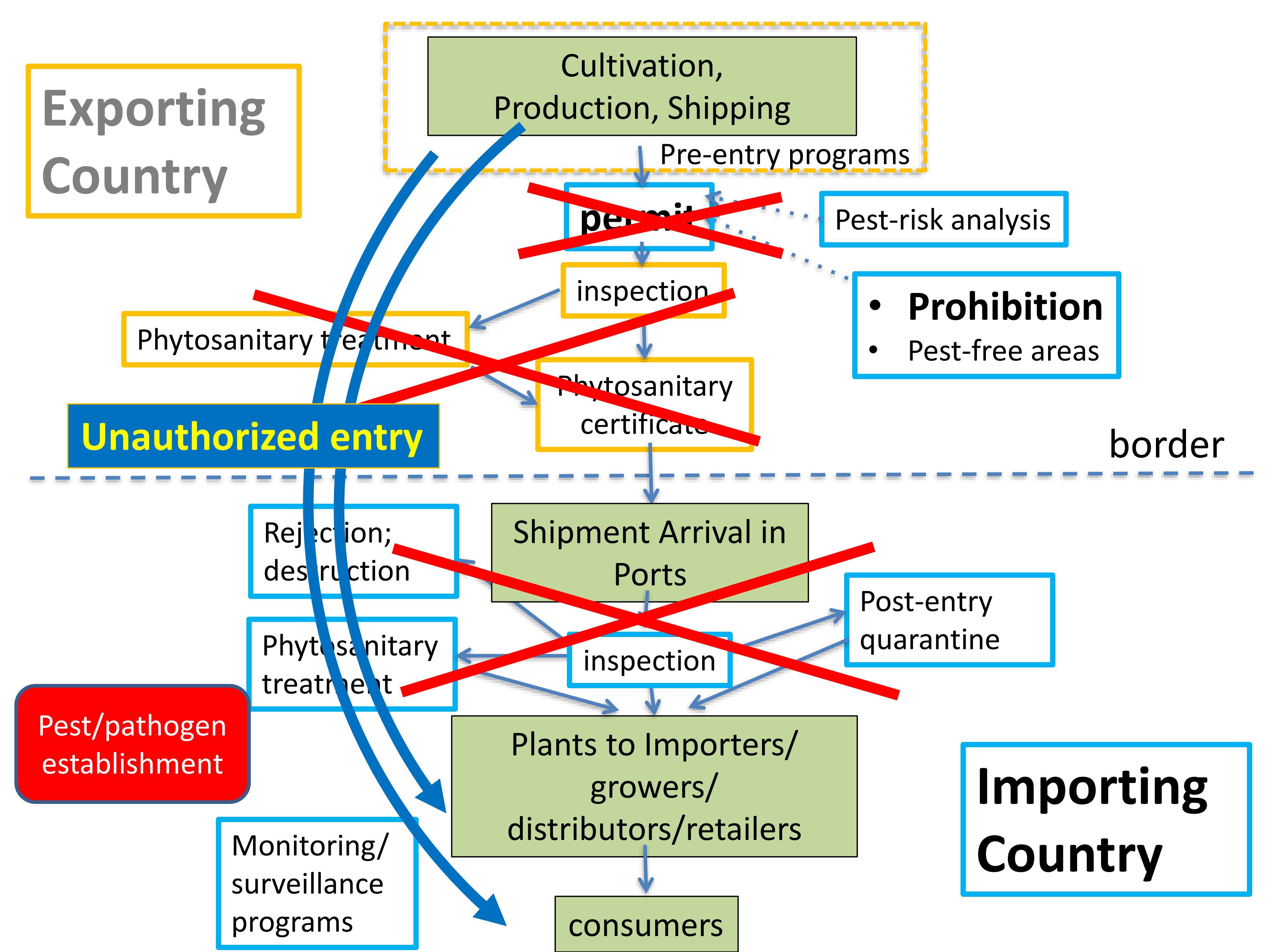
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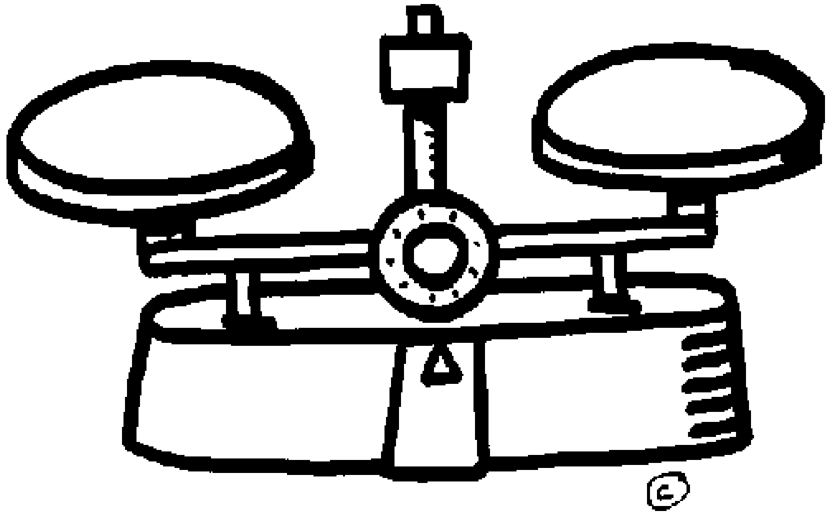
Pest Damages

X

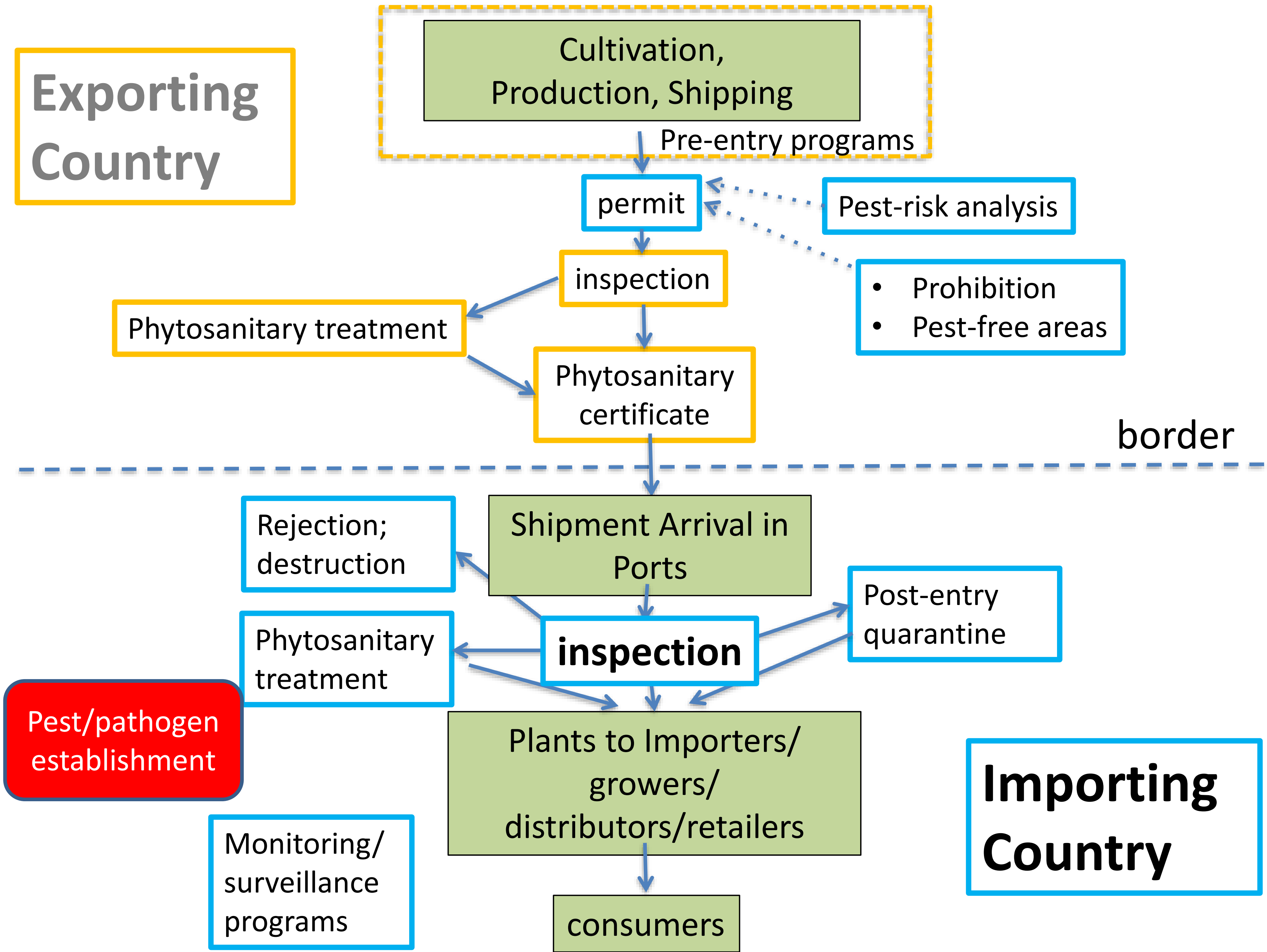
Probability of Introduction

Welfare benefits



Cost-Benefit Analysis of Live Plant Trade (work in progress)

- Compare welfare benefits and expected damages from trade
- Data limitations → challenging
- Focus: *woody plant imports* & *forest insect introduction*
- Evaluate benefits & costs based on relatedness of imports to US plant species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Inspection of Live Plant Imports

Inspection Goals:

1) Gain information about pest risks
2) Prevent introduction of pests
3) Deterrence

But:

Constrained inspection effort:

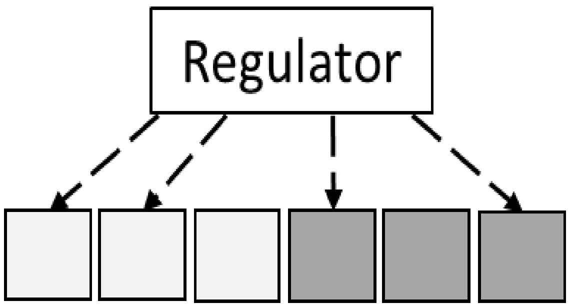
→ How allocate inspection effort across shipments to minimize acceptance of infested shipments or infested plants units?

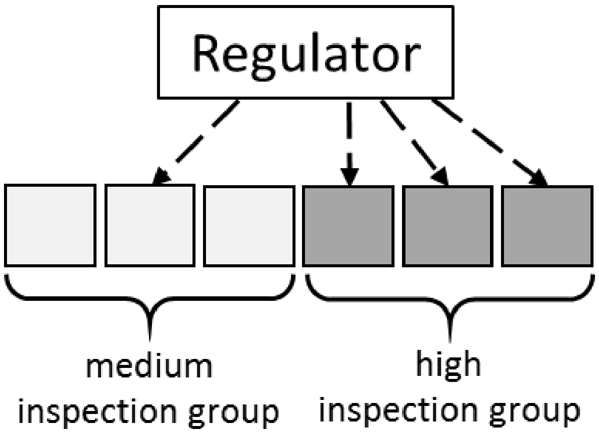
2 Studies on risk-based sampling

First Study:

Harnessing enforcement leverage at the border to minimize biological risk from international live species trade (Springborn, Lindsay, Epanchin-Niell 2016)

Uniform Inspection Policy → Risk-Based Inspection Policy



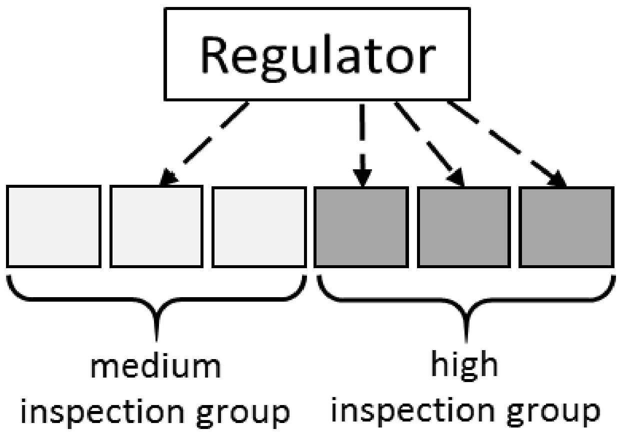


Study identifies inspection policy that minimizes accepted infested shipments, accounting for shipper response to policy

- shippers minimize their long term costs from abatement, inspections, and inspection outcomes

Results Preview:

Shifting to risk based system reduces # of accepted infested shipments by 20% simply by reallocating existing resources



Both high and lower risk group abate more under RBI

Lower risk group abates more because:

- Want to stay in lower risk group

High risk group abates more because:

- Inspected more (deterrence)
- Want to move to lower risk (low inspection) group

(Springborn, Lindsay, Epanchin-Niell, 2016)

Second Study:

Optimal Inspection of Imports to Prevent Invasive Pest Introduction

Risk Analysis (Forthcoming)

Cuicui Chen, Rebecca Epanchin-Niell, Robert Haight

How allocate fixed sampling resources across shipments to minimize acceptance of infested *plant units* (expected slippage)?

- Shipments vary in size and infestation rate
- # of infested plants proxy for propagule pressure

How many plants should be sampled from each shipment to minimize the number of accepted infested plant units?

Components of analysis:

- Define relationship between expected slippage (the expected number of accepted infested plant units per shipment) and shipment size, infestation rate, and sample size
- Develop optimization problem to determine number of plant units to sample from each shipment arriving at a port to minimize expected slippage
- Develop statistical approach to estimate infestation rate of commodities based on historic data
- Apply methods to a set of shipments

Expected Slippage (ES)

(Number of Accepted Infested Plants)

ES depends on

- j, J = Index and set of shipments
- N_j = Shipment size
- n_j = Sample size
- γ_j = Plant infestation rate
- e_j = Efficacy of detection

$$ES = (1-\gamma_j e_j)^{n_j}\left[\gamma_j(N_j - n_j) + \frac{1-e_j}{1-\gamma_j e_j}\gamma_j n_j\right]$$

Infested plants accepted	Probability shipment accepted	Expected number of infested plants in un-sampled portion	Expected number of undetected infested plants in sampled portion

Constrained optimization

Choose number of sampled plants (*n*) from each shipment *j* to minimize damage from imported infested plants (damage-weighted expected slippage)

$$\min_{(n_j)j\in J} \sum_{j\in J} \kappa_j ES(N_j, n_j, \gamma_j, e_j)$$

$$\text{subject to}: \sum_{j\in J} c_j n_j \leq \bar{c}$$

Capacity constraint

Note: In application assume *k* and *c* equal 1.

Estimating Plant Infestation Rates

(proportion infested plant units)

Developed (maximum likelihood) approach for estimating infestation rates from historic data based on:

- binary inspection results
- shipment sizes
- assuming 2% sample size

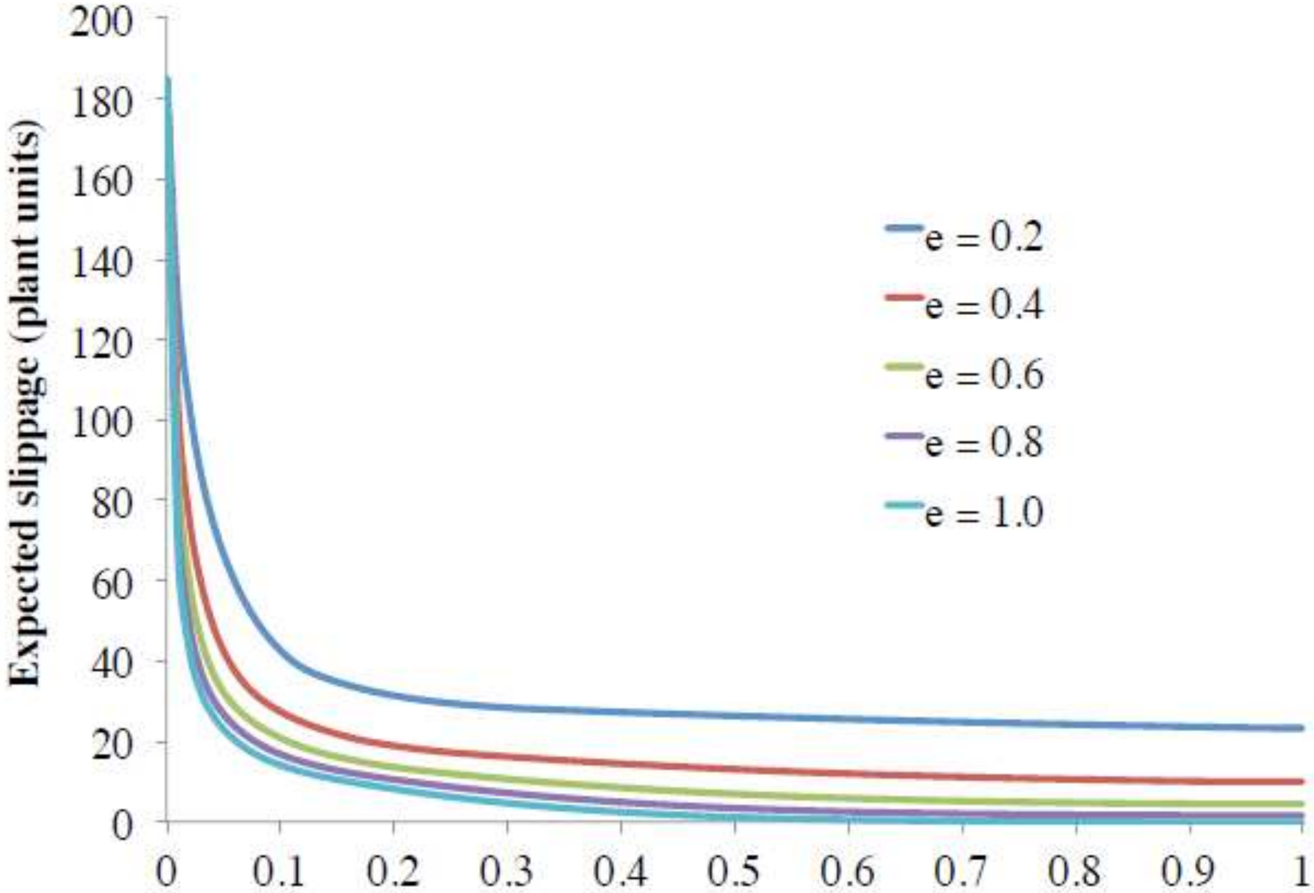
Infestation rate estimates for focal genera vary from 0.888% for Dendrobium to 0.0002% for Petunia.

<u>Application</u>: Optimize sampling of shipments received in Miami from Costa Rica

39 shipments; 756,762 plants

Plant genus	Infestation rate (%)	Shipment		Infestation rate (%)	Shipment size
Codiaeum	0.148	504		0.0188	10
Codiaeum	0.148	1250		0.0168	14700
Codiaeum	0.148	4000		0.0164	300
Codiaeum	0.148	7506			5350
Codiaeum	0.148	36800	Hedera		7035
Dracaena	0.104	193	Hedera		7340
Dracaena	0.104	956	Hedera		34800
Dracaena	0.104	1125	Salvia		8360
Dracaena	0.104	4900	Pachysandra		3600
Dracaena	0.104	5860	Pachysandra		5000
Dracaena	0.104	27697	Leucanthemum		1300
Schefflera	0.0811	1850	Lysimachia	0.00414	500
Cordyline	0.0695	10020		0.00373	15000
Cordyline	0.0695	49200		0.00361	23781
Lamium	0.0541	300	n	0.00158	200500
Aglaonema	0.0319	7625	n	0.00158	240500
Monarda	0.0302	1600		0.000486	100
Campanula	0.0245	400		0.00486	1700
Dianella	0.023	7500		0.000451	5800
Dianella	0.023	10800			

Expected slippage vs inspection capacity



Inspection Capacity

(Proportion of total plant units sampled)

Expected slippage

Optimal sampling strategy vs. 2% sampling rule
Total sample: 15,143 plants

Expected Slippage w/ Optimized Sampling	Expected Slippage w/ 2% Sampling	Reduction in Slippage
49.6	120.2	58.7%

Expected slippage

Optimal sampling vs. Risk-based sampling
Total sample: 2,692 plants.

Expected Slippage w/ Optimized Sampling	Expected Slippage w/ RBS	Reduction in Slippage
124.1	175.1	29.1%

Comparison of sampling plans

Lot attributes				Inspection capacity = 2,193		Inspection capacity = 15,143	
				Optimal sampling	Risk-based sampling	Optimal sampling	Proportional (2%) sampling
Plant genus	Infestation rate percentage	Lot size	Expected slippage without inspection	Sample size	Sample size	Sample size	Sample size
Codiaeum	0.148	36,800	54.30	1,197	59	2,817	736
Codiaeum	0.148	7,506	11.08	-	59	1,452	151
Codiaeum	0.148	4,000	5.90	-	58	956	80
Codiaeum	0.148	1,250	1.84	-	57	260	25
Codiaeum	0.148	504	0.74	[illegible]	54	[illegible]	11
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dracaena	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dracaena	0.104	4,900	5.09	-	59	851	98
Dracaena	0.104	1,125	1.17	-	57	-	23
Dracaena	0.104	956	0.99	-	57	-	20
Dracaena	0.104	193	0.20	-	49	-	4
Schefflera	0.081	1,850	1.50	-	58	-	37
Cordyline	0.069	49,200	34.19	410	59	3,815	984
Cordyline	0.069	10,020	6.96	-	59	1,109	201
…	…	…	…	…	…	…	…
Total		756,762	184.44	2,193	2,193	15,143	15,143

Focus sampling on largest, dirtiest samples

Combining goals: minimizing slippage and sampling all lots

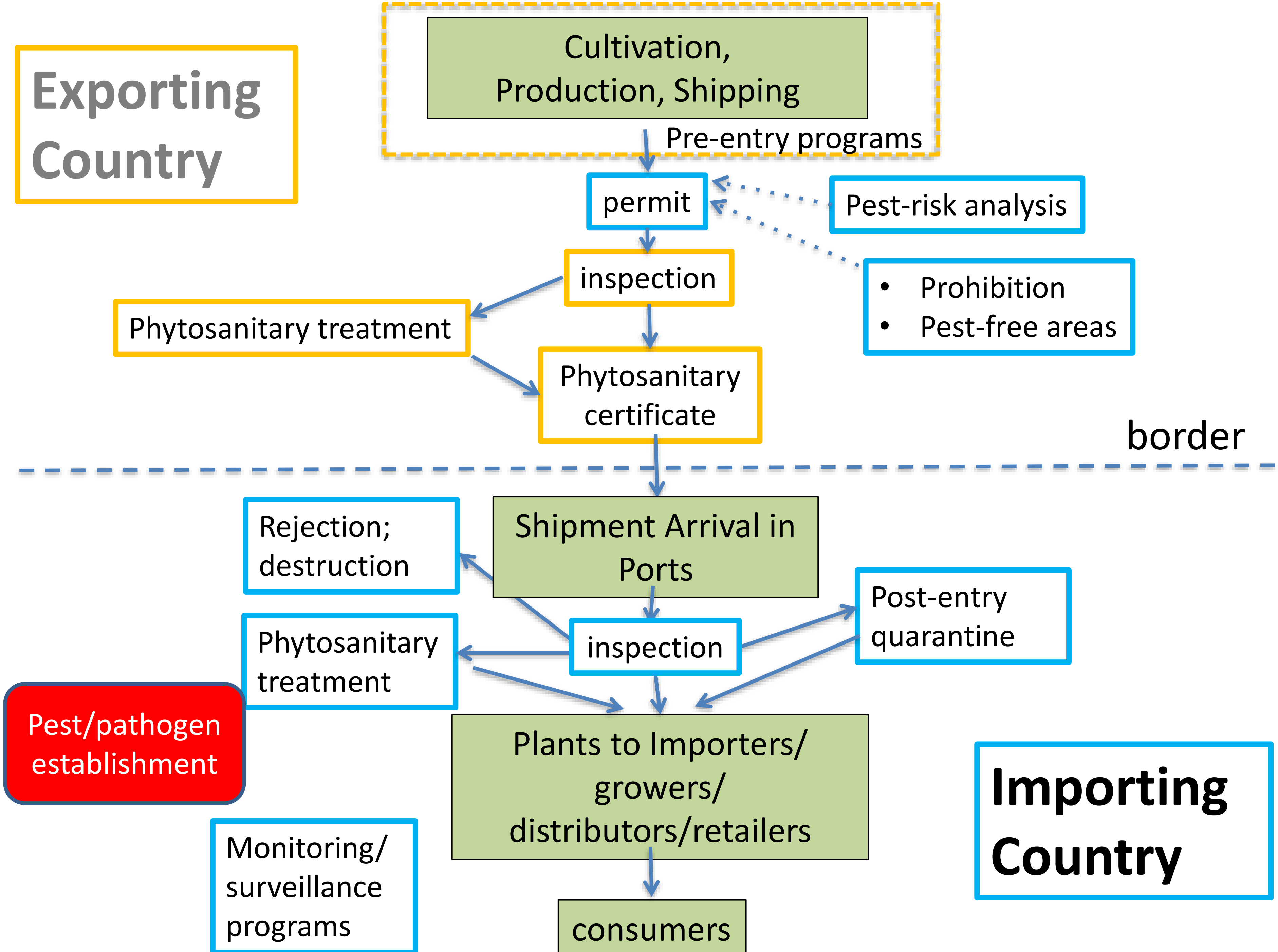
Plant genus	Infest. rate	Lot size	ES min.	ES min. + RBS
Codiaeum	0.148	36,800	2,817	2,671
Codiaeum	0.148	7,506	1,452	1,316
Codiaeum	0.148	4,000	956	830
Codiaeum	0.148	1,250	260	153
Codiaeum	0.148	504	-	54
Dracaena	0.104	28,697	2,855	2,650
Dracaena	0.104	5,860	1,028	845
Dracaena	0.104	4,900	851	673
Dracaena	0.104	1,125	-	57
Dracaena	0.104	956	-	57
Dracaena	0.104	193	-	49
Schefflera	0.081	1,850	-	58
Cordyline	0.069	49,200	3,815	3,509
Cordyline	0.069	10,020	1,109	831
…	…	…	…	…
Total		**756,762**	**15,143**	**15,143**
Exp. Slippage			**49.6**	**52.9**

Conclusions

Targeting inspections towards the largest, dirtiest shipments greatly reduces infested plant imports

Dual goals of slippage minimization and baseline sampling of all shipments can be achieved without substantial compromise

MLE provides method for estimating infestation rates with data on sample size and inspection outcome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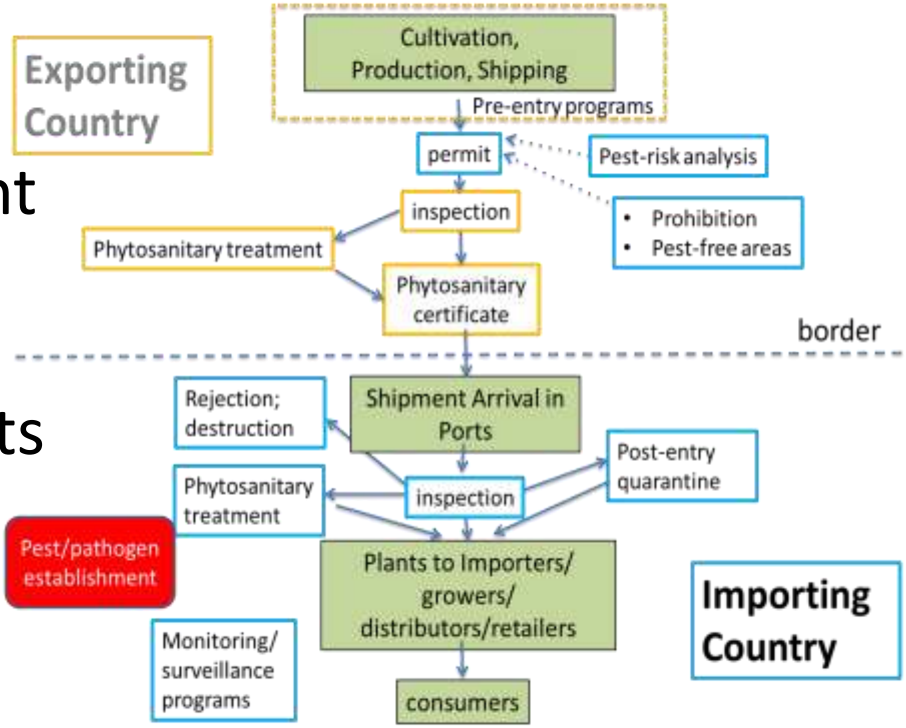
consumers

Advancing Policies

- Unauthorized entry
- Data collection and assessment
  - Integrated measures
  - Imports
- Evaluation of costs and benefits
- Pathogen management
- Early detection post-entry
- New technologies



- Fine tuning the safeguarding continuum
  - Recognizing tradeoffs of policies and how they can work together

Thank You!

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USDA United States Department of Agriculture
Animal and Plant Health Inspection Service

USDA EFETAC EASTERN FOREST ENVIRONMENTAL THREAT ASSESSMENT CENTER

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