Assessment of management strategies of sharka epidemics by modeling complemented with experiments
Loup Rimbaud, Gael Thébaud, Samuel S. Soubeyrand, Emmanuel Jacquot

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Assessing sharka management strategies through experiments and modeling

Loup Rimbaud, Ph.D. student

Montpellier SupAgro
UMR 385 BGPI, F-34398 Montpellier cedex 5, France
Sharka management strategy in France

Since the 1990’s

- Frequent visual inspections of the orchards
- Removal of the symptomatic trees (or whole orchards)
- Protection of the nurseries

Law published in 2011

- Definition of 4 areas around each infected tree

Disappointing outcome:

- Costly strategy
- Still many trees infected each year

Symptomatic trees detected in Gard (South of France)

Data from J.Y. Couderc
How to optimize management strategies?

Complex interactions between biological and human processes

Experiments

- Impossible in the laboratory
- Forbidden in the field
- Quarantine pathogen in France

Management strategy

- Large spatial scale
- Current strategy
- Optimization
- Modeling

Experts’ opinions
Research project

Experiments

Knowledge about biological processes

Joint simulation of:
- the epidemic process
- the management strategies

Steps:
1. Identification of key parameters
2. Sensitivity analysis
3. Proposal of management strategies
4. In silico test

SPATIOTEMPORAL SIMULATION MODEL

OPTIMIZED MANAGEMENT STRATEGIES

Knowledge about biological processes

2nd international symposium on Plum pox virus September 2013
Research project

Experiments

Knowledge about biological processes

Step 1

Joint simulation of:
- the epidemic process
- the management strategies

Step 2

SPATIOTEMPORAL SIMULATION MODEL

Proposal of management strategies

Step 3

Identification of key parameters

In silico test

Step 4

Sensitivity analysis

OPTIMIZED MANAGEMENT STRATEGIES

Step 1

Knowledge about biological processes

Step 2

SPATIOTEMPORAL SIMULATION MODEL

Proposal of management strategies

Step 3

Identification of key parameters

Step 4

Sensitivity analysis

OPTIMIZED MANAGEMENT STRATEGIES

Joint simulation of:
- the epidemic process
- the management strategies

2nd international symposium on Plum pox virus

September 2013
Consequences of symptom-based detection

Visual inspections allow the detection of symptomatic trees.

Infected trees without symptoms cannot be detected.

Infected
Healthy
Latency vs. Incubation

First hypothesis

$t_0$  PPV inoculation

$\text{INCUBATION}$

$\text{LATENCY}$

$t_i$  Symptom expression

$t_L = t_i$

$t_L$  Infectious plant

$t$  PPV transmission
Second hypothesis

Latency vs. Incubation

- \( t_0 \) PPV inoculation
- \( t_i \) Symptom expression
- \( t_L < t_i \)
- Infectious plant
- PPV transmission
Latency vs. Incubation

Third hypothesis

$t_0$  
PPV inoculation

$t_i$  
Symptom expression

$t_L > t_i$

Infectious plant

$t_L$

PPV transmission

PPV inoculation

INCUBATION

LATENCY
Consequences of these scenarios

- **Infectious with symptoms**
  - Visual inspections efficient
  - Examples in literature: Influenza virus, Hepatitis B virus

- **Infectious without symptom**
  - Virus source trees not detected by visual inspections
  - Need to apply alternative methods
  - Examples in literature: Rabies virus, Hepatitis A virus

- **Symptomatic but not infectious**
  - Visual detection possible before the spreading of the disease
  - Visual inspections efficient
  - Examples in literature: Mycosphaerella fijiensis, Septoria nodorum

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Exemples in literature

- Influenza virus
- Hepatitis B virus
- Rabies virus
- Hepatitis A virus
- Mycosphaerella fijiensis
- Septoria nodorum
Goal: assessment of the potential asynchronism

Experimental approach for PPV on peach trees

$\rightarrow$ PPV inoculation

$\rightarrow$ Symptom expression

$\rightarrow$ Infectious plant

$\rightarrow$ PPV transmission

$\rightarrow$ 2nd international symposium on Plum pox virus September 2013
Experimental approach

PPV inoculation $t_0$

Transmission test $t_{test 1}$

1st symptoms $t_i$

Transmission test $t_{test 2}$

Test plant ($N. benthamiana$)

Transmission rate

GF 305
Analysis of inter-plant variation of $t_i$
No significant difference between strains ($p = 0.70$)

- Symptom expression between days 6 and 18
- First symptoms on day 9 for 40% of the plants
Simulation of inter-plant variation of $t_L$

Low variation in the latency duration

High variation in the latency duration
Validation of the protocol by modeling

1. Simulation of the number of infected test plants
2. Model fitting & assessment of the mismatch between latency and incubation
3. Assessment of the adequacy between simulated and estimated mismatches

Empirical distribution to simulate the incubation period

3 theoretical distributions to simulate the latency period
Assessment of the mismatch

Variance of the estimated mismatch dependent on the latency scenario
Assessment of the mismatch
Adequacy between simulated and estimated mismatches

Mismatch between latency and incubation assessed with a precision of 1 day
Conclusions

- Model-based experimental design: a useful approach for assessing several scenarios and designing experiments
- We adopt this approach to acquire new data on latency and incubation periods for PPV
- Knowledge acquired through this experiment will be used to improve:
  - The spatiotemporal model of propagation
  - The proposed management strategies
Thank you for your attention