Castellana R. (Riviera Gardens), Tabone E. (Inra Antibes), Gigleux C. (Fredon Corse), Massimo Cristofaro (Enea Italy) & Pietra H. (Sauvons Nos Palmiers): Predictive diffusion of palms pests *Rhynchophorus ferrugineus* & *Paysandisia archon* and perspectives about biological control (Eunops 2019)

Journal of Pest Science
https://doi.org/10.1007/s10340-018-1044-3

REVIEW

Palmageddon: the wasting of ornamental palms by invasive palm weevils, *Rhynchophorus* spp.

Ivan Milosavljević[1] · Hamadttu A. F. El-Shafie[2] · Jose Romeno Faleiro[3] · Christina D. Hoddle[1] · Michael Lewis[1,4] · Mark S. Hoddle[1,4]

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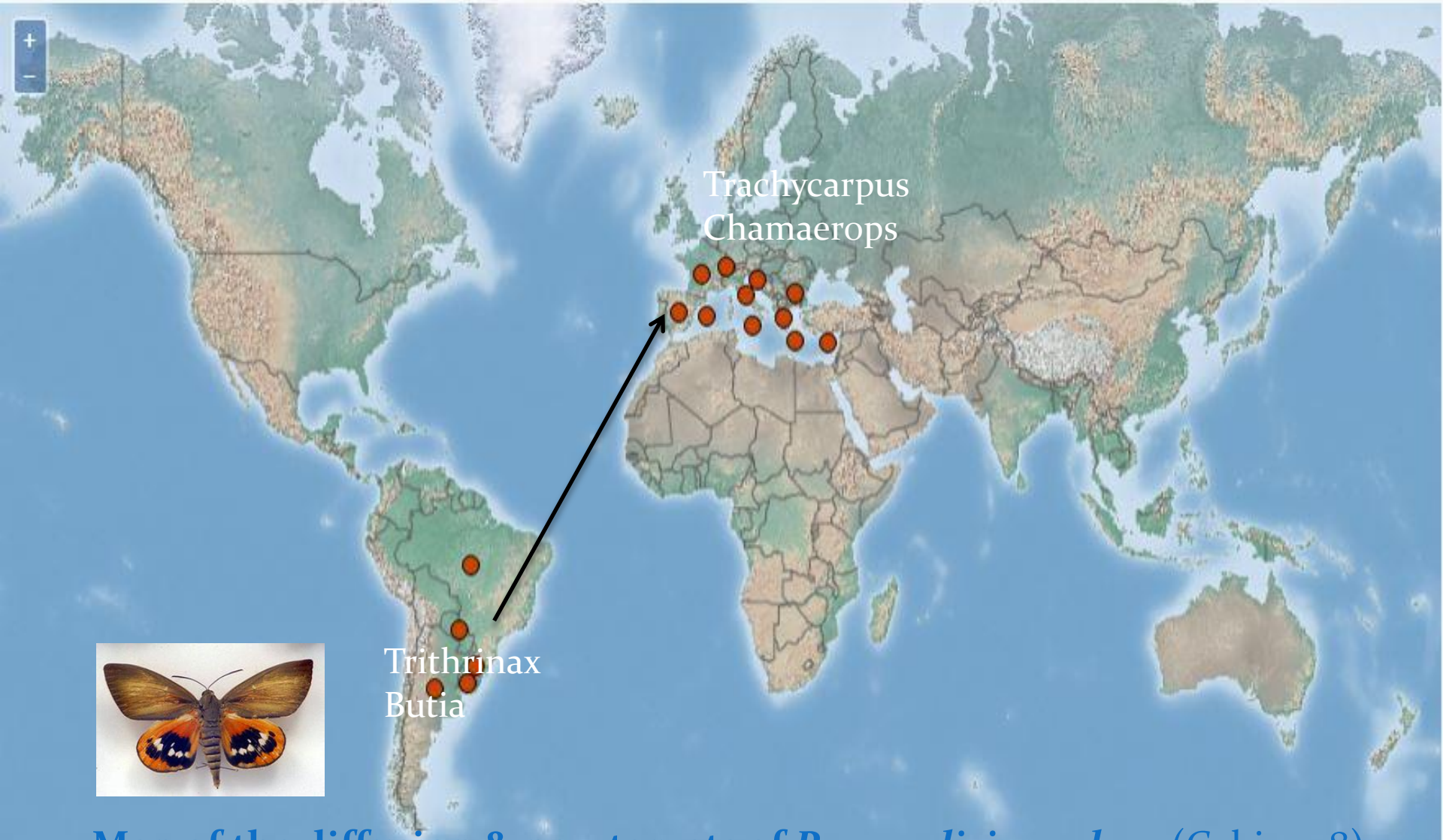
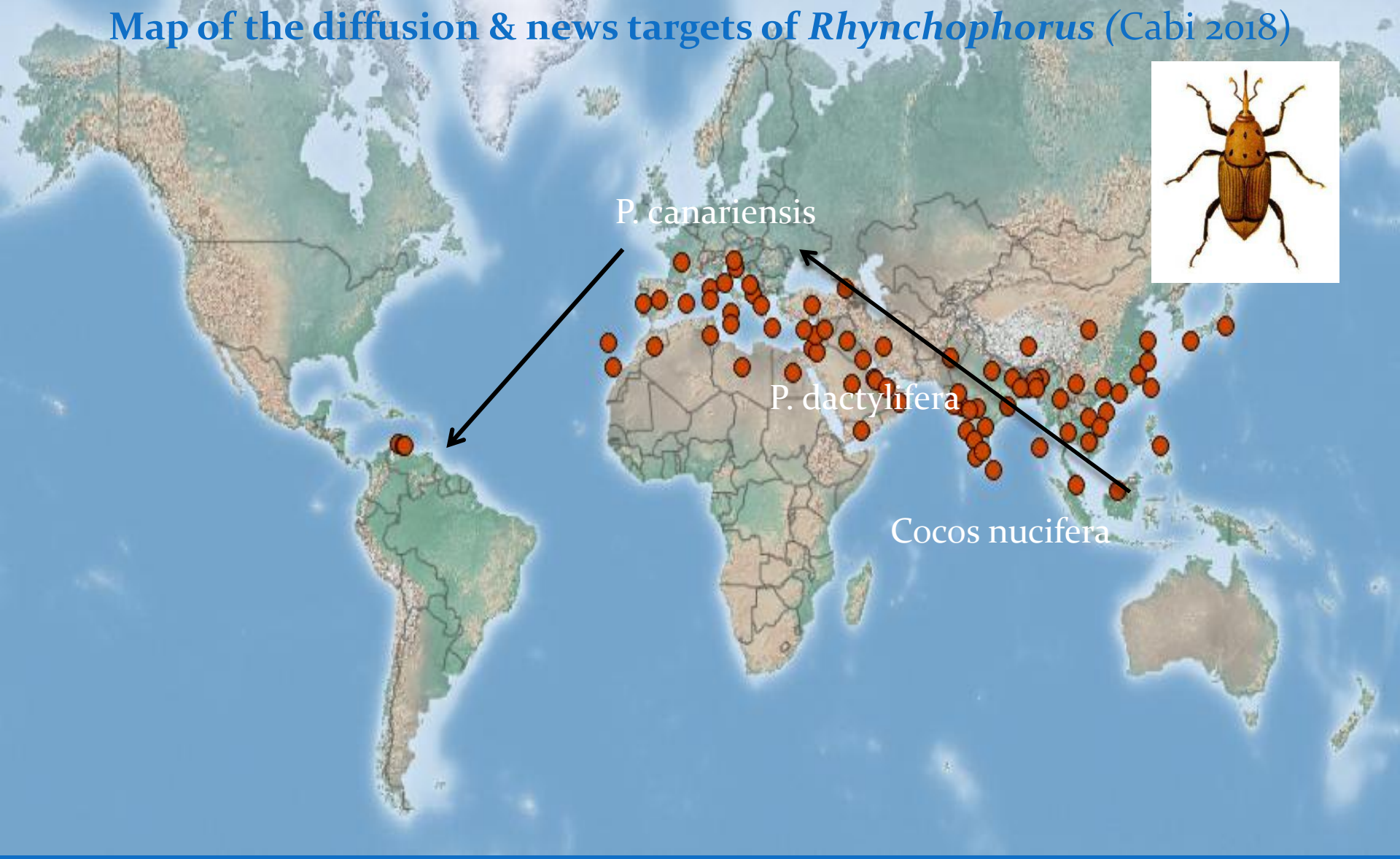
SUMMARY
This communication will treat about about our observations concerning the wasting of ornamental palms by PA & RPW (Part 1) & their impact on wild populations of these palms (Part 2). The third part will treat about biological control possibilities.

Actually more than 35 species of palms are infested since introduction of *Rhynchophorus ferrugineus* & *Paysandisia Archon*, according to the observations of our network of French & Italian Botanical Collections & Ornamental Palms



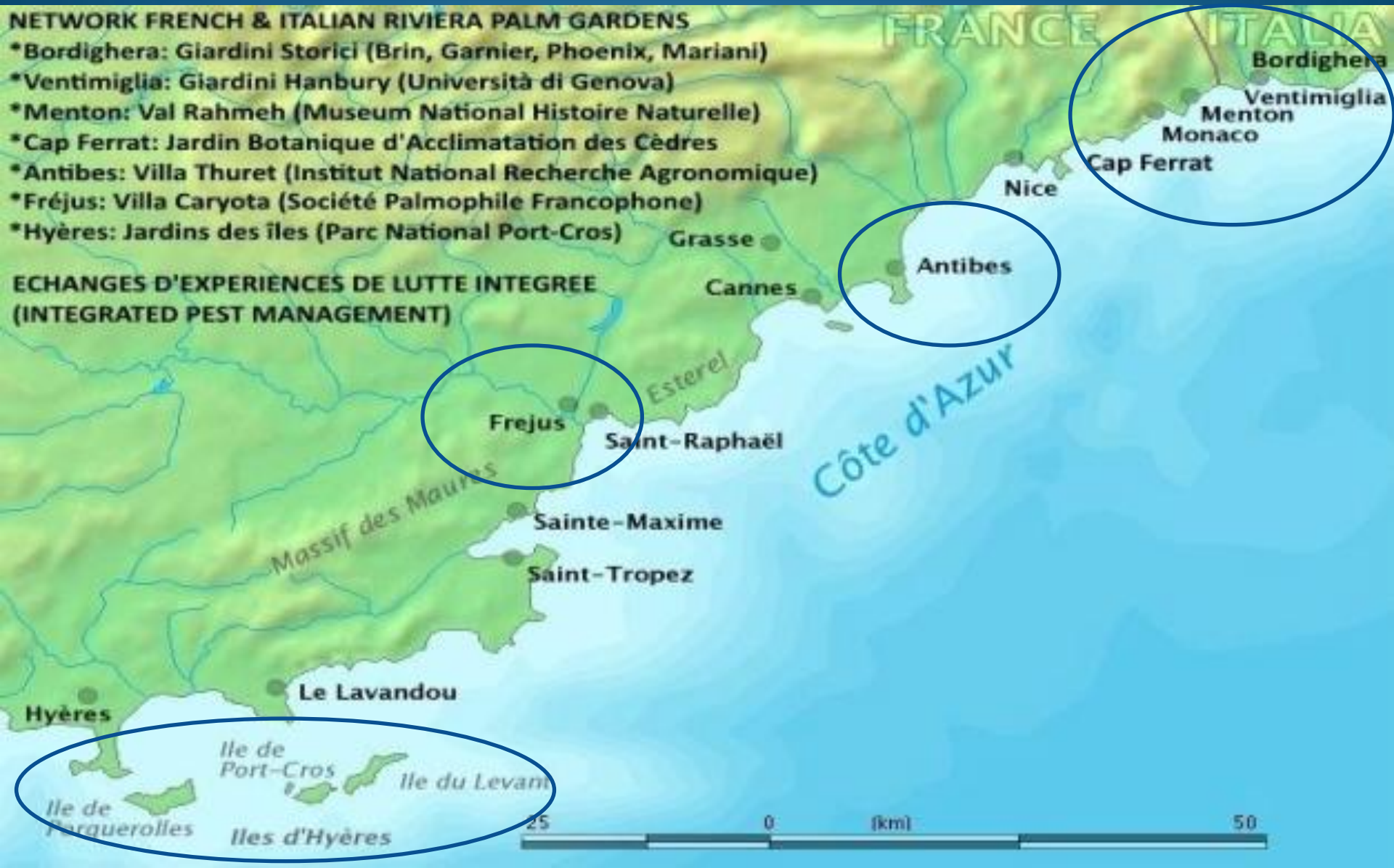
Map of the diffusion & new targets of *Paysandisia archon* (Cabi 2018)

Map of the diffusion & news targets of *Rhynchophorus* (Cabi 2018)



Predictive diffusion of these pests may also concern in the future wild populations of palms in south America and Africa, according to the observations of our network

PART 1.MATERIALS & METHODS: we are observing since 2008 the diversification of ornamental palm species infested by PA & RPW in our network of Botanical Gardens



1.RESULTS: Our observations concern ca 100 ornamental palms infestation by *Paysandisia archon* & *Rhynchophorus ferrugineus* listed here by species (non infested species are listed in red)

	PA	RPW	PA or RPW
*ACOELORRAPHE WRIGHTII	X		
*ALLAGOPTERA ARENARIA			
*ARENGA ENGLERI	X		
*BRAHEA	X		
aculeata,	X		
armata,	X	X	
dulcis,	X		
calcarea			
decumbens			
edulis	X	X	
*BUTIA			
capitata			X
catanirensis			
odorata			
yatay			X
*CHAMAEDOREA			
glaucifolia			
metallica			
radicalis			
seifriizii			
*CHAMAEROPS HUMILIS	X	X	
REFERENCES	Jacon 2017	Longo 2011	Others Ref.

Botanical Gardens

Ornamental Palms

1.RESULTS: a great part of the ornamental palms existing in Mediteranean area may be infested in the same timeby *Paysandisia* & *Rhynchophorus*

	PA	RPW	PA or RPW
*CARYOTA MAXIMA HIMALAYA			
*HOWEA FORSTERIANA	X	X	
*JUBAEA CHILENSIS	X	X	
*LIVISTONA			
australis,	X		
chinensis,	X	X	
decora decipiens,	X		
drudei			
nitida			
saribus	X		
*NANNORROHOPS ARABICA	X		
*PHOENIX			
canariensis		X	
dactylifera	X	X	
reclinata,	X		
robellini,	X		
sylvestris			X
theophrasti	X		
*RHAPIS			
excelsa			
humilis			
multifida			
Références	Jacon 2017	Longo 2011	Others

1.RESULTS: Our observations about infestation of ornamental palms show an important diversification of palm pests targets

	PA	RPW	PA or RPW
*SABAL		X (?)	
bermudana,	X		
causiarum			
domingensis			
etonia			
mauritiiformis,	X		
mexicana			X
minor,	X		
palmetto	X		
rosei			
texana			
uresana			
yapa			
*SERENAO REPENS	X		
*SYAGRUS ROMANZOFFIANA	X		
*TRACHYCARPUS			
fortunei	X	X	
10 sp	X		
5 sp			
*TRITHRINAX			
acanthocoma	X		
campestris			X
*WASHINGTONIA			
filifera		X	
robusta		X	
Références	Jacon 2017	Longo 2011	Others

1.RESULTS: Diversification of *Paysandisia archon* & *Rhynchophorus ferrugineus* targets appears clearly when ornamental palms by are listed by genere

S/FAMILY	TRIBU	S/TRIBU	GENERE	NB SP
ARECOIDEAE	Areceae	Linospadicinae	Howea	1/1
	Caryoteae		Arenga Caryota	1/1 0/1
	Cocoeae	Butiinae	Allagoptera Butia Syagrus Jubaea	0/1 2/4 1/1 1/1
CEROXYLOIDEAE	Hyophorbeae		Chamaedorea	0/4
CORYPHOIDEAE	Chuniophoeniceae		Nannorrhops	1/1
	Corypheae	Thrinacinae	Acoelorrhaphe Brahea Chamaerops Trachycarpus Trithrinax Rhapis	1/1 4/6 1/1 10/15 2/2 0/3
		Livistoninae	Acoelorraphe Brahea Livistona Serenao Washingtonia	1/1 4/6 4/6 1/1 2/2
		Sabalinae	Sabal	5/12
	Phoeniceae		Phoenix	6/6

1.RESULTS: Our observations about infestation are listed here concerning targets of *Paysandisia archon* versus *Rhynchophorus ferrugineus*

Brahea armata & edulis
Butia capitata & yatay
Chamaerops humilis
Howea fosteriana
Jubaea chilensis
Livistona chinensis

Nannorrohops arabica
Phoenix dactylifera, canariensis, sylvestris
Sabal mexicana

Serenao repens
Syagrus romanzoffiana
Trachycarpus fortunei
Trithrinax campestris
Washingtonia filifera & robusta

TOTAL RPW: 19 SPECIES

Acoelorraphe wrightii
Arenga engleri
Brahea aculeata, armata, dulcis, edulis

Chamaerops humilis
Howea fosteriana
Jubaea chilensis
Livistona australis, chinensis, decora (decipiens), saribus
Nannorrohops arabica
Phoenix dactylifera, reclinata, robellini, theophrasti
Sabal bermudana, mauritiiformis, minor, palmetto
Serenao repens
Syagrus romanzoffiana
Trachycarpus sp: 10 sp/15
Trithrinax acanthocoma

TOTAL PA: 35 SPECIES

PART 2. DISCUSSION. An essay of mapping the predictive distribution of Red Palm Weevil & *Paysandisia archon*

PA & RPW are infesting ca 1/3 of 100 ornamentals palms. They are also infesting wild populations of some of these palms. What about the 2500 species of palms in the word? Probability of infestation of palm hotspots by RPW crossing suitability & environment are listed here in red (fig A) and in blue (fig B) by Fiaboe et alii 2012)

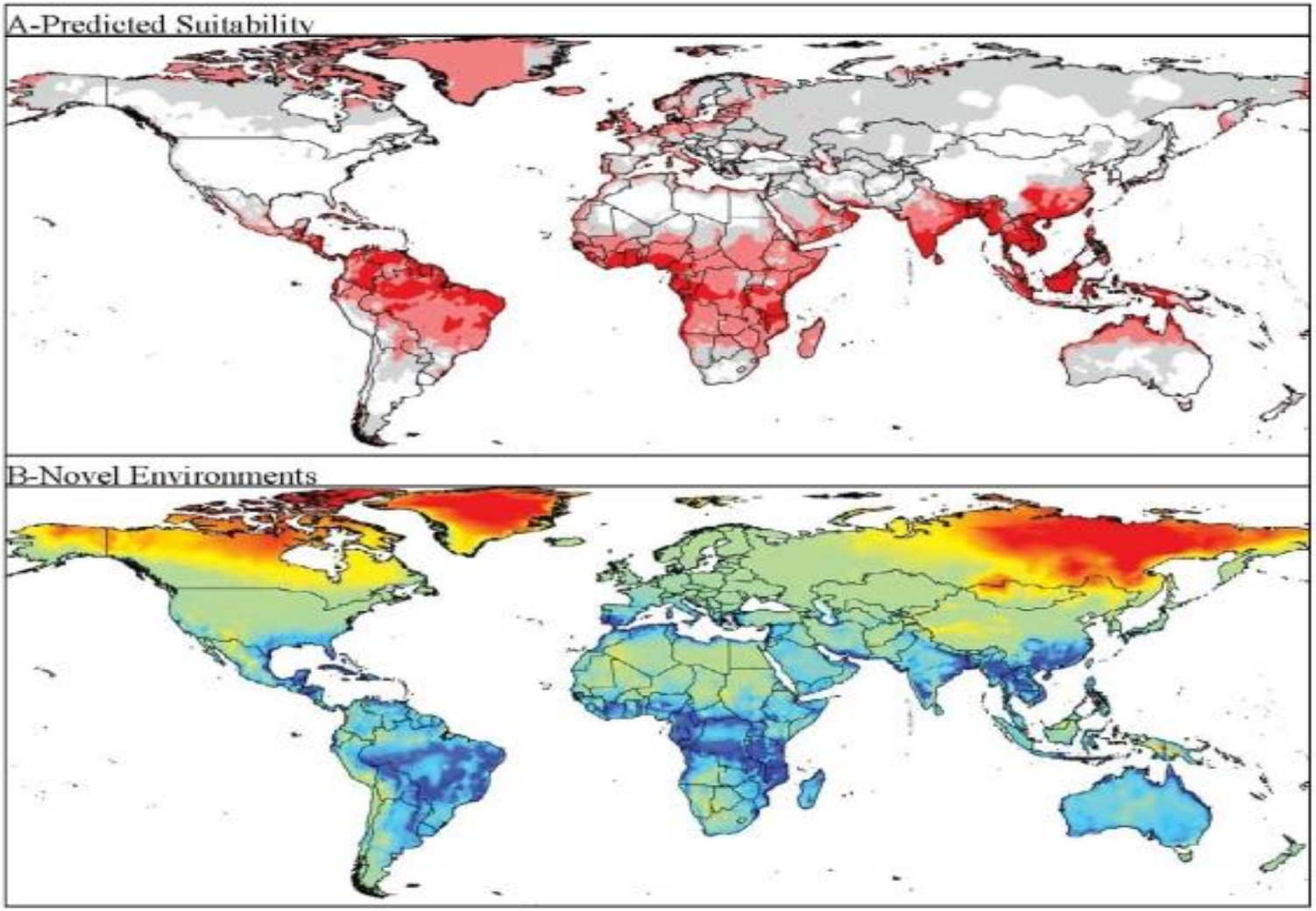
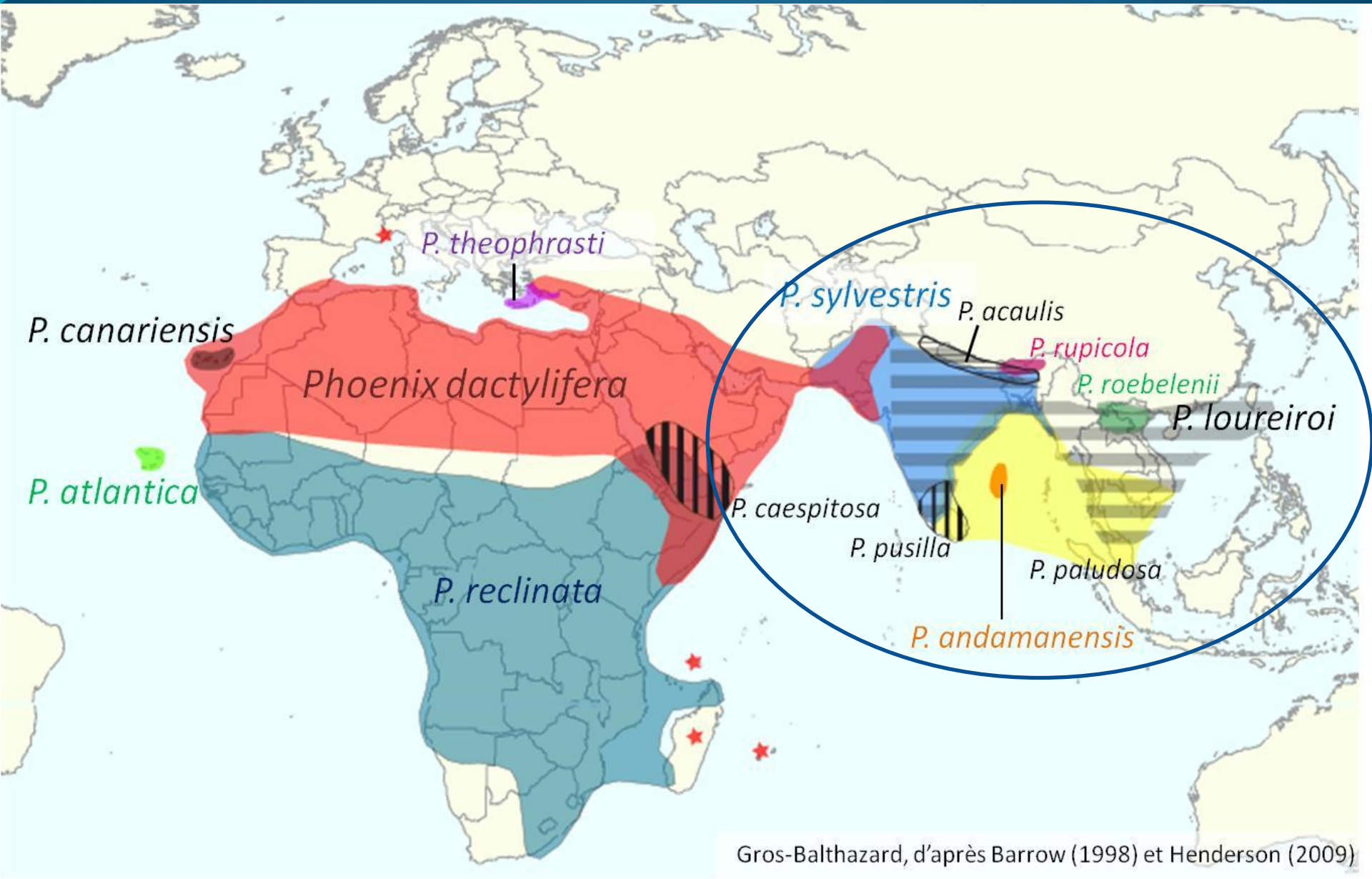


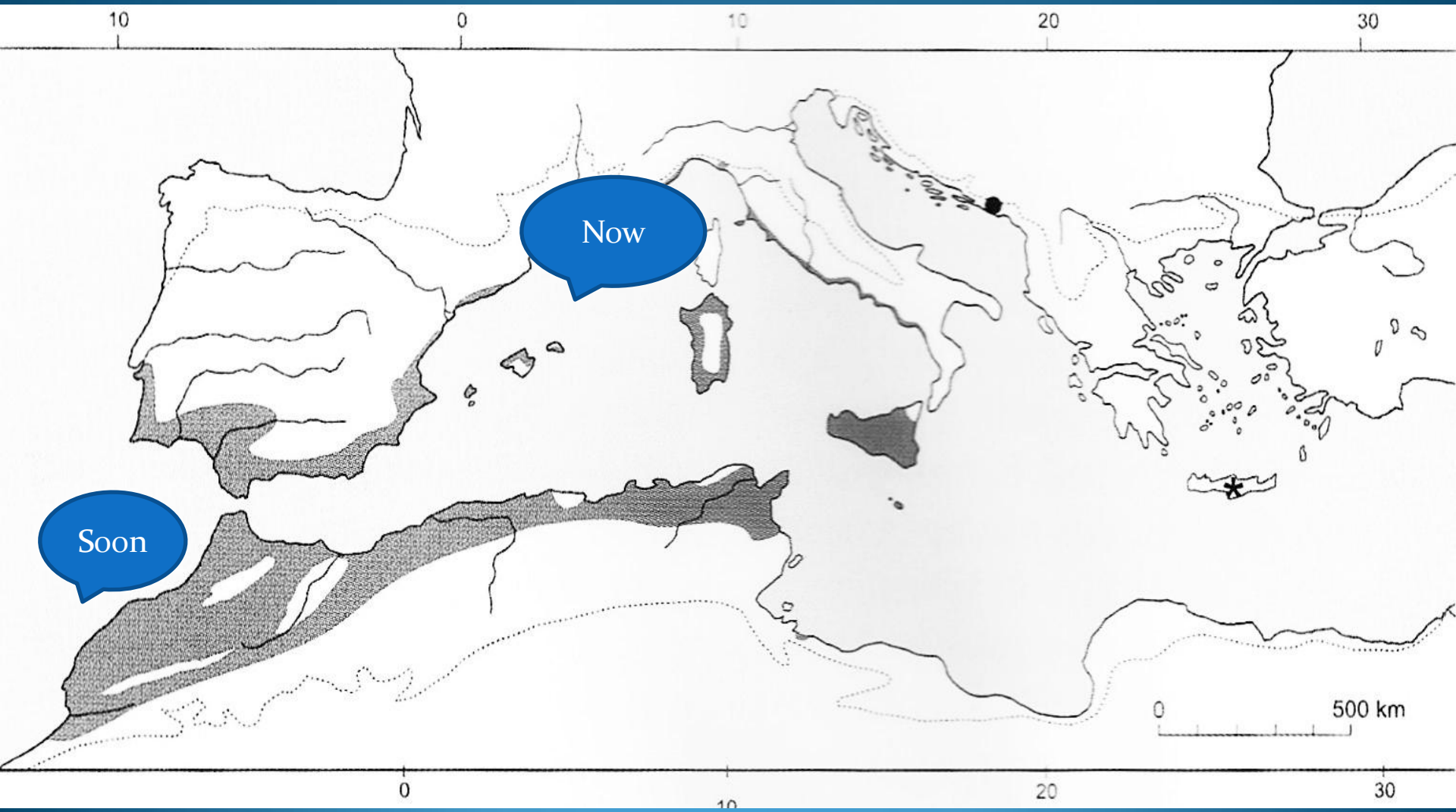
Fig. 2. Summary of global projections of ecological niche models trained based on the known occurrences of red palm weevils globally (except for the California occurrence, which was omitted from analyses). A = predicted suitability, on a ramp from white (unsuitable) to red (highly suitable). B = the degree of novelty of the environments represented, with blue indicating environments closely similar to the points of known occurrence, and red indicating environments that are widely different; model projections into regions at the latter end of this novelty scale are suspect.

2.DISCUSSION: infestation on palm area of genere Phoenix is attested in Canarian Islands and in oasis for P. Dactylifera (no data for Asia)



Gros-Balthazard, d'après Barrow (1998) et Henderson (2009)

2.DISCUSSION: infestation of Endemic Mediterranean palm *Chamaerops humilis* is only attested in European spots (for the moment...)



PART 3.CONCLUSION. Palms & Cantharophily. Pollinisation of palms by beetles may explain actual expansion of palm pests (according to Barford 2011) ?

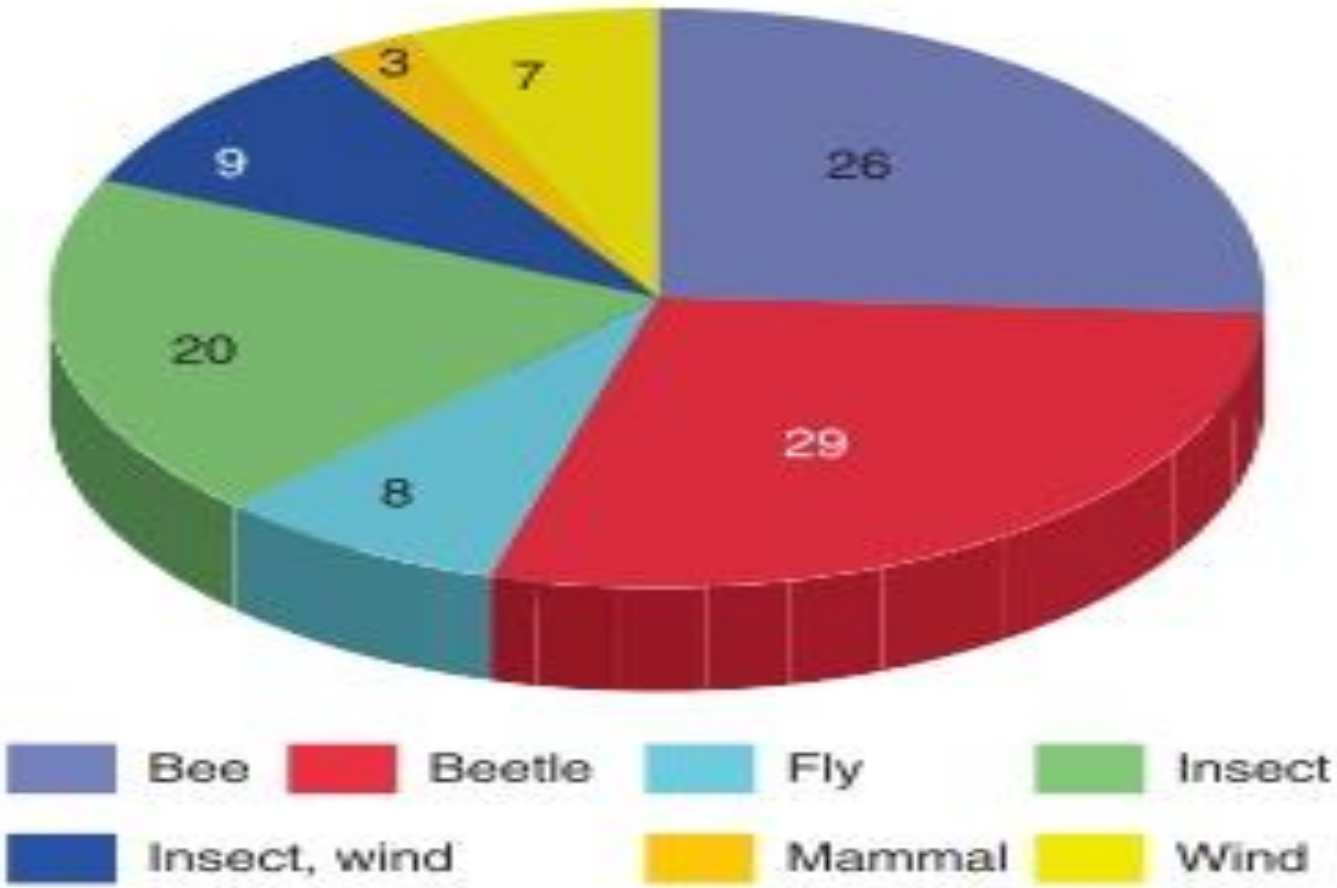


FIG. 1. A breakdown of the 77 palm species listed in the Appendix according to inferred 'most likely' pollination vector (numbers in percentages). The groups 'insect and wind' and 'insect' cover species for which the conclusion on pollination mechanism was less specific.

3.CONCLUSION. The researches associated with our French & Italian Network are concerning biological control of palm pests *Rhynchophorus ferrugineus* & *Paysandisia archon*

The strong fitness of the palm pests PA & RPW, their adaptation to new environments and climatic conditions, and the difficulties to easily detect the early symptoms of the infestation, were determining a failure of all eradication and suppression conventional control programs like IPM (Integrated Pest Management), based mainly upon the use of chemical or agronomic approaches.

We support a tripod of researches about biological control of these pests, with :
(1) Inra (Antibes) about Antagonists of PA (Oophages parasitoids)
& (2) Enea (Italy) about control of RPW by the Sterile Insect Technic (SIT).
We also try (3) to support Mass trapping (Snp & Fredon Corse) and researches about Antagonistic Entomopathogenic fungi (Snp) of RPW.

INRA SCIENCE & IMPACT

FREDON CORSE

PROGETTO PHOENIX

SNP

ENEA AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

3.CONCLUSION. Eradication conventional programs are mainly based upon the use of chemical. Researches about biological control need to be sustained.

Biological Control 77 (2014) 83–92

Contents lists available at ScienceDirect

Biological Control

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

Review

An overview on the natural enemies of *Rhynchophorus* palm weevils, with focus on *R. ferrugineus*

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3.1. Our researches about antagonists of *Paysandisia archon*

PALM PROTECT

Trichogramma are able to kill *Paysandisia archon* eggs (Burmeister, 1880) on Palm trees

Maurane Buradino, Bastien Cabrol, Etty Colombel and Elisabeth Tabone
INRA PACA- UEFM Laboratoire BioContrôle - Villa Thuret - 90 chemin Gustave Raymond
06160 Antibes - France

Introduction

Paysandisia archon (Lepidoptera, Castniidae) is an invasive insect from Argentina that attacks palm trees and is responsible for economic losses of millions of euros around the Mediterranean region. Palm Protect aims to find new treatments to control this pest that are less toxic to human health and the environment.

The Unity Entomology and Mediterranean Forest of the French Institute of Agronomy (INRA) has been evaluating whether egg parasitoids are able to parasitize *P. archon* eggs. The egg is the most accessible stage of development, attacking the egg would reduce damage caused by the endophytophagous larvae.

Methods

Eggs of *P.* archon were exposed to different strains of Trichogramma in either tubes or in mesocosms (palms). Experiments were conducted under controlled conditions (temperature, humidity, day length).

In tubes eggs were incubated for 24 or 48 hours at a ratio of 1 egg to 5 10, or 15 female parasitoids to determine the attractiveness of eggs to parasitoids and the impact of egg:female ratio.

In the mesocosm, 10 or 20 eggs were placed around the stipe of potted palms and exposed for 7 days to 1000 or 5000 Trichogramma to determine the attractiveness and ability of parasitoids to locate *P. archon* eggs.

At the end of the incubation periods eggs were assessed for parasitism and viability (abortion) and results are expressed as the global efficiency (parasitism + abortion) of Trichogramma.

E F
F E *Entomologie Faunistique – Faunistic Entomology* 2015 **68**, 185-191

Un parasitoïde oophage pour contrôler *Paysandisia archon* (Burmeister, 1880) (Lepidoptera : Castniidae) : Le Trichogramme. Premier succès en laboratoire

Emma Ferrero[(1)], Annabel Fourcade[(1)], Etty Colombel[(1)], Marine Venard[(1)], Maurane Buradino[(1)], Laurence Ollivier[(2)] & Elisabeth Tabone*[(1)]

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UNIVERSITÉ DE BOURGOGNE

BIOLOGIE DES ORGANISMES ET DES POPULATIONS

Université de Bourgogne
Master Sciences, Technologies, Santé_ Environnement-Terre-Evolution
Spécialité Biologie des Organismes et des Populations
Rapport de stage de Master deuxième année, Année Universitaire 2012-2013

Etude d'un hôte de substitution dans le cadre d'un programme de lutte biologique contre *Paysandisia archon*, ravageur du palmier

Par : Marion Salignon
Réalisé sous la direction d'Elisabeth TABONE (Ingénieure de recherche INRA), Maurane BURADINO (Assistante ingénieure INRA)
INRA, site de la Villa Thuret,
Laboratoire Biocontrôle

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

3.2. Our researches about Biological Control of *Rhynchophorus ferrugineus* by SIT

Atti Accademia Nazionale Italiana di Entomologia
Anno LXI, 2013: 239-246

CONTROLLO DEL PUNTERUOLO ROSSO MEDIANTE LA TECNICA DEL MASCHIO STERILE (SIT): UTOPIA O REALTÀ?

SERGIO MUSMECI (*) - MASSIMO CRISTOFARO (*) - SILVIA ARNONE (*) - RAFFAELE SASSO (*)
STEFANIA BACCARO (**) - ANGELO PASQUALI (**) - SILVIA CATARCI (***)

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(**) *ENEA, UTTMAT, CR Casaccia, Via Anguillarese 301, 00123 Roma.*
(***) *BBCA-onlus, Via del Bosco 10, Sacrofano (RM).*

Lettura tenuta durante la Tavola Rotonda "Il punteruolo rosso delle palme: nuove acquisizioni e possibilità di controllo demografico". Seduta pubblica dell'Accademia - Firenze, 15 novembre 2013.

RPW Conference- Jeddah – Saudi Arabia- March 15-18, 2013

Mating Behavior bioassays in an Integrated SIT Project for the Control of the Red Palm Weevil in Italy

IAEA International Atomic Energy Agency *Atoms For Peace*

Technical Project 15804 (2009 – 2013) 'Laboratory and Confined-Field Assessments for the Feasibility of an Integrated SIT Project for the Control of the Red Palm Weevil in Italy'

Sapienza Rome University FARI project: Bioinformatics, molecular ecology and invasive species: in silico mining of SSR from 454 genomic libraries (FARI C26I10SBMC/2010)

M. Cristofaro, S. Arnone, R. Sasso, S. Musmeci, A. Lai, A. La Marca, S. Belvedere, A. De Biase, S. Catarci, A. F. Inghilesi, G. Mazza, R. Cervo

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development · BBCA · Università degli Studi Firenze · Sapienza Università di Roma

Entomology 2010 - ESA 58TH Annual Meeting - December 12-15, 2010. San Diego, CA

Preliminary studies of the biological cycle of the Red Palm Weevil (*Rhynchophorus ferrugineus*) in Italy, aimed to the application of Sterile Insect Tecnique

Cristofaro M., Colazza S., De Biase A., Belvedere S., Arnone S, Di Ilio V., Isidoro N., Musmeci S., Sasso R., Barlattani M.

3.3. Our researches about Mass trapping & Antagonists of RPW, Entomopathogenic fungi (EPF)

BONNES PRATIQUES EN MATIERE DE PIEGEAGE A DESTINATION DES COLLECTIVITES TERRITORIALES

Robert Castellana (Projet Phoenix & Riviera Gardens)
Catherine Gigleux (Fredon Corse) Hervé Pietra (SNP)

Rédigé en collaboration avec un collectif d'acteurs publics (jardins botaniques, associations & collectivités territoriales), ce document vise à faire le point sur les expériences de piégeage du charançon des palmiers, *Rhynchophorus ferrugineus*, actuellement en cours sur la Riviera franco-italienne et en Corse.

Universitat d'Alacant
Universidad de Alicante

Our botanical gardens (Phoenix Project), Snp & Fredon Corse actually support mass trapping experiences, in association with researches about aggregative pheromones, sexual confusion & infested traps using entomopathogenic fungi (EPF). Investigations about EPF mainly concern Beauveria bassiana, Metarhizium anisopliae, Paecilomyces sp & Lecanicillium. Mass trapping is also part of the SIT strategy.

Informations about our meetings, partnerships, links & publications

Phoenix Project web site: listephoenix.com

EUNOPS 2008 & 2010 & PHOENIX PROJECT
Pintaud J.-C. & alii. Geometric morphometry of leaf apices as a taxonomic and phenotyping tool in *Phoenix*.
Castellana R. Distribution and ecology of *Phoenix theophrasti* in Egean region.
Lecoustre R. & alii. Modelling and Simulating the Architecture and Growth of Arecaceae (Mocaf Phoenix research network).

Riviera gardens website: sauvonsnospalmiers.fr

MONACO 2015-2017 & IPM
Our Botanical networks Riviera (Palms) Gardens & Phoenix Project organize annuals meetings about palms pests in French & Italian Riviera with support of Principate of Monaco
INRA 2012-2019
Our french scientific partner is involved in European program Palm Protect (2012-2014) & Regional program (PACA) BioPalme (2018-2019)
ENEA 2010-2019
Our italian scientific partner is involved in application of Sterile Insect Technique (SIT) on Red Palm Weevil (*Rhynchophorus ferrugineus*)
MOROCCO 2019
Our network recently participate at the 11th National Congress of the Plant Protection Moroccan Association (AMPP- Rabat)

Bibliography

Ivan Milosavljević, Hamadttu A. F. El-Shafie, Jose Romeno Faleiro, Christina D. Hoddle, Michael Lewis, Mark S. Hoddle 2018. Palmageddon: the wasting of ornamental palms by invasive palm weevils, Rhynchophorus spp. Journal of Pest Science

Mazza et alii 2014. An overview on the natural enemies of Rhynchophorus palm weevils, with focus on R. ferrugineus. Biological Control 77 (2014) 83–92

Fiaboe et al.2012. Predicting the Potential Worldwide Distribution of the Red Palm Weevil Rhynchophorus ferrugineus (Olivier) (Coleoptera: Curculionidae) using Ecological Niche Modeling. Florida Entomologist 95(3) September 2012

Barford & alii 2011.Twenty-five years of progress in understanding pollination mechanisms in palms (Arecaceae). Annals of Botany 108: 1503–1516, 2011

EUNOPS