An overview of practical management of forest and tree diseases relating AOD research to management principles

Sandra Denman

Stakeholder meeting
March 2023

Six fundamental steps to disease management

1. What?
- Recognise that trees are diseased
- Describe symptoms
- Train surveyors symptom recognition

2. How?
- Identify the cause(s) of the disease
-
- Introduced invasive threats (Quarantine) – Emergency and Response Team
- Existing or emerging disease

3. Where
- Survey and establish distribution and incidence of the disease
- Damage assessment

4. Rate
- Establish databases
- Develop rapid testing methods
- Raise awareness
- Monitor

5. Understand : Why?
- disease epidemiology and rate of spread, keep monitoring
- host range,
- disease drivers
- risks (losses and impacts – monetary and environmental)
- economics, social attitudes

6. Possible Actions
Derive and carry out management research and engage in management guidance activities

Forest Research

1. Recognise that trees are diseased and describe the symptoms

2014:

Forestry *An International Journal of Forest Research*

Institute of Chartered Foresters

Forestry 2014; **87**, 535–551, doi:10.1093/forestry/cpu010
Advance Access publication 18 April 2014

A description of the symptoms of Acute Oak Decline in Britain and a comparative review on causes of similar disorders on oak in Europe

Sandra Denman[1]*, Nathan Brown[1,2], Susan Kirk[1], Mike Jeger[2] and Joan Webber[1]

[1] *Forest Research, Centre for Ecosystems, Society and Biosecurity, Alice Holt Lodge, Farnham, Surrey GU10 4LH, England*
[2] *Imperial College, London, England*

*Corresponding author. Tel.: +44 142022255; Fax: +44 142023653; E-mail: sandra.denman@forestry.gsi.gov.uk

Received 19 August 2013

Acute Oak Decline (AOD) is a relatively new decline-disease affecting both native oak species (*Quercus robur* and *Q. petraea*) in Britain. The key aim of this study was to describe the symptoms, and signs of AOD, to set a baseline.

2009:

NEW DEFINITIONS AND NEW EPISODES IN BRITAIN

Sandra Denman and Joan Webber provide an update on the latest developments and clarify some of the confusion surrounding this worrying problem.

Increased visibility of deteriorating oak health in Britain and media reports on 'Sudden Oak Death' have led to growing public concern about their long-term future. However, there is considerable confusion about the cause of ill-health and the names that people use to describe it. Over the past century oaks in diminishing health have been said to be suffering from dieback or decline. In Britain, periodic episodes of decline have affected populations of native oak (*Quercus robur* and *Q. petraea*), and this has been documented by Day (1927); Osmaston (1927); Robinson (1927); Young (1965); Gibbs and Wainhouse (1995); Gibbs and Greig (1997). These episodes of oak decline are of complex cause, often implicating poor site conditions, drought, excessive soil nitrogen, attack by root disease fungi such as *Armillaria*, *Collybia* and *Phytophthora*, as well as recurrent insect defoliation followed by mildew attack.

More recently, concern has also been expressed about the widespread, general decrease in crown density of pedunculate oak in Britain (Innes and Boswell, 1991; Pinchin, 1999 and Hendry, 2005). Thinning tree canopies are usually indicative of worsening overall health and between the mid 1970s and early 1980s it was thought that poor air quality and increased soil acidity, both as a consequence of heavy industrial activity, could be a cause or

'Sudden Oak Death' (SOD) sweeping through native coastal forests in California and causing significant levels of mortality amongst native oak and tan oak posed the possibility of another threat to native British oak species. And now, yet another disorder – called 'Acute Oak Decline' (AOD), is on the rise in Britain. In this article we will differentiate and discuss a number of causes of oak death and decline, apply an appropriate name to each then place them in context in the British landscape.

Figure 7 A mature oak with occluded AOD lesions. The outer bark has fallen away from the occluded areas giving a pock-marked appearance to the stem.

Figure 8 X-S through AOD lesions on tree trunk: occluded area (red arrow), lesion and cavity formed in a subsequent attack (sky blue arrow), original AOD lesion (green arrow) and *Agrilus* larval galleries (dark blue arrow).

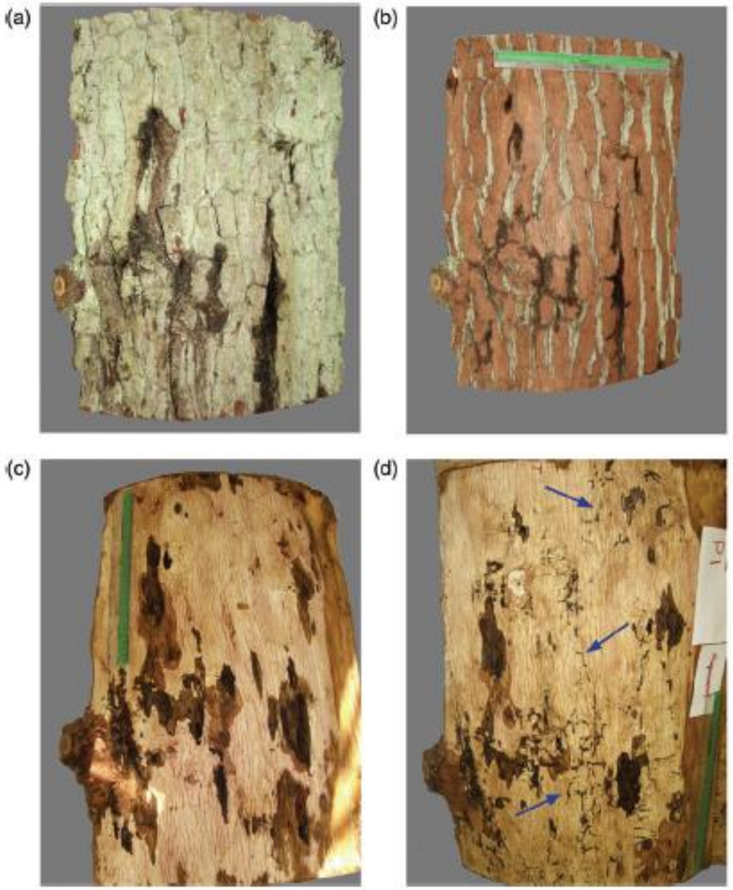

Figure 9 (a) External symptoms of AOD on bark panel removed for further analyses. (b) Stem bleeds in the sub-surface outer bark showing good correlation with external bleed points (a). (c) Lesions in the inner bark. Note the greater extent of necrosis than the weeping patch (a and b) indicates. (d) Lesions still present but reducing the outer sapwood and cambium layers where the *Agrilus* galleries become evident (dark blue arrows).

Forest Research

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Forestry An International Journal of Forest Research

Institute of Chartered Foresters

Forestry 2014; **0**, 1–11, doi:10.1093/forestry/cpu039

A review of *Agrilus biguttatus* in UK forests and its relationship with acute oak decline

Nathan Brown[1–3], Daegan J.G. Inward[1]*, Mike Jeger[2] and Sandra Denman[1]

[1]Centre for Ecosystems, Society and Biosecurity, Forest Research, Alice Holt Lodge, Farnham, Surrey GU10 4LH, UK
[2]Division of Ecology and Evolution, Imperial College London, Silwood Park Campus, Ascot SL5 7PY, UK
[3]Present Address: Department of Computational and Systems Biology, Rothamsted Research, West Common, Harpenden, Hertfordshire AL5 2JQ, UK

Figure 1 Adult *Agrilus biguttatus*.

Figure 2 *Agrilus biguttatus* larva.

near to the surface, where they overwinter in a folded position (Figure 3). Pupation occurs in the spring, taking ~14 days (Habermann and Preller, 2003), after which the adult beetle emerges through a characteristic D-shaped exit hole, typically 2.5–4 mm wide (Figure 4).

Distribution and abundance

Agrilus biguttatus is widespread across central Europe, extending east to the Ukraine and south to North Africa (Bily, 1982; Davis et al., 2005). Most of this range is characterized climatically as mild to warm, or having warm continental summers. The British population is at the northerly limit of this range and until the 1970s was regarded as exhibiting a relictual distribution, occurring

Figure 3 Pre-pupal larva of *Agrilus biguttatus*, exposed within its pupal cell excavated in the outer bark of host oak tree.

Figure 4 D-shaped exit hole created in the outer bark by an emerging adult *Agrilus biguttatus*.

Forest Research

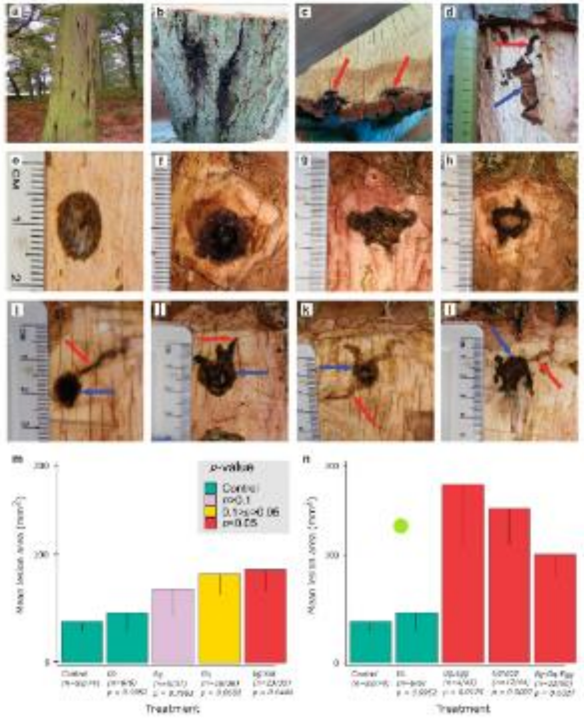
2. Identify the cause(s) of the disease

- Primary diseases – no/little host defence – single pathogen - *Phytophthora*
- Secondary diseases – cause disease in weakened hosts - *Armillaria*
- Opportunistic diseases – need a wound
- Complex aetiology diseases – different stages on different plants
- Decline diseases – interaction with multiple factors allowing biotic deterioration of weakened trees
- Pathobiome – consortium of micro-organisms that all contribute something to degrading tree tissue

Not always straight forward!! Maybe more than 1 factor, novel pathogens, involvement of insects??

Forest Research

2. Identify the cause(s) of the disease (10 years! And still working on it)



The ISME Journal (2018) 12, 386–399
www.nature.com/ismej

OPEN

ORIGINAL ARTICLE

Microbiome and infectivity studies reveal complex polyspecies tree disease in Acute Oak Decline

Sandra Denman[1,6], James Doonan[2,6], Emma Ransom-Jones[2], Martin Broberg[2], Sarah Plummer[1], Susan Kirk[1], Kelly Scarlett[1], Andrew R Griffiths[1,2], Maciej Kaczmarek[1,2], Jack Forster[1], Andrew Peace[1], Peter N Golyshin[2], Francis Hassard[3], Nathan Brown[4], John G Kenny[5] and James E McDonald[2]

[1]*Forest Research, Centre for Forestry and Climate Change, Farnham, UK;* [2]*School of Biological Sciences, Bangor University, Bangor, UK;* [3]*School of Ocean Sciences, Bangor University, Bangor, UK;* [4]*Department of Computational and Systems Biology, Rothamsted Research, Harpenden, UK and* [5]*Centre for Genomic Research, Institute of Integrative Biology, University of Liverpool, Liverpool, UK*

Systematic and Applied Microbiology 33 (2010) 444–450

Contents lists available at ScienceDirect

Systematic and Applied Microbiology

journal homepage: www.elsevier.de/syapm

ELSEVIER

Description of *Gibbsiella quercinecans* gen. nov., sp. nov., associated with Acute Oak Decline☆

Carrie Brady[a], Sandra Denman[b,*], Susan Kirk[b], Stephanus Venter[a], Pablo Rodríguez-Palenzuela[c], Teresa Coutinho[a]

[a] *Department of Microbiology and Plant Pathology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria 0002, South Africa*
[b] *Forest Research, Centre for Forestry and Climate Change, Alice Holt Lodge, Farnham, Surrey GU10 4LH, United Kingdom*
[c] *Centro de Biotecnología y Genómica de Plantas UPM-INIA, Campus de Montegancedo, Autovía M-40 Km 38, 28223 Pozuelo de Alarcón, Madrid, Spain*

«paper no. ije037879 charlesworth ref: ije037879»

New Taxa - Proteobacteria

International Journal of Systematic and Evolutionary Microbiology (2012), 62, 000–000 DOI 10.1099/ijs.0.037879-0

Brenneria goodwinii sp. nov., associated with acute oak decline in the UK

Sandra Denman,[1] Carrie Brady,[2] Susan Kirk,[1] Ilse Cleenwerck,[2] Stephanus Venter,[3] Teresa Coutinho[3] and Paul De Vos[2]

[1]Forest Research, Centre for Forestry and Climate Change, Alice Holt Lodge, Farnham, Surrey GU10 4LH, UK

[2]BCCM/LMG Bacteria Collection, Ghent University, K. L. Ledeganckstraat 35, B-9000 Ghent, Belgium

[3]Department of Microbiology and Plant Pathology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Pretoria 0002, South Africa

Correspondence
Sandra Denman
sandra.denman@forestry.gsi.gov.uk

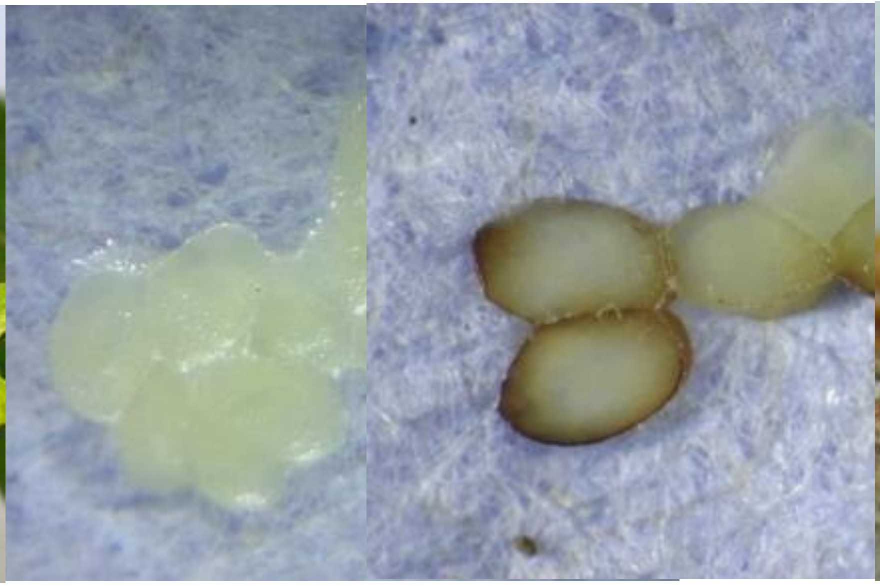
Forest Research

2. Identify the cause(s) of the disease: Rear beetles in captivity for research and testing

Insectory

Breeding cages

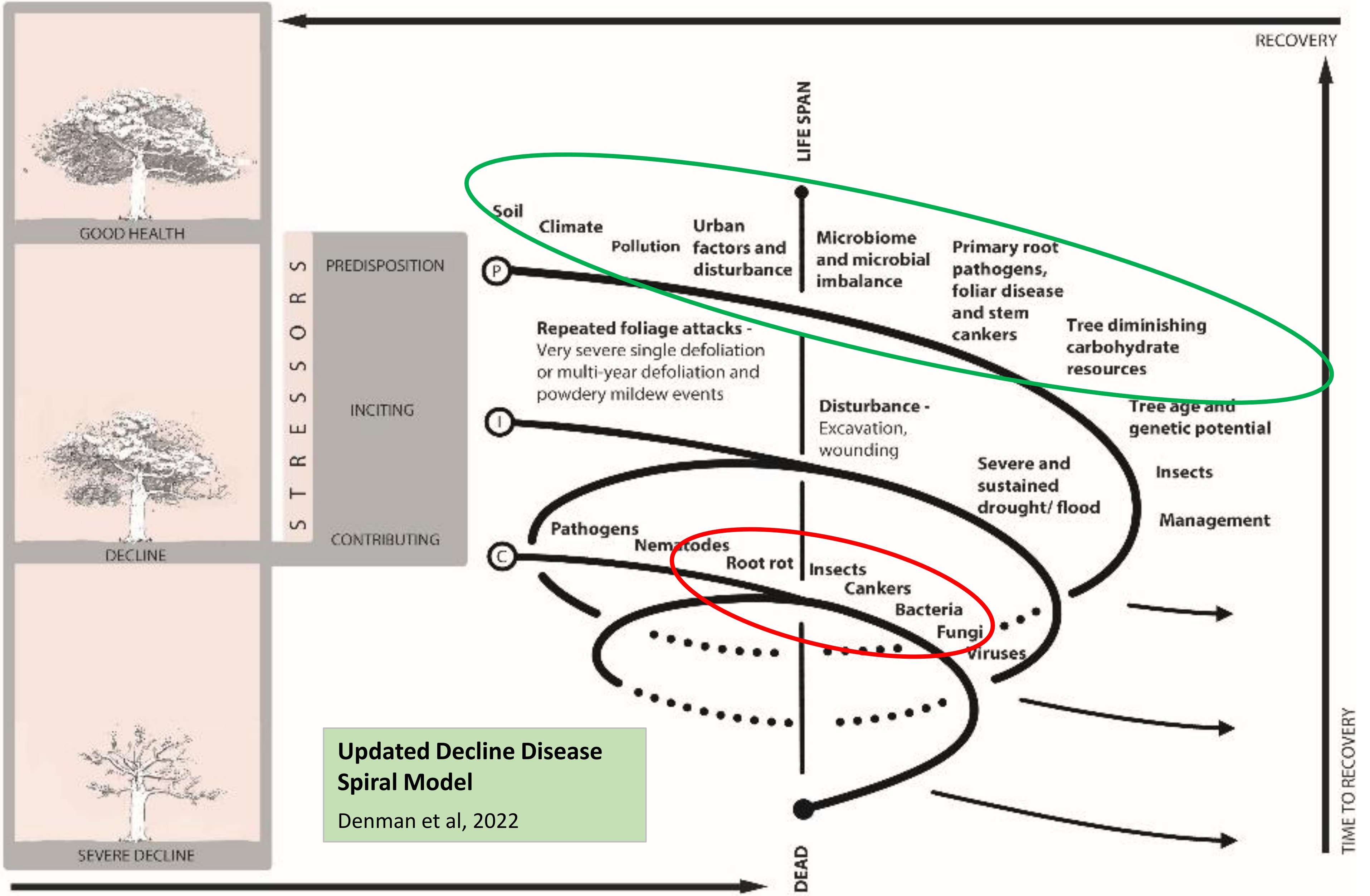
Mating



Eggs

Hatching larvae

Decline: Arises from interactions of interchangeable, specifically ordered, abiotic and biotic factors that produce a gradual general deterioration, often ending in death of trees.



Updated Decline Disease Spiral Model

Denman et al, 2022

Back track to the drivers

Began

Forest Research

3+4. Distribution – where is it – Survey – National Scale + rapid diagnostic

Data: Woodland Sources + CSR

Forestry Commission

NATURAL ENGLAND

N ational
F orest
I nventory

National Trust

WOODLAND TRUST

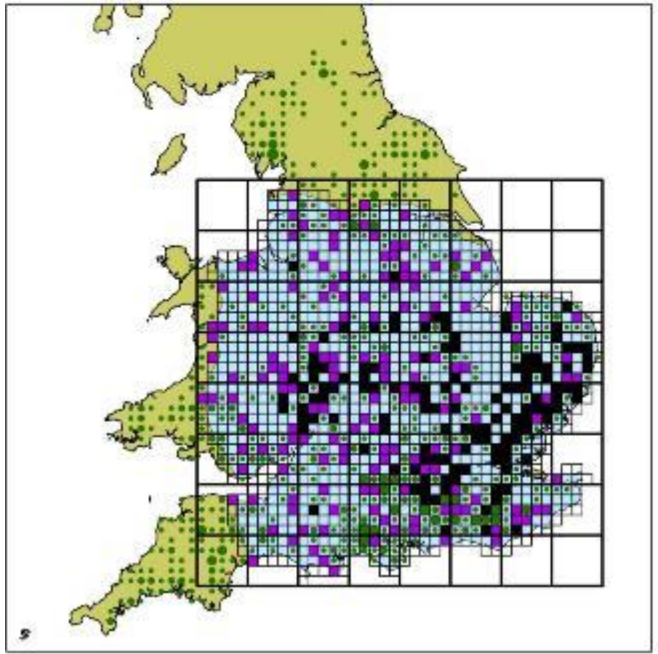
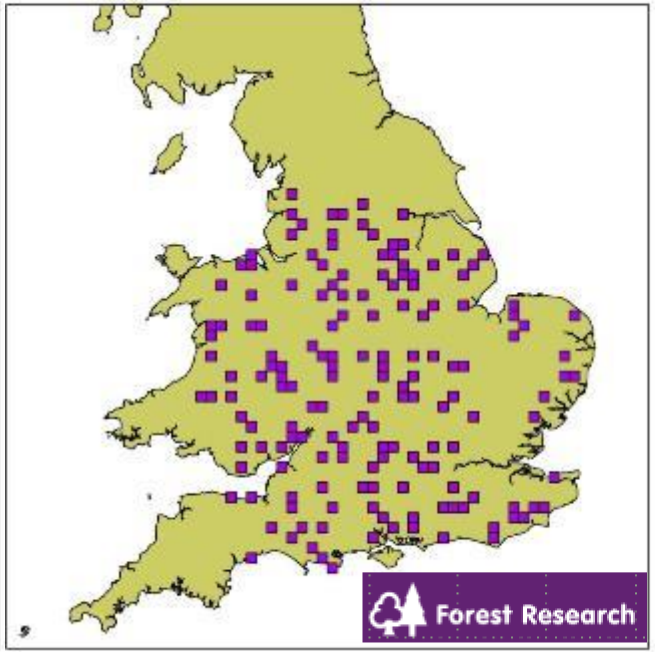
THE wildlife TRUSTS

Data base and analyses

Training and survey



Sites elected for 2014 survey

Forest Ecology and Management 360 (2016) 97–109

Contents lists available at ScienceDirect

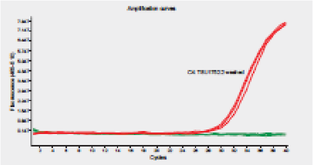
Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Spatial and temporal patterns in symptom expression within eight woodlands affected by Acute Oak Decline

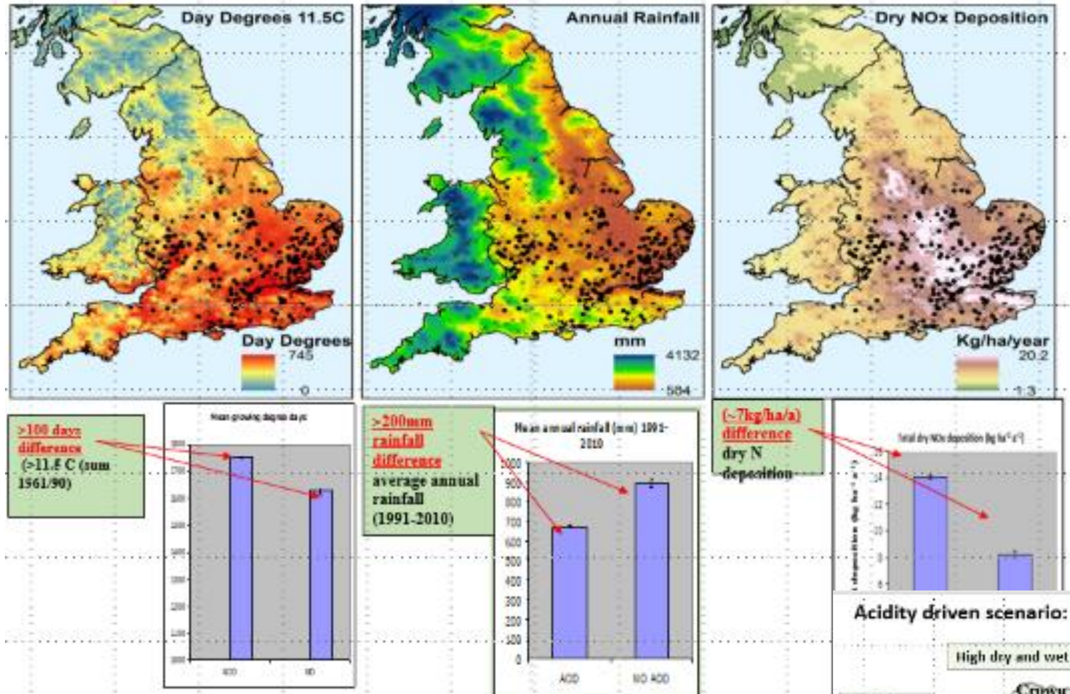
Nathan Brown [a,b,c,*], Mike Jeger [d], Susan Kirk [b], Xiangming Xu [e], Sandra Denman [b]

Verification – rapid diagnostics and photo identifications


5. Understand how the disease works – spatial epidemiology

Predisposition drivers: Environment influences distribution



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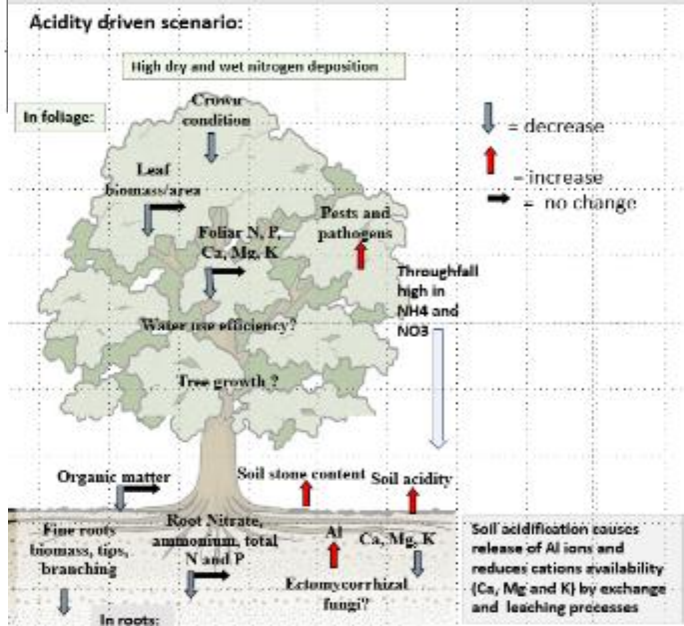
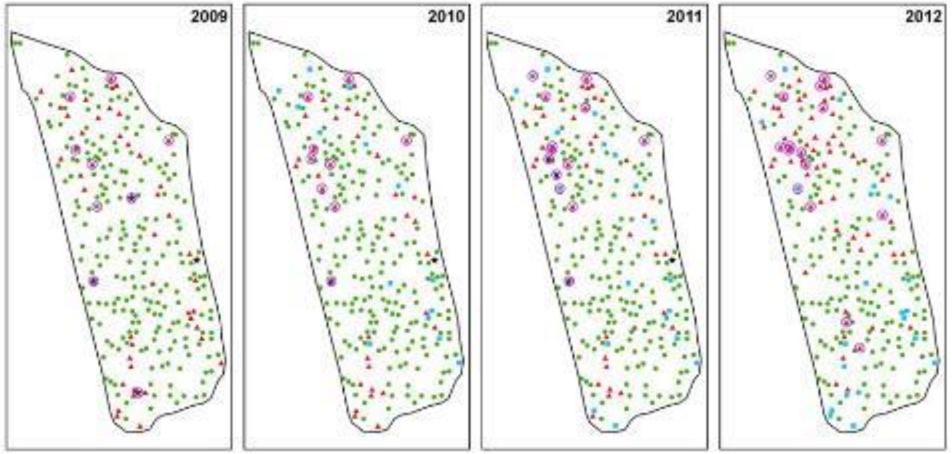
journal homepage: www.elsevier.com/locate/foreco

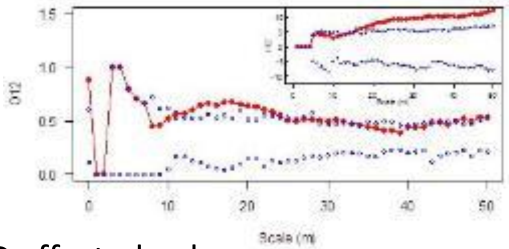
Predisposition of forests to biotic disturbance: Predicting the distribution of Acute Oak Decline using environmental factors

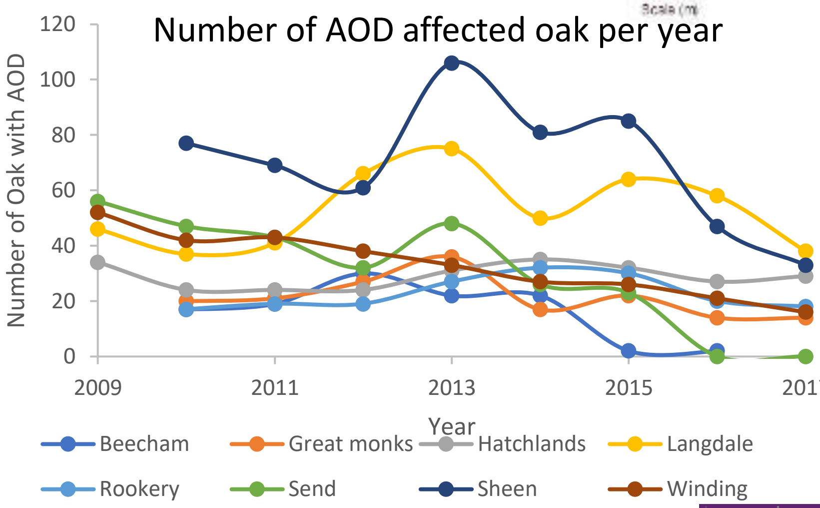
Nathan Brown[a,*], Elena Vanguelova[b], Stephen Parnell[c], Samantha Broadmeadow[b], Sandra Denman[b]

- Within site disease development
- Rate + direction of spread
- Correlations with environmental factors
- Risk mapping – landscape scale
- National & site scale









Forest Research

5. Understand how the disease works – Current research Bac-Stop

Correlations with environmental factors: Models, Testing specific factors – e.g. drought

Genetic approaches from the host aspect – Kew GWAS

Investigating practitioner attitudes and actions regarding development and implementation of AOD management practices

Gaps:

Need controlled trials for:

- Soil amelioration with chemicals and
- Synthetic rhizosphere microbiomes
- Natural soil rebalancing

Planned PhD: Natural C:N rebalancing, decompaction, rhizosphere effects

Role of *Agrilus* & host range of trees affected by AOD associated bacteria

6. Derive and carry out management research and engage in management guidance activities

General Principles: Disease management decision process / options

Preventative management

Indirect methods

Exclusion:
- Legislation - Phytosanitary regulations & Inspections
- Avoid international purchase

Awareness & keeping up to date

Monitoring – Sentinel traps & trees

Direct methods: Avoidance

Cultural:

Avoid high risk environments (risk maps and analyses)

Use genetically resistant stock

Apply good silvicultural practices:
- Sanitation
- Stand densities
- Avoid decompaction
- Ensure optimal growth conditions
- Monitor tree health and pest levels

BCA's / Synthetic microbiome

Boost tree health proactively

Suggested new research

Protection

Chemical?

Reactive management (therapy / curative actions)

Chemical

.....cides/antibiotics sprays & injections – very damaging non-target effects

BCA's / Synthetic microbiome

Single agent BCA, hypovirulent viruses, endophytes. Partial control, environmental conditions, reapplications, single organisms, lose efficacy, resistance

Native – manipulated microbiomes - rebalance disturbed microbiomes, can improve host own defence & fitness, as well as counter pathogenic action

Cultural

Felling & thinning

Natural amelioration of environment

Mixed plantings

Pest: *Agrilus*: Trapping, relocating

Novel technologies

Genomic molecules – RNAi-interference and blockage of pathogen signals

IPM = Integrated Pest Management

Disease management Conclusions

Trees are:

- long lived, hardy
- grown for a wide variety of reasons (crop, environmental protection / improvement; biodiversity, amenity)
- Have multiple parts, don't only suffer from a single infliction

Management decisions - many considerations to take into account

There will be costs (not only financial, but environmental, social, economic and unknown?) to management practices

No single solution to management for improved health, can't be prescriptive, management is an evolution

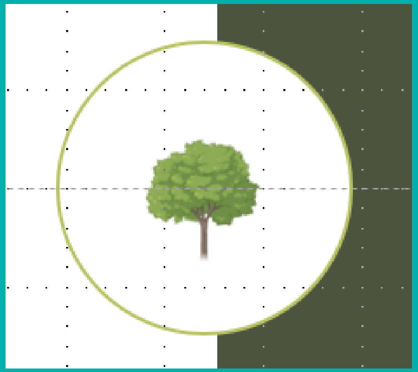
AOD research has delivered 1-5 and is busy with stages 5-6

How can researchers help?

- Present information (steps 1-5)
- Keep up with new technologies, try new things – time, cost, many unknowns, risks
- Can be supportive

How can practitioners help?

- Be involved
- Talk to the researchers, join discussion groups, share ideas and experiences



Let's help each other to help trees help themselves. Together we can make things better.

With thanks to our funders, supporters, critics, and fellow scientists who help move the frontiers forward

UKRI Biotechnology and Biological Sciences Research Council | The Scottish Government | UKRI Natural Environment Research Council | Department for Environment Food & Rural Affairs | Forest Research | Prifysgol Bangor University | 1872 Prifysgol Aberystwyth University | UWE Bristol University of the West of England | Rothamsted Research

6. Derive and carry out management research and engage in management guidance activities

General Principles: Disease management decision process / options

Reactive/curative management

Cultural: Help trees help themselves

Ameliorate environments

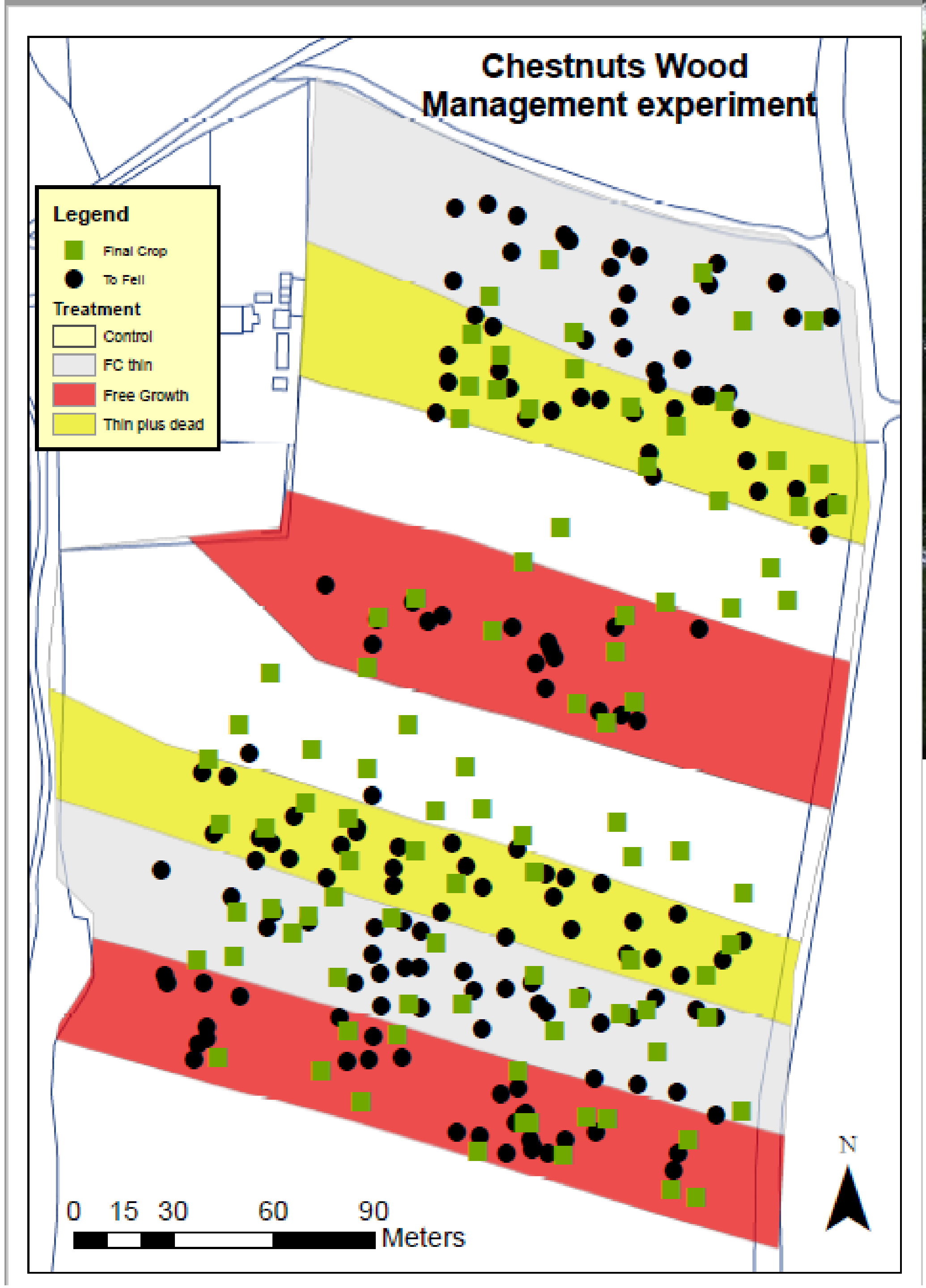
- Improve drainage
- Air circulation - spacing
- Soil decompaction *
- Soil nutritional rebalancing – natural or fertilisers *
- Thinning – reduce competition dependent upon environment and management objectives

Apply sanitation – lower inoculum levels, prevent spread (beetles and inoculum)

- Fell infected trees, burn/disinfect
- Sweep up leaves, compost
- Disinfect tools
- Boot & vehicle biosecurity
- Avoid transporting firewood

What if the bacteria are everywhere?

Forest Research



Armillaria thinning trial

- No model plant
- Enough trees for statistical replication
- Time taken until results

Disease management decision process tree

Preventative management

Indirect methods

Exclusion:
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Awareness & keeping up to date

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Direct methods: **Avoidance**

Cultural

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