Developing surveillance strategies for *Xylella fastidiosa* in the Mediterranean region

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PLAN OF TALK

1) Surveillance for *Xylella fastidiosa* in Apulia, Italy.

2) Optimising surveillance strategies.

3) Applying the method to *X. fastidiosa* in Apulia.

4) Preliminary conclusions.
1) SURVEILLANCE FOR XYLELLA FASTIDIOSA IN APULIA, ITALY
XYLELLA FASTIDIOSA IN APULIA

A large amount of surveillance effort is focussed on the region around the border of the known infected and uninfected areas.

Containment area (“Zona contenimento”) 30km wide
Where should we conduct surveillance in the uninfected zone, accounting for both “primary spread” of Xylella fastidiosa from the infected zone, and further “secondary spread” within the uninfected zone?
2) OPTIMISING SURVEILLANCE STRATEGIES
XYLELLA FASTIDIOSA IN APULIA

- **Surveillance strategies** are needed to detect further spread beyond the buffer zone so that appropriate control and containment measures can be implemented.

- These measures should account for the **biology of the pathogen**.

- Deterministic growth in incidence within infected cells

- “Stratified dispersal”:
  - Deterministic shorter-distance, “local”, spread
  - Stochastic longer-distance “jumps”
Distribution of olive trees
Reported cases of CoDiRO 2016
MODELLING LONG DISTANCE SPREAD

Mean incidence of infection (10,000 realisations)

Default parameters
(Gaussian long distance dispersal)

More long range spread
(Uniform long distance dispersal)

2017 prediction

2017 prediction
MODELLING SPREAD

Mean incidence of infection (10,000 realisations)

**Default parameters**
(Gaussian long distance dispersal)

**More long range spread**
(Uniform long distance dispersal)

2018 prediction
MODELLING SPREAD

Area of Apulian uninfected zone with **at least one predicted incursion** (from 10,000 model realisations, over two years) in the absence of any control/surveillance measures.

**Default parameters**

**More long range spread**
MODELLING SPREAD

Mean incidence in the uninfected zone (10,000 model realisations).

Gaussian spread

Maximum incidence: 1.1%

Uniform spread

Maximum incidence: 0.2%
OPTIMISING SURVEILLANCE

- We want our surveillance strategy to minimise the probability of failing to detect infection.

- We can calculate this probability when we inspect:
  - $N$ locations
  - $x$ trees per location

  When the incidence in each location is $p_n$

\[
P(\text{no det}) = \prod_{n=1}^{N} (1 - p_n)^x
\]
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Probability of **not** selecting an infected tree, *if we took one sample from site $n$*
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Probability of not selecting any infected trees, **when we sample** $x$ trees from site $n$
OPTIMISING SURVEILLANCE

- We want our surveillance strategy to **minimise the probability of failing to detect infection.**

- We can calculate this probability when we inspect:
  - $N$ locations
  - $x$ trees per location

When the incidence in each location is $p_n$, the probability of not selecting any infected trees, when we sample all $N$ sites, with $x$ trees from each

$$P(\text{no det}) = \prod_{n=1}^{N} (1 - p_n)^x$$
OPTIMISING SURVEILLANCE

- *X. fastidiosa* CoDiRO is characterised predominantly by “secondary spread” (i.e. **within** olive groves)

- To account for this, we used two consecutive years’ incidence predictions ($p_{n_1}$ and $p_{n_2}$):

\[
P(\text{no det}) = \prod_{n=1}^{N} (1 - p_{n_1})^x (1 - p_{n_2})^x
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OPTIMISING SURVEILLANCE

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\[
P(\text{no det}) = \prod_{n=1}^{N} (1 - p_{n_1})^x (1 - p_{n_2})^x
\]

Probability of not selecting any infected trees **in either year 1 or 2**, when we sample all $N$ sites, with $x$ trees from each
OPTIMISING SURVEILLANCE

- For any set of $N$ sites, we can estimate the probability of failing to detect infection.

- We need a way of finding the combination of sites which minimises this probability.

- However, the number of combinations of sites is too great to evaluate all possible combinations.

- We can use algorithmic optimisation routines (such as simulated annealing) to identify the best combination without having to evaluate all combinations.
SIMULATED ANNEALING

Exploring the parameter space

\[ P(\text{no det}) \]

Iteration of algorithm
SIMULATED ANNEALING

Rejecting poor selections

\[ P(\text{no det}) \]

Iteration of algorithm
SIMULATED ANNEALING

Identifying optimal locations

\[ P(\text{no det}) \]

Iteration of algorithm
We used simulated annealing to identify which locations should be sampled in order to minimise the probability that we fail to detect infection.

We assumed that an average of 1 tree per hectare was inspected (100 trees per km$^2$ grid cell).

We repeated this approach for different numbers of sample locations – from 50 to 500.
APPLYING THE METHOD TO X. FASTIDIOSA IN APULIA: PRELIMINARY RESULTS
PRELIMINARY RESULTS

Probability of no detection when sampling 100 trees in each of a specified number of sites:

**Default parameters**

50 sites. Final probability of no detection: 0.38

**More long range spread**

50 sites. Final probability of no detection: 0.78
Default parameters

50 sites

500 sites

More long range spread

50 sites

500 sites
Probability of no detection when visiting a specified number of sites randomly from the population:

**Default parameters**

Probability of no detection when 100 samples collected per site

**More long range spread**

Probability of no detection when 100 samples collected per site
PRELIMINARY RESULTS

Probability of no detection when visiting the specified number of optimal sites:

**Default parameters**
Probability of no detection when 100 samples collected per site

**More long range spread**
Probability of no detection when 100 samples collected per site
PRELIMINARY CONCLUSIONS
SURVEILLANCE COMPARISON: DEFAULT PARAMETERS

Actual surveillance, 2017

Optimal surveillance

From http://webapps.sit.puglia.it/freewebapps/MonitoraggioXFSintesi/
Accessed 02/11/2017
SURVEILLANCE COMPARISON: LONG DISTANCE SPREAD

Actual surveillance, 2017

Optimal surveillance

Preliminary results

From http://webapps.sit.puglia.it/freewebapps/MonitoraggioXFSintesi/
Accessed 02/11/2017
PRELIMINARY CONCLUSIONS

- **Simulation models** of *Xylella fastidiosa* spread can be used to identify **where best to conduct surveillance** in the uninfected zone of Apulia.

- The best place to conduct surveillance depends on the **nature of pathogen spread** from the infected zone – and may not always be close to the buffer zone boundary.

- Correctly **characterising this long-distance spread is crucial**, this is now the focus of work with the CEH to improve upon our current (provisional) findings.
Thank you!

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