# Invasive Species Denialism and the Future of Invasion Management


Dan Simberloff
University of Tennessee











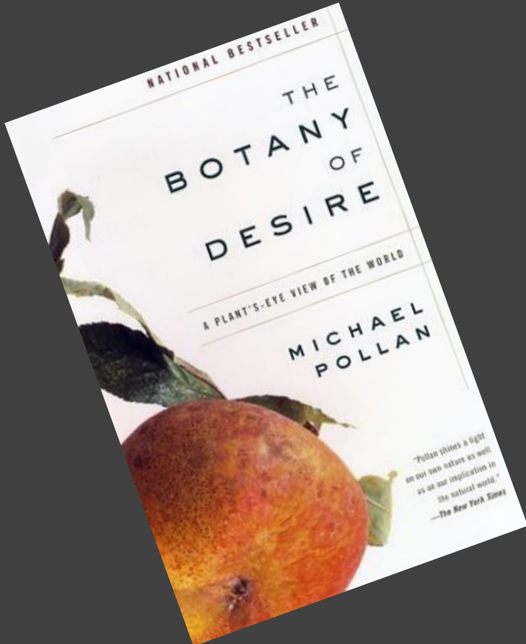

Philip Pauly

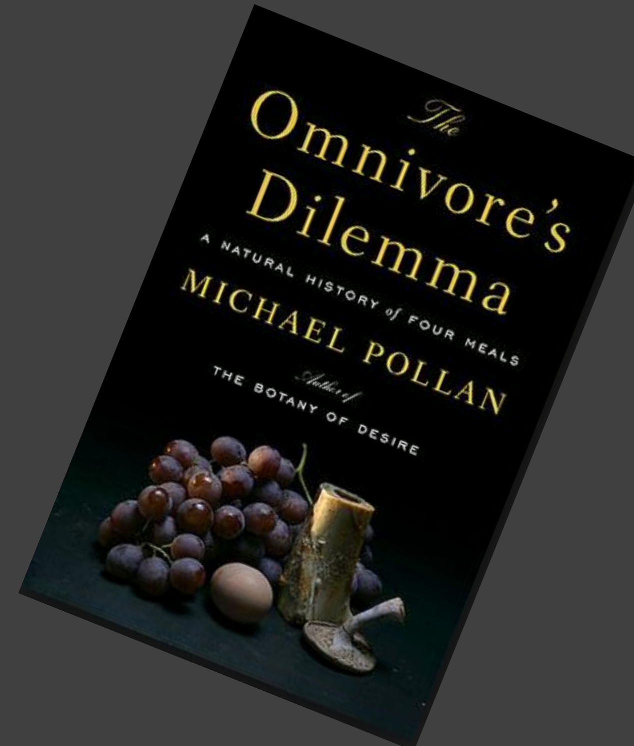
1950-2008

1996



**Figure 1.** *Japanese cherry trees in flames near Agriculture Department greenhouses on the Washington Monument grounds, 28 January 1910. (Courtesy of the National Agricultural Library.)*

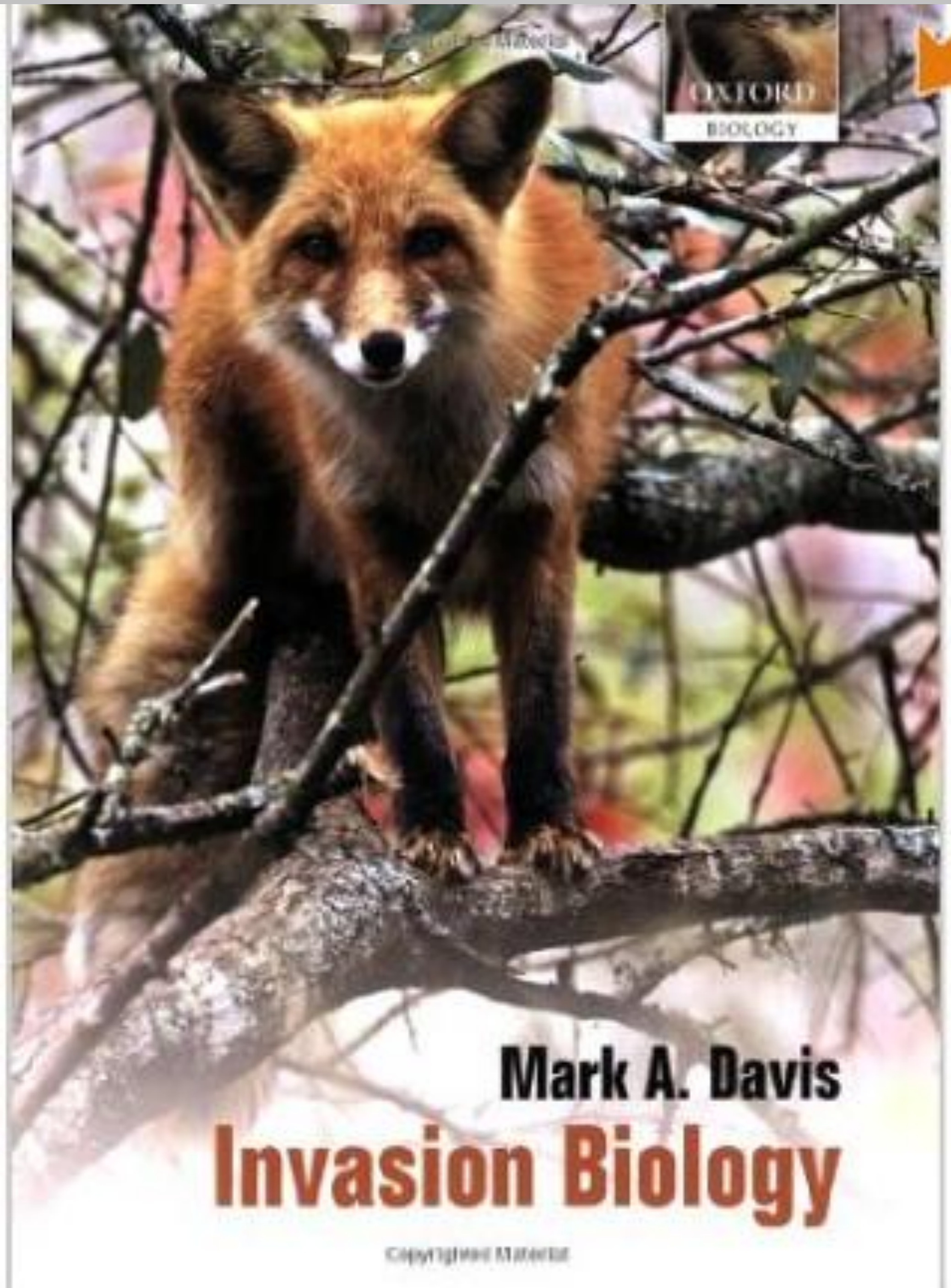



“The ‘natural garden’ movement has all but seized control of official garden taste in this country. [It] is decreed that the ‘new American garden’ is henceforth a place that …grants citizenship exclusively to native plants (any immigrant to be treated as ‘flora non grata’ with ‘invasive aliens’ subject to deportation).” – M Pollan, 1994

“Am I implying that natural gardening in America is a **crypto-Fascist movement**? I hope not. I mention the historical precedent partly to suggest that the ‘new American garden’ is neither as new nor as American as its proponents would have us think.” – M Pollan, 1994

“The German example also suggests we would do well to beware of ideology in the garden masquerading as science. It’s **hard to believe that there is nothing more than scientific concern about invasive species** behind the current fashion for natural gardening and native plants in America – not when our national politics are rife with anxieties about immigration and isolationist sentiment.” – M Pollan, 1994




2009

Mark
Davis

Emma
Marris


Nature, 2009

# The end of the invasion?

**Invasion Biology**
by Mark A. Davis
Oxford University Press: 2009. 288 pp. $55

Ascension Island in the South Atlantic Ocean is a good example of the changes that invasive species can wreak. Its volcanic mountain tops once hosted a monotonous carpet of ferns. But

foothold only by finding a vacant niche or by throwing out another species.

Niche theory gives rise to the diversity-invasibility hypothesis, which posits that the more species there are in an ecosystem, the more niches will be filled and the harder it will be for a new species to become established.

But the evidence does not bear this out.

2009

# Correspondence

*Nature* **460**, 324 (16 July 2009) | doi:10.1038/460324b; Published online 15 July 2009

## Invasion biology is a discipline that's too young to die

Petr Pyšek[1] & Philip E. Hulme[2]

1. Institute of Botany, Academy of Sciences of the Czech Republic, Zámek 1, 252 43 Průhonice, Czech Republic
   Email: pysek@ibot.cas.cz
2. Bio-Protection Research Centre, PO Box 84, Lincoln University 7647, Canterbury, New Zealand

Mark Davis suggests in his book *Invasion Biology* that the discipline should be reabsorbed into general community ecology, as Emma Marris reports in her Review 'The end of the invasion?' (*Nature* **459**, 327–328; 2009). In fact, invasion biology has a much wider remit than the management of a few highly invasive species. The comparison of alien and native species has contributed to a better understanding of population dynamics, ecosystem function and species evolution. The field still has much to teach us about biodiversity and ecological processes in general, and its relevance to conservation policy is growing.

Oikos 2013

# Another call for the end of invasion biology

**Loïc Valéry, Hervé Fritz and Jean-Claude Lefeuvre**

*L. Valéry (lvalery@mnhn.fr) and J.-C. Lefeuvre, Dépt d'Ecologie et de Gestion de la Biodiversité, Muséum National d'Histoire Naturelle, and URU Biodiversité et Gestion des Territoires, Univ. de Rennes 1, Bât 25 – Avenue du Général Leclerc, FR-35042 Rennes cedex, Franc – H. Fritz, Laboratoire de Biométrie et Biologie Evolutive, Univ. Lyon 1; CNRS; UMR 5558, 43 boulevard du 11 Novembre 1918, FR-69622 Villeurbanne, France.*

# A call for an end to calls for the end of invasion biology

**Daniel Simberloff and Jean R. S. Vitule**

*D. Simberloff (dsimberloff@utk.edu), Dept of Ecology and Evolutionary Biology, Univ. of Tennessee, Knoxville, TN 37996, USA. – J. R. S. Vitule, Laboratório de Ecologia e Conservação, Depto de Engenharia Ambiental, Setor de Tecnologia, Univ. Federal do Paraná, 81531, 980, Curitiba, Paraná, Brazil.*

Nature
2011

A forester engages in efforts to eradicate the velvet tree *Miconia calvescens* in Hawaii.

# Don't judge species on their origins

Conservationists should assess organisms on environmental impact rather than on whether they ar natives, argue **Mark Davis** and 18 other ecologists

Over the past few decades, 'non-native' species have been vilified for driving beloved 'native' species to extinction and generally polluting 'natural' environments. Intentionally or not, such characterizations have helped to create a pervasive bias against alien species that has been embraced by the public, conservationists, land managers and policy-makers, as well by as many scientists, throughout the world.

approaches to the conservation ment of species — approach to our fast-changing plane

The concept of nativen by the English botanist By the late 1840s, b terms native and help them disting posed a 'true' British

Over the next century,

exaggerated claims of impending harm to help convey the message that introduced species are the enemies of man and nature.

Certainly, some species introduced by humans have driven extinctions and undermined important ecological services such as clean water and timber resources. In Hawaii, for instance, avian malaria — probably introduced in the early 1900s when European settlers brought in song and game birds — has killed off more than half of the islands' native bird species. Zebra mussels (*Dreissena polymorpha*), originally native to the lakes of southeast Russia and accidentally introduced to North America in the late 1980s, have cost the US power industry and water utilities hundreds of millions (some say llions) of dollars in damage by clogging

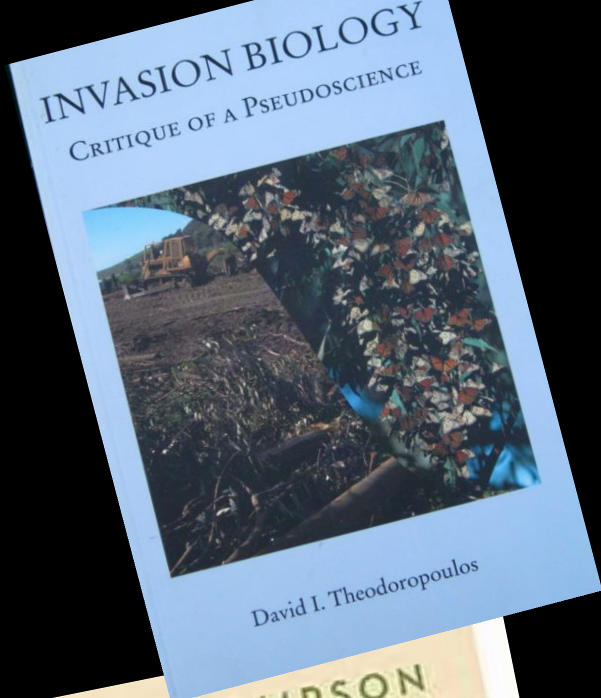
But many of the claims perception that introduc apocalyptic threat to backed by data. Take a 1998 paper[4] that greatest threat or endangered tion. Little o this clai author recer rer

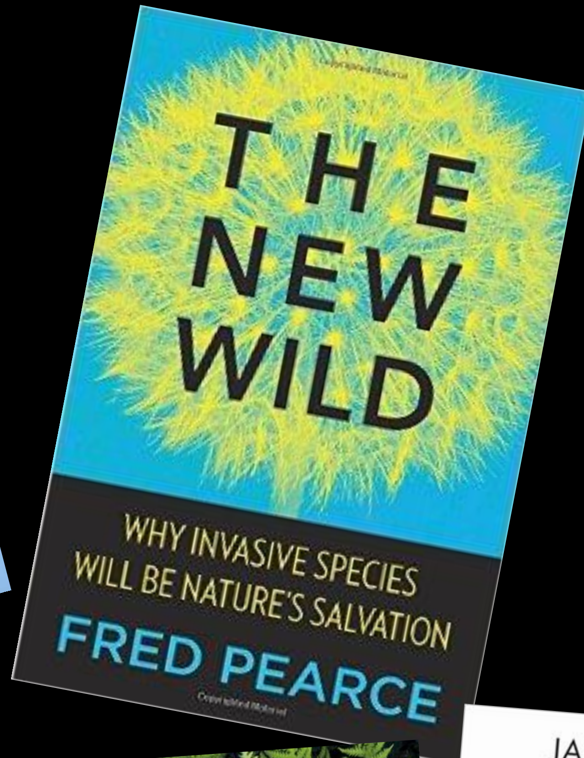
CORRESPO

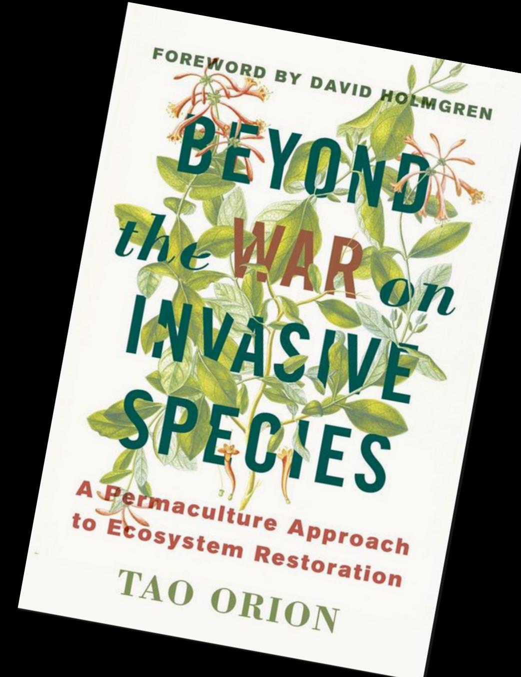
## Non-natives: 141 scientists object

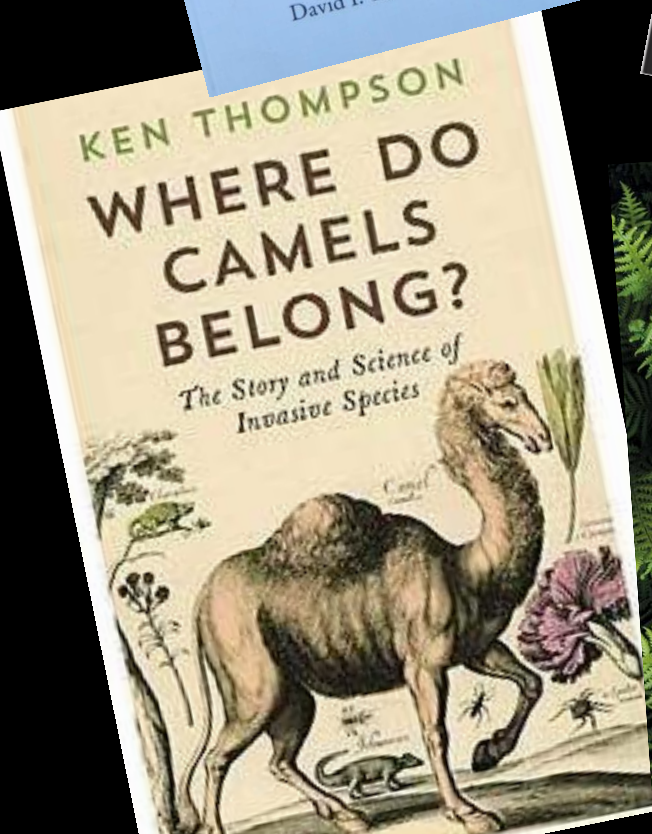
We the undersigned feel that in advocating a change in the environmental management of introduced species (Nature 474, 153–154; 2011), Mark Davis and colleagues a straw men.

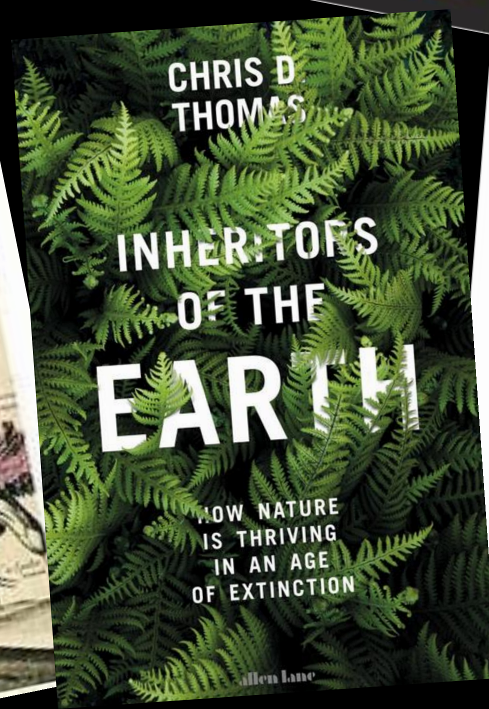
First, most co biologists a


INVASION BIOLOGY
CRITIQUE OF A PSEUDOSCIENCE
David I. Theodoropoulos

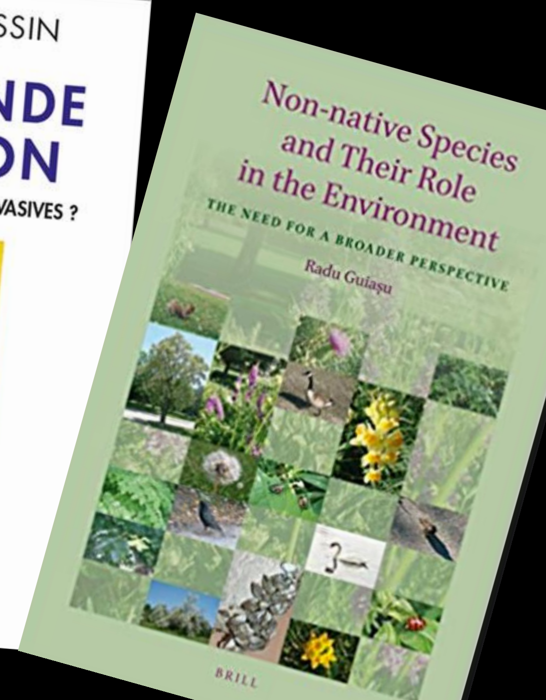

THE NEW WILD
WHY INVASIVE SPECIES WILL BE NATURE'S SALVATION
FRED PEARCE

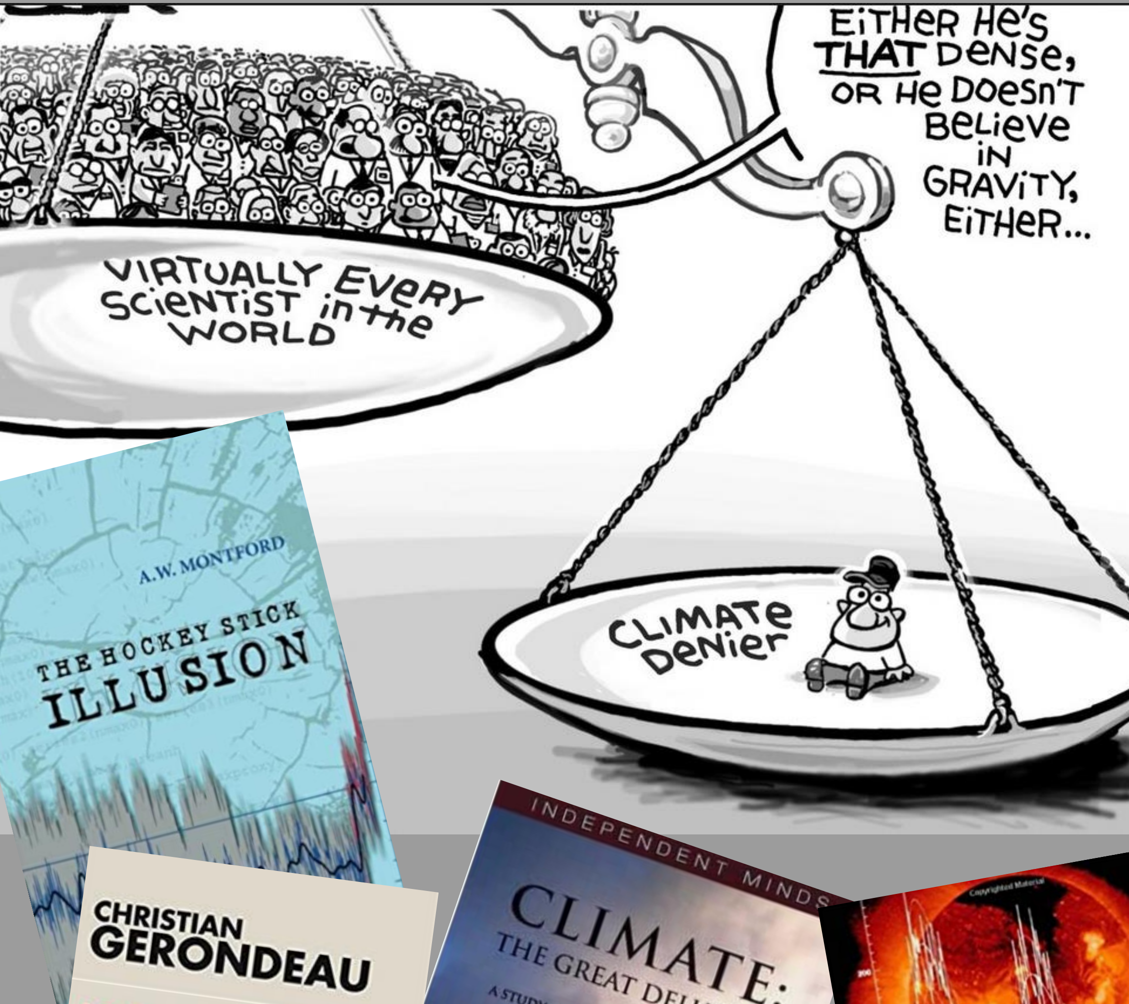

FOREWORD BY DAVID HOLMGREN
BEYOND the WAR on INVASIVE SPECIES
A Permaculture Approach to Ecosystem Restoration
TAO ORION


KEN THOMPSON
WHERE DO CAMELS BELONG?
The Story and Science of Invasive Species


CHRIS D. THOMAS
INHERITORS OF THE EARTH
HOW NATURE IS THRIVING IN AN AGE OF EXTINCTION
allen lane

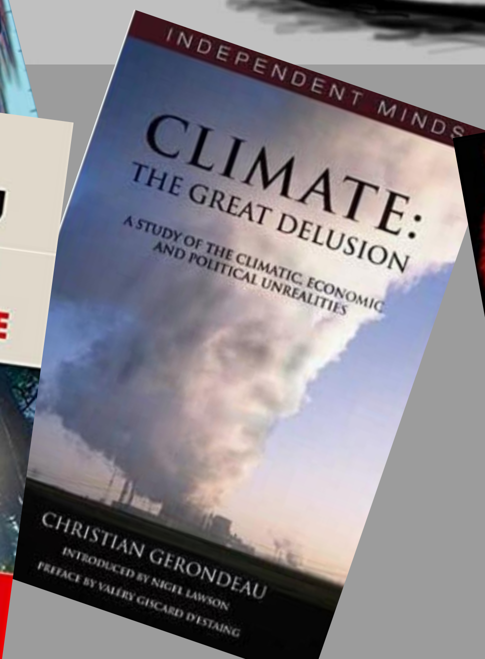

JACQUES TASSIN
LA GRANDE INVASION
QUI A PEUR DES ESPÈCES INVASIVES ?
Odile Jacob
sciences

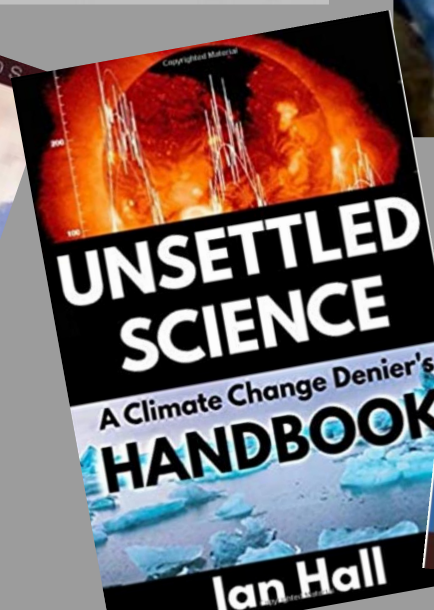

Non-native Species and Their Role in the Environment
THE NEED FOR A BROADER PERSPECTIVE
Radu Guiașu
BRILL


EITHER HE'S THAT DENSE, OR HE DOESN'T BELIEVE IN GRAVITY, EITHER...
VIRTUALLY EVERY SCIENTIST IN THE WORLD
CLIMATE DENIER
A.W. MONTFORD
THE HOCKEY STICK ILLUSION


GLOBAL WARMING IS A SOCIALIST SCAM

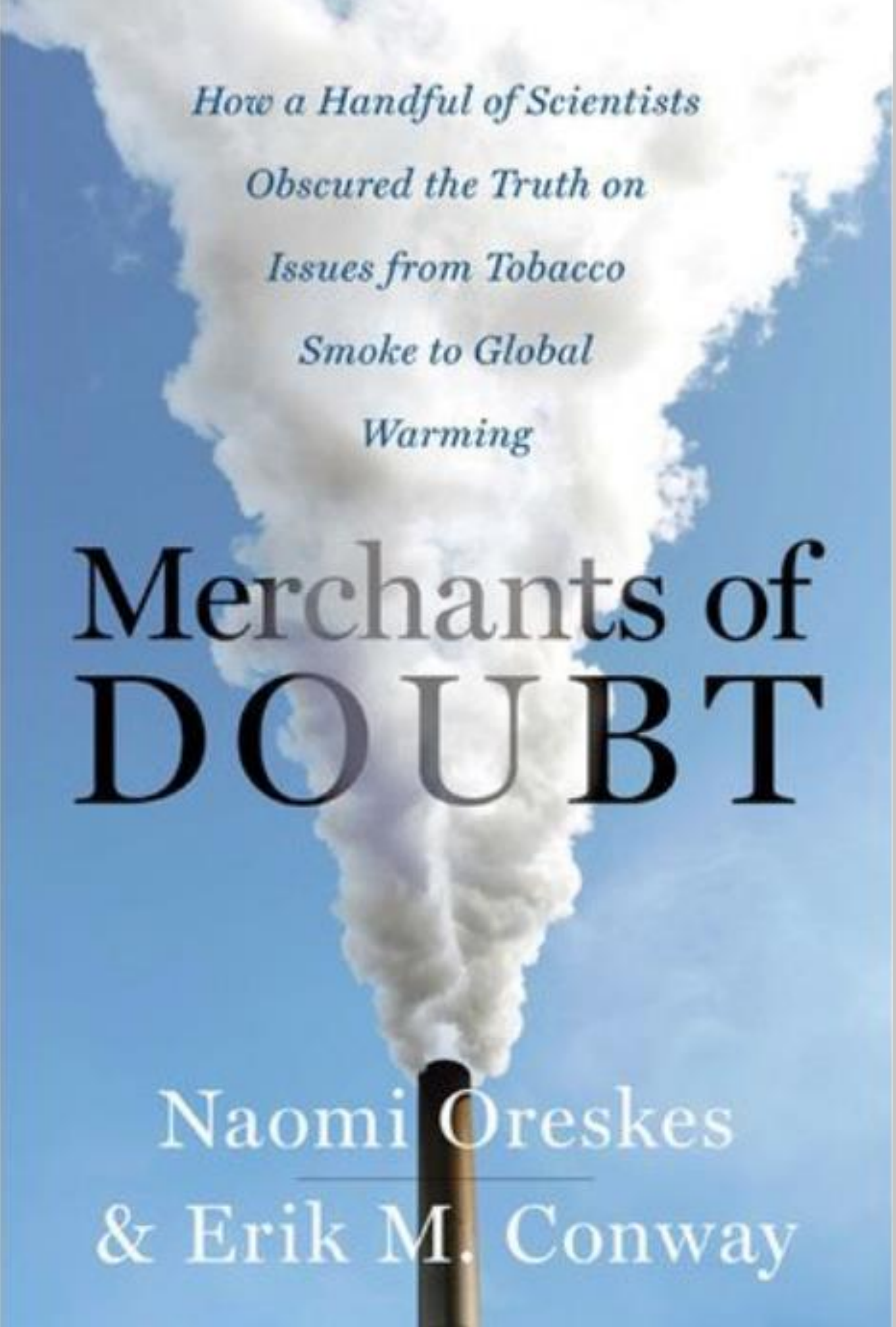

CHRISTIAN GERONDEAU
LE CO2 EST BON POUR LA PLANETE
CLIMAT, LA GRANDE MANIPULATION


INDEPENDENT MINDS
CLIMATE: THE GREAT DELUSION
A STUDY OF THE CLIMATIC, ECONOMIC AND POLITICAL UNREALITIES
CHRISTIAN GERONDEAU
INTRODUCED BY NIGEL LAWSON
PREFACE BY VALÉRY GISCARD D'ESTAING


UNSETTLED SCIENCE
A Climate Change Denier's HANDBOOK
Ian Hall

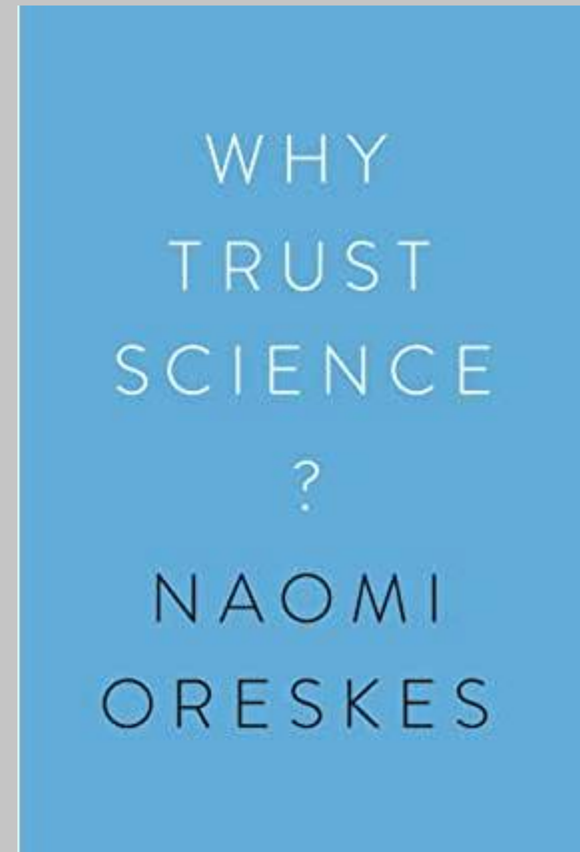

CLIMATE CHANGE: NATURAL OR MANMADE?
JOE FONE


Great Global Warming Swindle
THE GREAT GLOBAL WARMING SWINDLE
A documentary by Martin Durkin




2010

2019




2019

2017, Trends in Recent Ecology and Evolution

Science & Society

# The Rise of Invasive Species Denialism

James C. Russell[1,2,@,*] and Tim M. Blackburn[3,4,@]

**Scientific consensus on the negative impacts of invasive alien species (IAS) is increasingly being challenged. Whereas informed scepticism of impacts is important, science denialism is counterproductive. Such denialism arises when uncertainty on impacts is confounded by differences in values. Debates on impacts must take into account both the evidence presented and motivations.**

**vs.**

Mark A. Davis[1,*] and Matthew K. Chew[2]

Russell and Blackburn's [1] call to action against 'invasive species denialism' appears to be invasion biology's desperate last stand. Invasion biologists' insistence that species introductions constitute a unified ecological crisis is losing support from both the scientific community and the informed public. It is being replaced by a more equivocal notion of ecological novelty, which can accommodate recognizing and responding to a spectrum of phenomena ranging from great good to great harm, with a good deal of relative insignificance in between.

Biol Invasions (2018) 20:549–553
https://doi.org/10.1007/s10530-017-1561-7

2018

INVASION NOTE

# The exponential growth of invasive species denialism

Anthony Ricciardi · Rachael Ryan

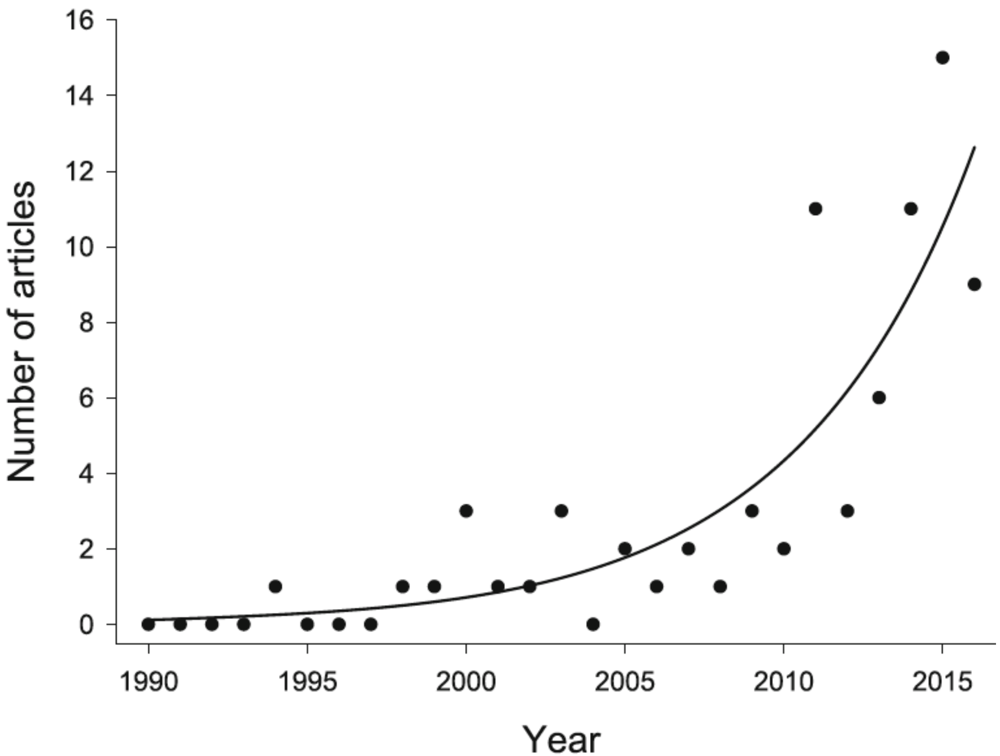



**Fig. 1** Annual number of published articles (journal papers, radio and video broadcasts, news and magazine articles, books) that promote invasive species denialism—defined here as ignoring or denying scientific facts and making claims that have already been refuted in the peer-reviewed literature. Articles published between 1990 and 2016, inclusive, were searched through Web of Science, Google Scholar, and Google News archives using *invasive species, non-native species,* and *alien species* as search terms. Exponential curve fitted by nonlinear regression: $y = e^{0.18x-2.10}$, where $x$ is the number of years since 1990 ($R^2 = 0.745$, $P < 0.0001$)

2019

Conservation Biology

*Essay*

# On allegations of invasive species denialism

David Munro,[1] Jamie Steer,[2] and Wayne Linklater[1,3,4*]
[1]Centre for Biodiversity and Restoration Ecology, Victoria University of Wellington, P.O. Box 600, Wellington, 6140, New Zealand
[2]Biodiversity Department, Greater Wellington Regional Council, Wellington, New Zealand
[3]Department of Environmental Science, Policy and Management, University of California-Berkeley, CA, U.S.A.
[4]Centre for African Conservation Ecology, Nelson Mandela University, Port Elizabeth, South Africa

1) How many introduced species are harmful?

a) Most have not been studied

b) Lag effect (‘invasion debt”)

c) Subtle effects not quickly evident

1) How many introduced species are harmful?

2) (Some) introduced species are good!

Conservation Biology

*Review*

# The Potential Conservation Value of Non-Native Species

2012

MARTIN A. SCHLAEPFER,*† DOV F. SAX,‡ AND JULIAN D. OLDEN§
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†INRA, Ecologie et Santé des Ecosystèmes, 35042 Rennes, France
‡Department of Ecology and Evolutionary Biology, 80 Waterman Street, Brown University, Providence, RI 02912, U.S.A.
§School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA 98195, U.S.A.

Conservation Biology

*Comment*

VS.

# Revisiting the Potential Conservation Value of Non-Native Species

JEAN RICARDO SIMÕES VITULE,* CAROLINA A. FREIRE,† DIEGO P. VAZQUEZ,‡ MARTIN A. NUÑEZ,§ AND DANIEL SIMBERLOFF§ **
*Laboratório de Ecologia e Conservação, Departamento de Engenharia Ambiental, Setor de Tecnologia, Universidade Federal do Paraná, 81531, 980, Curitiba, Paraná, Brazil
†Departamento de Fisiologia, Setor de Ciências Biológicas, Centro Politécnico, Universidade Federal do Paraná, 81531, 980, Curitiba, Paraná, Brazil
‡Instituto Argentino de Investigaciones de las Zonas Áridas, CONICET; Instituto de Ciencias Básicas, Universidad Nacional de Cuyo, Mendoza, Argentina
§Department of Ecology and Evolutionary Biology, University of Tennessee, Knoxville, TN 37996, 1610, U.S.A.

PLOS BIOLOGY

2018

OPEN ACCESS

PERSPECTIVE

# Do non-native species contribute to biodiversity?

Martin A. Schlaepfer

Published: April 17, 2018 • https://doi.org/10.1371/journal.pbio.2005568

Article | Authors | Metrics | Comments | Media Coverage



## Abstract

The Convention on Biological Diversity (CBD) emphasises the role of biodiversity in delivering benefits essential for all people and, as a result, seeks to safeguard all life-forms. The indices that are used to measure progress towards international conservation and sustainability goals, however, focus solely on the 'native' component of biodiversity. A subset of non-native species can cause undesirable economic, social, or biological effects. But non-native species also contribute to regional biodiversity (species richness and biotic interactions) and ecosystem services. In some regions and cities, non-native species make up more than half of all species. Currently, the contributions of these species to biodiversity and ecosystem services are overlooked. Here, I argue that biodiversity and sustainability indices should include all species. This is not only consistent with definitions of biodiversity but also will promote the idea that long-term, sustainable, human well-being is intricately tied to benefits derived from nature.

1) How many introduced species are harmful?

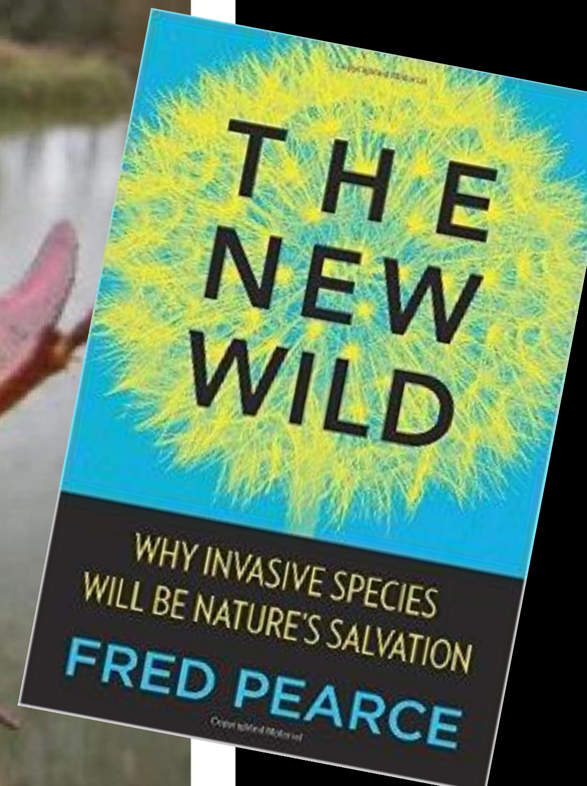
2) (Some) introduced species are good!

3) Actions against introduced species are xenophobic.

ECOLOGIST
SETTING THE ENVIRONMENTAL AGENDA SINCE 1970

# Does 'green xenophobia' mean nature's go-getters are wrongly attacked as invasive species?

Fred Pearce | 29th March 2018




*The signal crayfish was introduced from the US to Europe in the 1960s.*

**Invasive species imported - sometimes accidentally - by us humans are seen as a threat to 'pristine' and 'fragile' ecosystems. But FRED PEARCE, the legendary environmental correspondent, argues in his new book The New Wild that they could be the salvation of environments put under stress by modern development**

Hugh Raffles


The Opinion Pages | OP-ED CONTRIBUTOR

Mother Nature's Melting Pot

By HUGH RAFFLES APRIL 2, 2011

"The anti-immigrant sentiment sweeping the country, from draconian laws in Arizona to armed militias along the Mexican border, has taken many Americans by surprise. It shouldn't — nativism runs deep in the United States. **Just ask our non-native animals and plants**: they too are commonly labeled as aliens, even though they also provide significant benefits to their new home. While the vanguard of the anti-immigrant crusade is found among the likes of the **Minutemen and the Tea Party**, the native species movement is led by environmentalists, conservationists and gardeners. Despite cultural and political differences, both are motivated by **the fear of being swamped by aliens.**"

H. Raffles, 2011
NY Times

If all you have is a hammer,
everything looks like a nail

~ Law of the instrument

1) How many introduced species are harmful?

2) (Some) introduced species are good!

3) Actions against introduced species are xenophobic.

4) Efforts to contain invasions are futile.

Mark Gardener, Director, Charles Darwin Research Station, Galapagos, 2011:

"It's time to embrace the aliens. Blackberries now cover more than 30,000 ha here, and our studies show that island biodioversity is reduced by at least 50% when it's present. But as far as I'm concerned, it's now a Galapagos native, and it's time we accepted it as such."

*Rubus niveus*

2018

Journal of Applied Ecology

BRITISH ECOLOGICAL SOCIETY

Standard Paper | Open Access

Environmental DNA (eDNA) detects the invasive rusty crayfish *Orconectes rusticus* at low abundances

Matthew M. Dougherty, Eric R. Larson, Mark A. Renshaw, Crysta A. Gantz, Scott P. Egan, Daniel M. Erickson, David M. Lodge

*Annual Review of Ecology, Evolution, and Systematics*

Uses and Misuses of Environmental DNA in Biodiversity Science and Conservation

Melania E. Cristescu[1] and Paul D.N. Hebert[2]

Front Ecol Environ 2018; 16(5): 265–270,

RESEARCH COMMUNICATIONS RESEARCH COMMUNICATIONS

Early detection of invasive exotic insect infestations using eDNA from crop surfaces

Rafael E Valentin[1*], Dina M Fonseca[1,2], Anne L Nielsen[2], Tracy C Leskey[3], and Julie L Lockwood[1]

PLOS | ONE

Evaluation of the Environmental DNA Method for Estim[…] Distribution and Biomass of Submerged Aquatic Plants

Saeko Matsuhashi, Hideyuki Doi, Ayaka Fujiwara, Sonoko Watanabe, Toshifumi Minamoto

Published: June 15, 2016 • https://doi.org/10.1371/journal.pone.0156217

RAPID COMMUNICATION

Detection of Asian carp DNA as part of a Great Lakes basin-wide surveillance program

Christopher L. Jerde, […] Chadderton, Andrew R. Mahon, Mark A. Renshaw, Joel Corush, Michelle L. Budny, Sagar Mysorekar, and David M. Lodge

Received: 7 November 2018 | Revised: 16 April 2019 | Accepted: 14 May 2019

DOI: 10.1002/edn3.17

ORIGINAL ARTICLE

Environmental DNA

WILEY

High-resolution biomonitoring of plant pathogens and plant species using metabarcoding of pollen pellet contents collected from a honey bee hive

Émilie D. Tremblay | Marc-Olivier Duceppe | Graham B. Thurston | Marie-Claude Gagnon | Marie-José Côté | Guillaume J. Bilodeau

Ecological Indicators

Ecological Indicators 102 (2019) 617–622

Efficacy of eDNA as an early detection indicator for Burmese pythons in the ARM Loxahatchee National Wildlife Refuge in the greater Everglades ecosystem

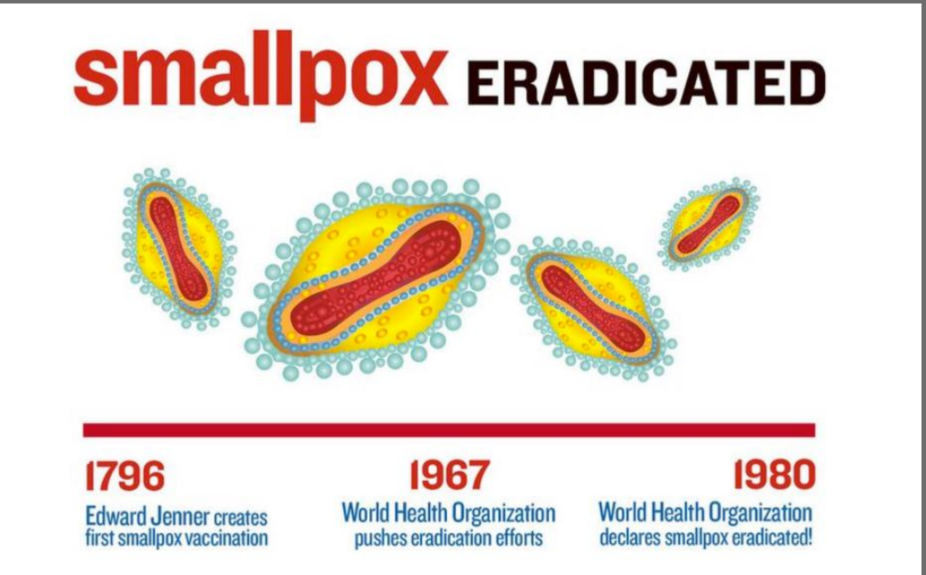
Margaret E. Hunter[a,*], Gaia Meigs-Friend[a], Jason A. Ferrante[b], Brian J. Smith[c], Kristen M. Hart[d]

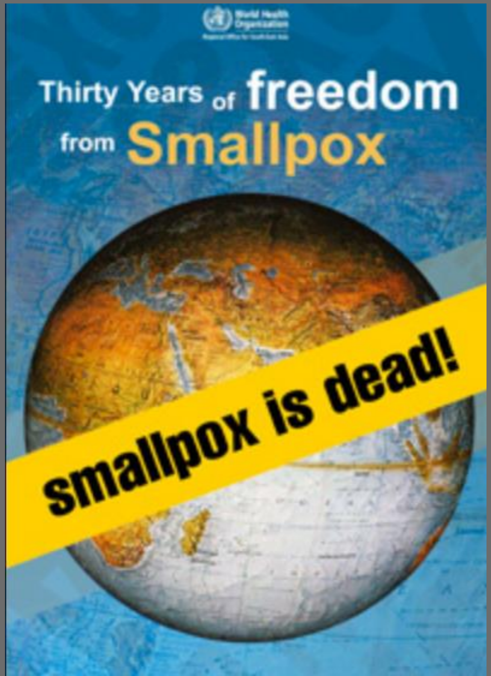
eradication = total elimination of
population(s) from a
discrete, separate region

maintenance management = maintaining
population(s) at low level
= “population control”

**"It is easy to write laws for compulsory vaccination against smallpox, but ……………………….... For this reason, and many others, eradication programs will eventually become a curiosity item on library shelves, just as have all social utopias."**

**- René Dubos, 1965, <u>Man Adapting</u>**



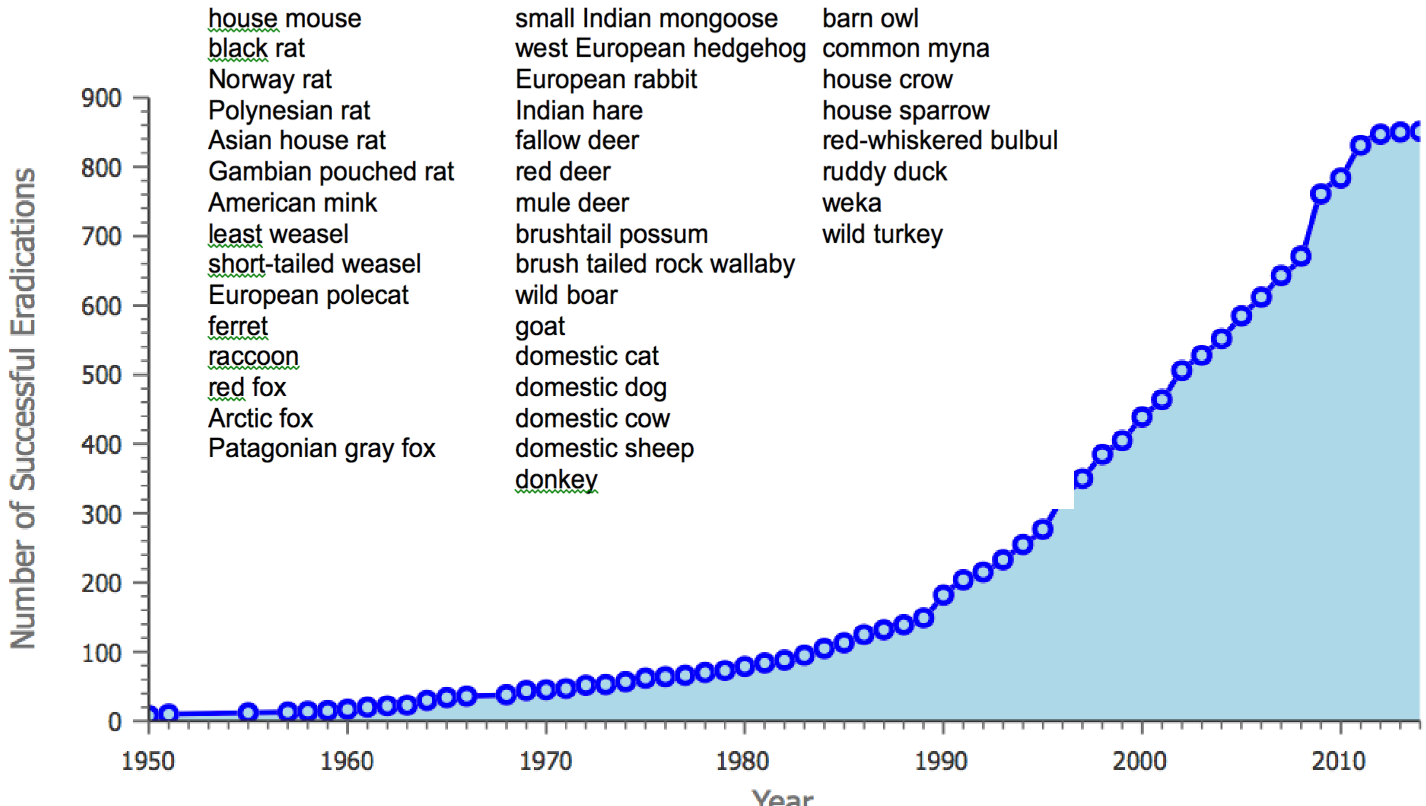



# http://diise.islandconservation.org/

**What is the Database of Island Invasive Species Eradications?**

Islands are the epicenter of the current global extinction crisis and invasive vertebrates are a key threat to native plants and animals on islands. Removing invasive vertebrates from islands is an important island restoration tool to protect and restore island ecosystems and prevent extinctions.

The Database of Island Invasive Species Eradications attempts to compile all historical and current invasive vertebrate eradication projects on islands. The vast majority of the dataset is focused on invasive mammals. Data gathered from each project includes island location and characteristics, details about the eradication including focal species, methods and outcome, plus links and or contact details for learning more about the project. Parameter descriptions are described here.



## Some island mammal eradications

| | | |
|---|---|---|
| rats: | Macquarie Island | 12,873 ha |
| | Campbell Island | 11,330 ha |
| | South Georgia Island | 352,758 ha |
| house mouse: | Macquarie Island | 12,873 ha |
| carnivore (mink): | Hiiumaa Island (Estonia) | 102,560 ha |
| boar | Santiago (Galapagos) | 58,041 ha |
| goat | Isabela (Galapagos) | 458,812 ha |

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292 of 1,086 eradication attempts were parts of 125 multispecies projects on 120 islands.

194 of 1,086 eradication attempts on 94 islands inhabited by humans.

http://b3.net.nz/gerda/index.php

gerda
global eradication and response database

Home · FAQ · User manual · Publications · Sponsors · Target taxa · Countries · Bibliography · Log in / register

## Gerda · global eradication and response database

This database summarises incursion response and eradication programmes from around the world.

The scope of the database is terrestrial arthropod pests and plant pathogens. Weeds, vertebrate pests, aquatic pests, and animal diseases are not currently included. Read more about the scope and purposes of the database in the frequently asked questions (FAQ) section.

Arthropod pests and plant pathogens

970 eradication campaigns

103 nations

308 taxa, including 165 arthropods

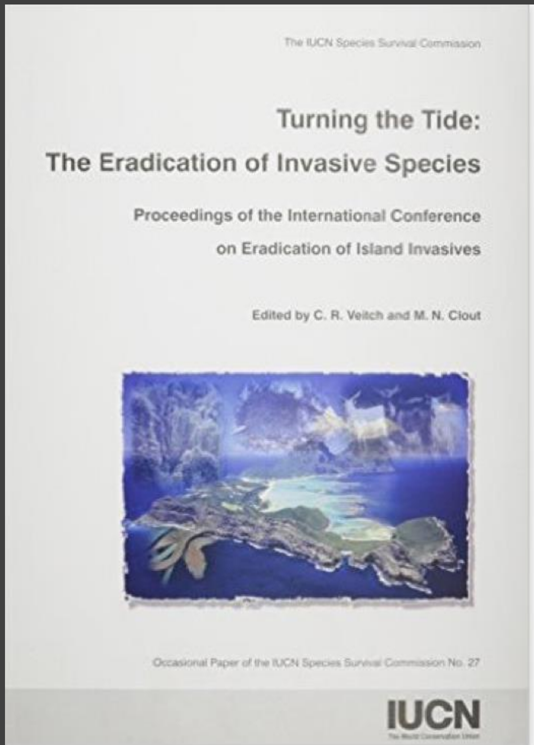
Biol Invasions (2014) 16:401–414
DOI 10.1007/s10530-013-0529-5

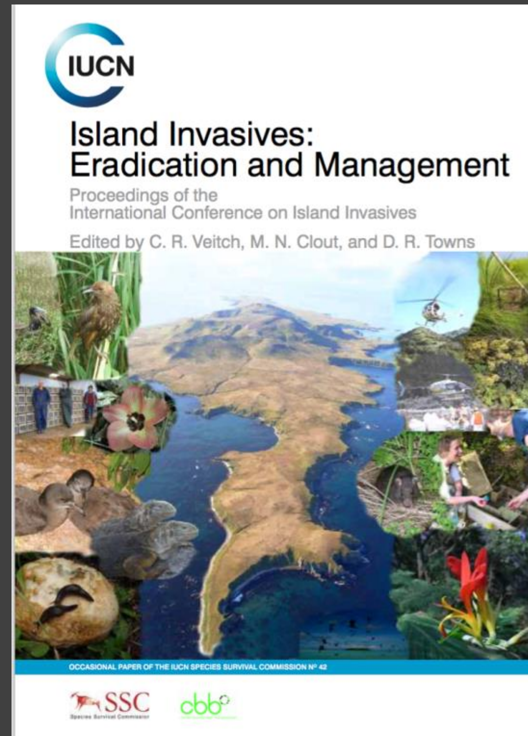
ORIGINAL PAPER

# Determinants of successful arthropod eradication programs

**Patrick C. Tobin · John M. Kean · David Maxwell Suckling · Deborah G. McCullough · Daniel A. Herms · Lloyd D. Stringer**

| 2002 | | 2011 | | 2017 | |
|---|---|---|---|---|---|





| animals | plants | animals | plants | animals | plants |
|---|---|---|---|---|---|
| 59 | 14 | 129 | 8 | 64 | 6 |

# *Kochia scoparia* in Western Australia

**1990 – introduced**

**1992 – eradication campaign begun**

**1993 – 3,200 ha over 900 km**

**1995 – 139 ha**

**1999 – 5 ha**

# MAINTENANCE MANAGEMENT

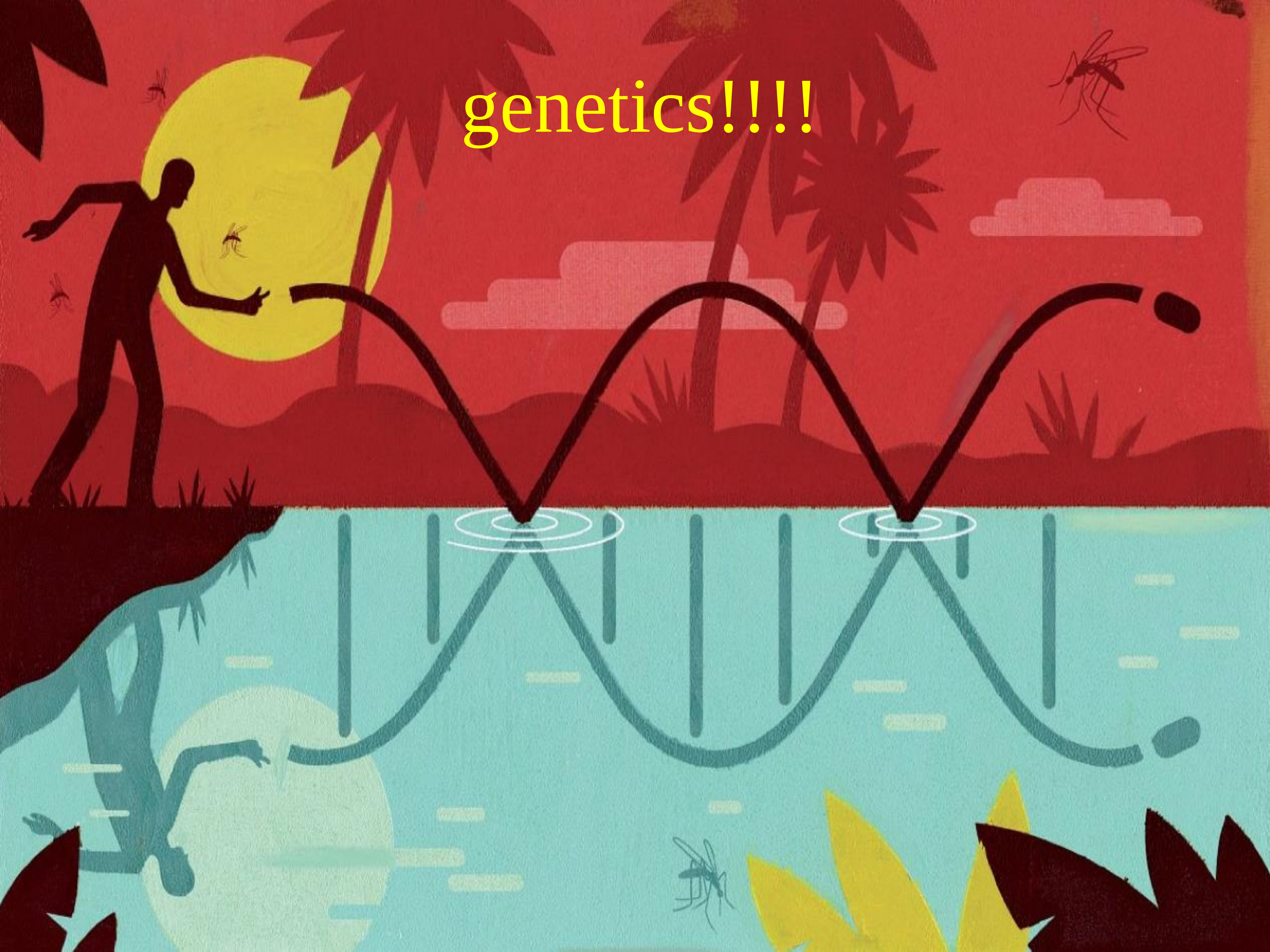
physical and mechanical control

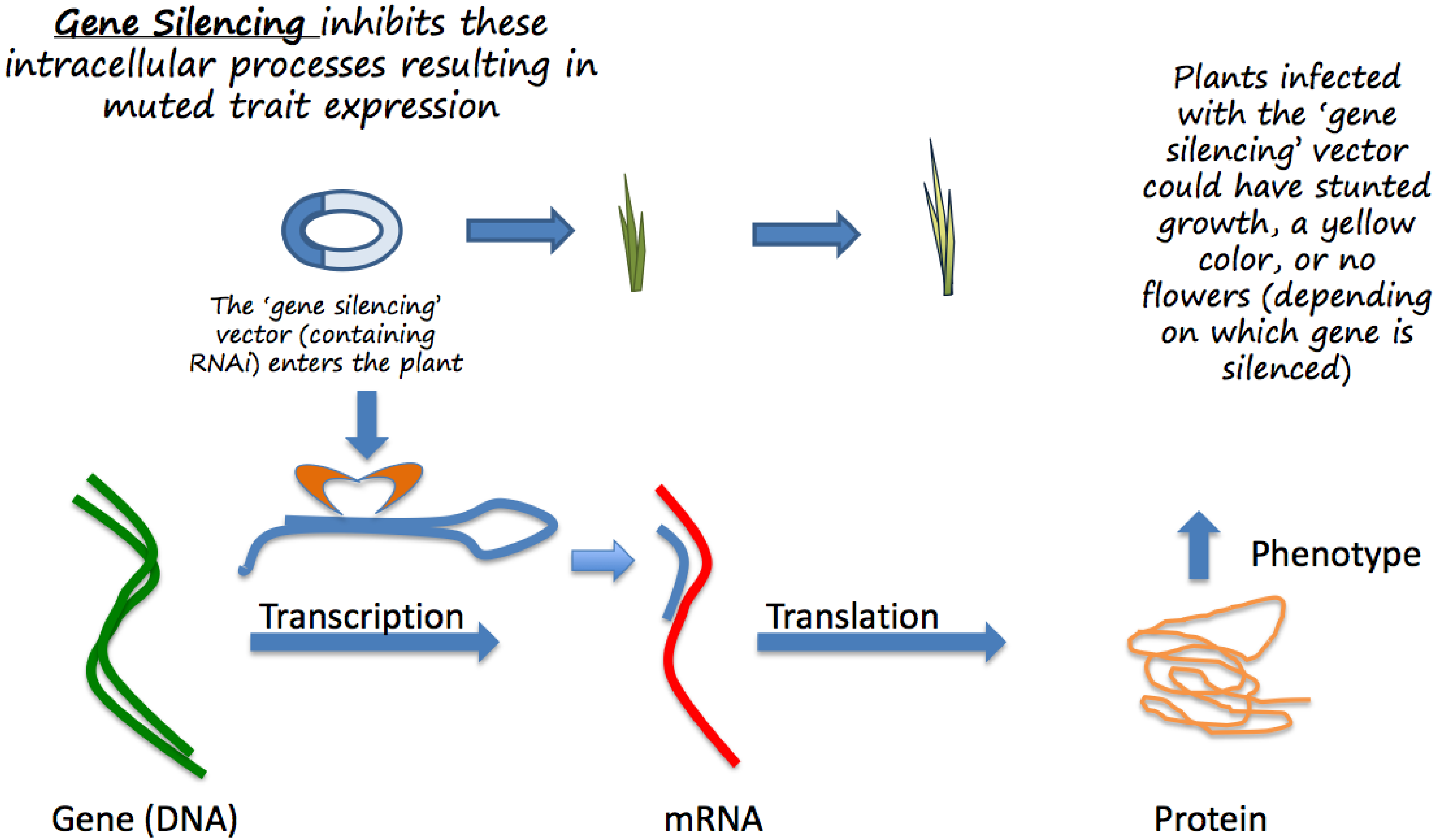
chemical control

biological control

sterile male, mating disruption, etc.

# genetics!!!!






from E.M. Golenberg -

http://greatlakesphragmites.net/files/GLC-Webinar.pdf

Pest Management Science 72:801-809. 2016

# The next generation of insecticides: dsRNA is stable as a foliar-applied insecticide

Keri San Miguel and Jeffrey G Scott*

## Abstract

**BACKGROUND:** RNAi is a powerful tool used to study gene function. It also has been hypothesized to be a promising new method for control of insect pests on crops, although the perceived instability of dsRNA in the environment has constrained thinking about the options for this new type of pest control.

**RESULTS:** We confirmed that foliar application of Colorado potato beetle dsRNA actin is highly effective for control, demonstrated that treatment with actin-dsRNA protects potato plants for at least 28 days under greenhouse conditions and found that the dsRNA is not readily removed by water once dried on the leaves.

**CONCLUSION:** These new results suggest that foliar application of dsRNA could be a valuable control strategy for some pests. Technological aspects of spraying dsRNA that need to be considered in the future are discussed.


**Keywords:** Colorado potato beetle (*Leptinotarsa decemlineata*); crop protection; RNAi; double-stranded RNA

# The EPA Quietly Approved Monsanto's New Genetic-Engineering Technology

It's the first time RNA interference will be used to kill insect pests.

SARAH ZHANG | JUN 23, 2017 | SCIENCE

EPA United States Environmental Protection Agency

Environmental Topics Laws & Regulations About EPA Search EPA.gov

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## Pesticide Registration

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- About Pesticide Registration
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## EPA Registers Innovative Tool to Control Corn Rootworm

In June 2017, EPA registered four products containing the Ribonucleic acid interference (RNAi) based Plant-Incorporated Protectant (PIP) called SMARTSTAX PRO. This product will help U.S. farmers control corn rootworm, a devastating corn pest that has developed resistance to several other pesticides.

**Related Information**

- Overview of Plant-Incorporated

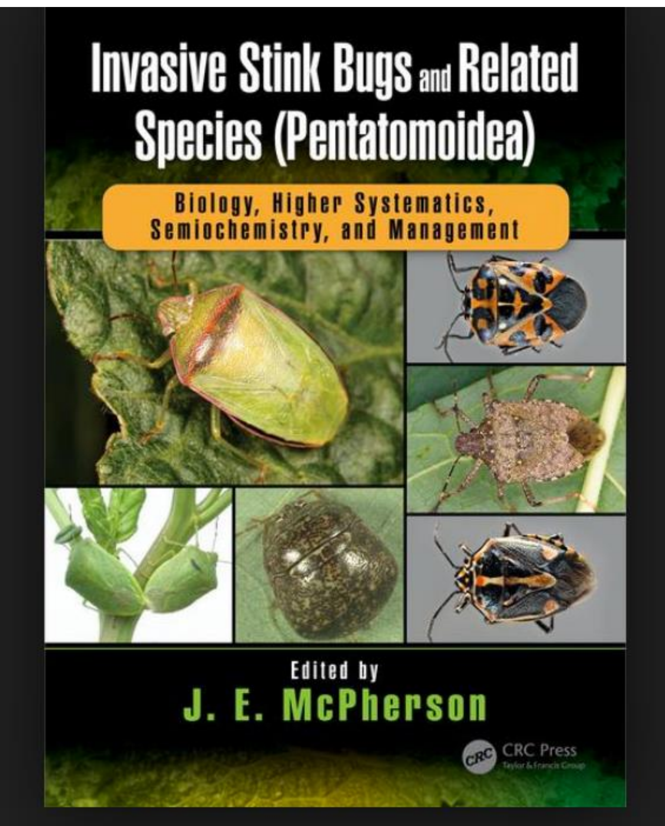
# DuPont, Jan. 19, 2019 patent application:

**Title:** **Compositions and methods for insecticidal control of stinkbugs**

**Document Type and Number:** United States Patent 10190134

**Abstract:** Methods and compositions are provided which employ a silencing element that, when ingested by a pest, such as a Pentatomidae plant pest, decrease the expression of a target sequence in the pest. The present invention provides various target polynucleotides set forth in any one of SEQ ID NOS: 6-12, 18-40 or active variants and fragments thereof, wherein a decrease in expression of one or more the sequences in the target pest controls the pest (i.e., has insecticidal activity). Plants, plant part, bacteria and other host cells comprising the silencing elements or an active variant or fragment thereof of the invention are also provided.

ı employ a silencing element that, when ingested by a pest, such as a Pentatomidae plant pest,




brown marmorated stink bug

Leonard *et al.*, *Science* **367**, 573–576 (2020)     31 January 2020


BEE HEALTH

## Engineered symbionts activate honey bee immunity and limit pathogens

Sean P. Leonard[1,2], J. Elijah Powell[1], Jiri Perutka[2], Peng Geng[2], Luke C. Heckmann[1], Richard D. Horak[1], Bryan W. Davies[2], Andrew D. Ellington[2], Jeffrey E. Barrick[2]*, Nancy A. Moran[1]*

varroa mite

MICROBIAL ENGINEERING

# A microbiome silver bullet for honey bees

## A genetically engineered honey bee gut bacterium knocks down two major bee threats

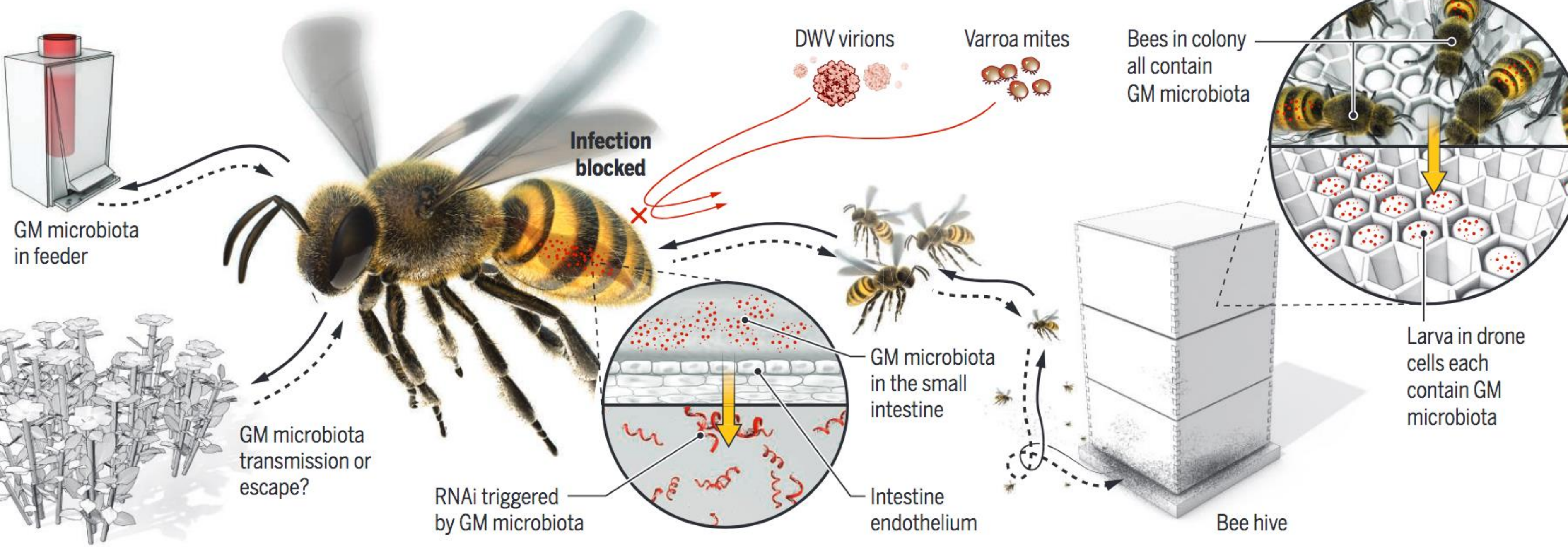
*By* **Robert J. Paxton**

stressors (*1*) that are unlikely to diminish with

induce host RNA interference (RNAi)–base

### Improving honey bee survival

Symbiotic bee gut bacteria were genetically modified (GM) to release specific RNA that triggers an immune response in the host involving RNA interference (RNAi). Once RNAi was activated, honey bees survived infection by a particular virus or parasitic mite. Whether this RNAi-based defense can be passed from adult to larva or via flowers has yet to be determined.



# Extraordinary Sex Ratios

A sex-ratio theory for sex linkage and inbreeding has new implications in cytogenetics and entomology.

Science 156:477-488 1967

W. D. Hamilton

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ELSEVIER

Journal of Theoretical Biology

Volume 241, Issue 2, 21 July 2006, Pages 333-341


## A model describing the effect of sex-reversed YY fish in an established wild population: The use of a Trojan Y chromosome to cause extinction of an introduced exotic species

Juan B. Gutierrez [a], John L. Teem [b]

“supermales” = YY

North American Journal of Aquaculture 78:72–83, 2016

ISSN: 1522-2055 print / 1548-8454 online
DOI: 10.1080/15222055.2015.1100149

ARTICLE

# Production of a YY Male Brook Trout Broodstock for Potential Eradication of Undesired Brook Trout Populations

**Daniel J. Schill* and Jeff A. Heindel**
*Idaho Department of Fish and Game, 600 South Walnut Street, Post Office Box 25, Boise, Idaho 83707, USA*

**Matthew R. Campbell**
*Idaho Department of Fish and Game, 1800 Trout Road, Eagle, Idaho 83616, USA*

**Kevin A. Meyer and Elizabeth R. J. M. Mamer**
*Idaho Department of Fish and Game, 1414 East Locust Lane, Nampa, Idaho 83686, USA*

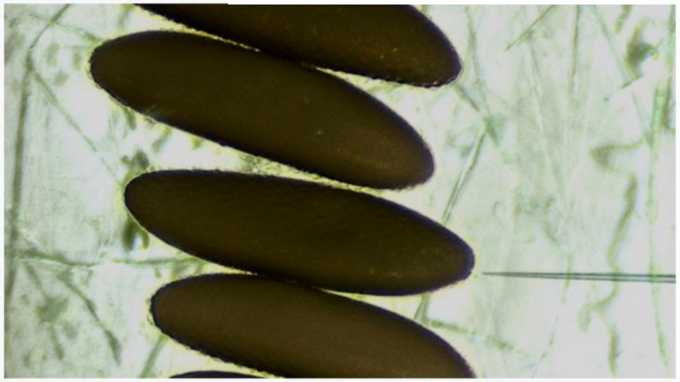
tilapia

common carp

trout

OXITEC

# The Friendly™ Mosquitoes



We're applying advanced science to develop new and better pest control

Oxitec's approach uses advanced genetics to develop solutions for controlling dangerous disease-carrying mosquitoes, and harmful agricultural pests.

Haedes, Aegypta and the Oxitec approach

Oxitec's vector control solution – A paradigm shift in mosquito control

TED Talk: Re-engineering mosquitos to fight disease

Science 354: 164-167,2016

NEWS

# WINGED WARRIORS

Brazil plans to release billions of designer mosquitoes to stop the spread of infectious diseases. Will it work?

*By* **Kelly Servick**, *in Brazil*

Every Saturday morning, Maria do Carmo Tunussi goes door to door asking her neighbors to scour their houses and yards for flowerpots, buckets, clogged gutters—anything that could collect water and offer mosquitoes a place to breed. For 17 years, Tunussi has been a community health agent at the local clinic in CECAP/Eldorado, a district of about 5000 people in the small city of Piracicaba, 2 hours northwest of São Paulo, Brazil. She has seen many surges of the mosquito-borne dengue virus, which causes fever, nausea, and agonizing joint pain. The task sometimes feels futile. "You remove the breeding site one day, and the next day, it's back," she says. "It never ends."

Last April, CECAP became the first

that effective against *A. aegypti*, and breeding site removal, which, despite Tunussi's efforts, is hard to keep up year after year. So it's not surprising that, 7 years after releasing the world's first genetically modified (GM) mosquito, Oxitec has chosen Brazil as the site of a major scale-up. It is moving from small-scale pilot projects like the one in CECAP to planned releases covering tens of thousands of people.

Indeed, Brazil is becoming a proving ground for tailored mosquitoes. About 600 kilometers to the east, in the coastal cities of Niterói and Rio de Janeiro, another lab strain of mosquitoes is on the wing. Bred by a nonprofit organization called Eliminate Dengue, this one is infected with a bacterium called *Wolbachia pipientis* that protects it from infection with dengue, Zika, and

Oxitec's transgenic mosquitoes swarm out of a container in Piracicaba, Brazil.

bouncing around in plastic tubs the size of take-out containers.



# CORRESPONDENCE

## International law should govern release of GM mosquitoes


SIR — Your News story 'Sterile mosquitoes near take-off' (*Nature* **453**, 435; 2008) discusses the likely release of genetically engineered mosquitoes to help contain dengue fever. It demonstrates just how close we are to a radically new set of strategies for managing a whole range of diseases and wildlife using genetically modified organisms (GMOs). But after assessing the risks and benefits, nations may reach different conclusions about their use. And that's quite a problem, considering that genetically modified bugs won't recognize national borders.

Malaysia may successfully avoid spreading the sterile

politics, and appropriately so. The potential for conflict over

Biological Station, CSIC, Apdo. 153, 41080 Sevilla, Spain

NEWS OF THE WEEK

SCIENCE AND SOCIETY

## GM Mosquito Trial Alarms Opponents, Strains Ties in Gates-Funded Project

For about a decade, scientists have debated how and when to carry out the first test release of transgenic mosquitoes designed to fight human disease—a landmark study they imagined might trigger fierce resistance from opponents of genetic engineering. A stream of papers and reports has argued that a release of any genetically modified (GM) mosquito should be preceded by years of careful groundwork, including an exhaustive public debate to win the hearts and minds of the local population.

But now, it turns out that with little public debate, a company released such mosquitoes a year ago in a fiscal paradise in the Caribbean, where they have been flying under the world's radar screen until last week. At a press conference in London on 11 November, British company Oxitec announced that it carried out the world's first small trial with transgenic *Aedes aegypti* mosquitoes in Grand Cayman in the fall of

*"I would completely reject any notion that this was done secretively."*

—LUKE ALPHEY, CHIEF SCIENTIFIC OFFICER, OXITEC

says Bart Knols, a medical entomologist at the University of Amsterdam in the Netherlands. "This could well trigger a backlash."

Nor does the trial sit well with the collaborators in a big international project, in which Oxitec is a key member, to develop and test GM mosquitoes. The program, funded by a $19.7 million grant from the Bill & Melinda Gates Foundation and led by Anthony James of the University of Cali-

difficult situation," he says. "I would completely reject any notion that this was done secretively," says Alphey, who notes that the trial was well-known within the island's population of 50,000, "but just not picked up internationally."

Few deny that in the race to develop disease-fighting mosquitoes, Oxitec has an impressive lead. Its key idea, pioneered by Alphey while at the University of Oxford in the 1990s, is to release massive numbers of lab-bred male mosquitoes equipped with a gene that kills any offspring in the larval or pupal stage. When the males mate with females of a natural population, there are no progeny—and if the transgenic males mate more often than the natural ones, the mosquito population will dwindle or even collapse. (And because male mosquitoes don't bite, their release does not increase the risk of disease transmission to humans.)

Oxitec sees a key market in *Ae. aegypti*, the vector for dengue, a painful and sometimes fatal viral infection for which no drugs or vaccines exist. Many middle- and high-income countries already invest heavily in traditional mosquito-control measures to fight dengue, but the results are

SCIENTIFIC REPORTS
natureresearch

OPEN

# Transgenic *Aedes aegypti* Mosquitoes Transfer Genes into a Natural Population

Received: 11 February 2019
Accepted: 29 August 2019
Published online: 10 September 2019

Benjamin R. Evans[1], Panayiota Kotsakiozi[1], Andre Luis Costa-da-Silva[2,3], Rafaella Sayuri Ioshino[2,3], Luiza Garziera[3], Michele C. Pedrosa[2,3,4], Aldo Malavasi[4], Jair F. Virginio[4], Margareth L. Capurro[2,3] & Jeffrey R. Powell[1]

# Oxitec response, 9/18/2019:


THE STUDY'S DATA IN SCIENTIFIC REPORTS PAPER DOES NOT IDENTIFY NEGATIVE, DELETERIOUS OR UNANTICIPATED EFFECT ON PEOPLE OR THE ENVIRONMENT FROM THE RELEASE OF OXITEC'S 1ST GENERATION (OX513A) MOSQUITOES.

THE PAPER'S AUTHORS MADE SPECULATIVE STATEMENTS AND SELECTIVELY IGNORED BODY OF CRITICAL PEER-REVIEWED EVIDENCE, INCLUDING THEIR OWN, DESCRIBING SAFETY AND EFFECTIVENESS OF TECHNOLOGY.


1234 20 SEPTEMBER 2019 • VOL 365 ISSUE 6459 Science

INFECTIOUS DISEASES

GM mosquito study draws fire

Release of altered strain spread DNA to local mosquitoes

By Kelly Servick

For 10 years, the company Oxitec has

to transmit disease—has triggered anti-GM news reports, a backlash from some scientists, and strong pushback from Oxitec.

eLIFE
elifesciences.org
FEATURE ARTICLE

2014

EMERGING TECHNOLOGY

# Concerning RNA-guided gene drives for the alteration of wild populations

KEVIN M ESVELT*, ANDREA L SMIDLER, FLAMINIA CATTERUCCIA* AND GEORGE M CHURCH*

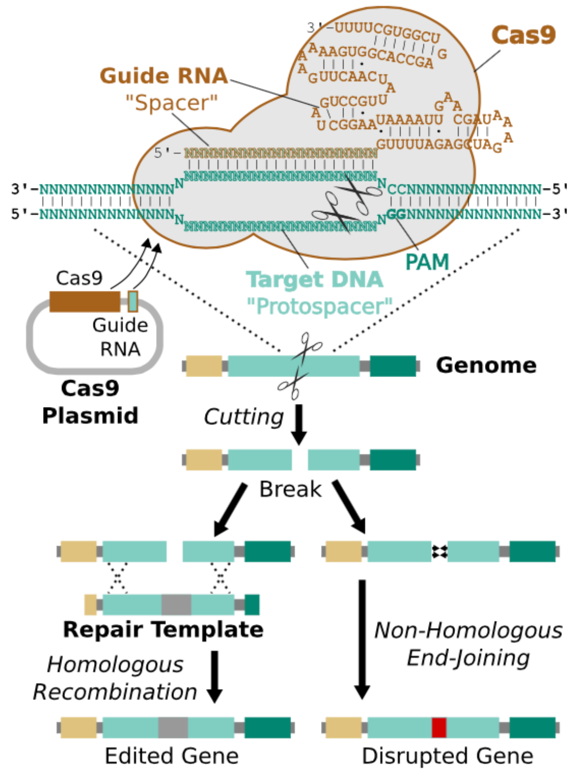



**Figure 3**. RNA-guided genome editing via Cas9. T

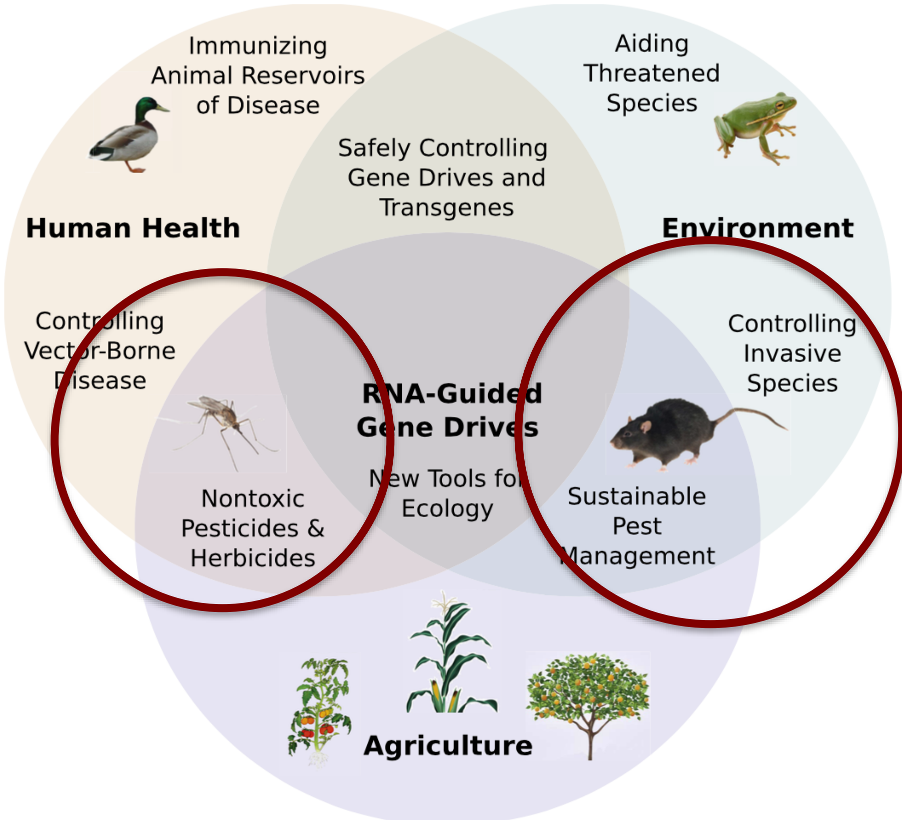



**Figure 7**. Potential applications of RNA-guided gene drives. Clockwise from left. Disease vectors such as

Science & Society

Trends in Biotechnology May 2014, Vol. 32, No. 5

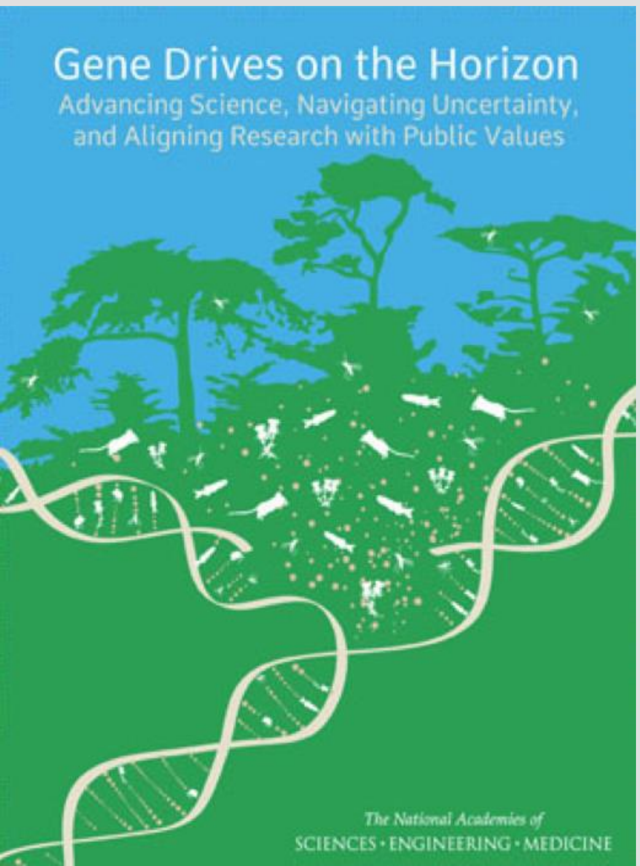
## Caution required for handling genome editing technology

**Motoko Araki[1], Kumie Nojima[2], and Tetsuya Ishii[1]**

[1] Office of Health and Safety, Hokkaido University, Sapporo 060-0808, Japan
[2] Molecular Imaging Center, National Institute of Radiological Sciences, Chiba 263-8555, Japan

**Genome-editing technology, although a robust tool for genetic engineering, is creating indistinct regulatory** ism using physical, chemical, or biological methods. The modified cells, such as protoplasts, callus cells, or embryonic

# 2016 – US National Research Council




PERSPECTIVES

BIOTECHNOLOGY

## A prudent path forward for genomic engineering and germline gene modification

A framework for open discourse on the use of CRISPR-Cas9 technology to manipulate the human genome is urgently needed

By David Baltimore, Paul Berg, Michael Botchan, Dana Carroll, R. Alta Charo, George Church, Jacob E. Corn, George Q. Daley, Jennifer A. Doudna, Marsha Fenner, Henry T. Greely, Martin Jinek, G. Steven Martin, Edward Penhoet, Samuel H. Sternberg

ture developments. The meeting identified immediate steps to take toward ensuring that the application of genome engineering technology is performed safely and ethically. The promise of so-called "precision medicine" is propelled in part by synergies between two powerful technologies:

**CURRENT APPLICATIONS.** The simplicity of the CRISPR-Cas9 system allows any researcher with knowledge of molecular biology to modify genomes, making feasible experiments that were previously difficult or impossible to conduct. For example, the CRISPR-Cas9 system enables

Sciencexpress

Policy Forum

## Regulating gene drives

Kenneth A. Oye,[1,2*†] Kevin Esvelt,[3*] Evan Appleton,[4] Flaminia Catteruccia,[5,6] George Church,[3] Todd Kuiken,[7] Shlomiya Bar-Yam Lightfoot,[2] Julie McNamara,[2] Andrea Smidler,[5,8] James P. Collins[9]

[1]Political Science Department, Massachusetts Institute of Technology. [2]Engineering Systems Division, Massachusetts Institute of Technology. [3]Wyss Institute, Harvard University. [4]Bioinformatics, Boston University. [5]Harvard School of Public Health. [6]University of Perugia, Italy. [7]Woodrow Wilson International Center for Scholars. [8]Harvard Medical School. [9]School of Life Sciences, Arizona State University.

*Principal contributors to this piece.
†Corresponding author. oye@mit.edu

**Regulatory gaps must be filled before gene drives could be used in the wild**

nome engineering that uses nuclease Cas9 to cut seq fied by guide RNA mol This technique is in wides has already engineered th more than a dozen specie enable "RNA-guided ger edit nearly any gene in se ducing populations (1).

To reduce potential ne in advance of construction Esvelt et al. have proposed el types of drives (1). Pr could exclusively affect p cies or subpopulations sequences

2016

# A Call for Conservation with a Conscience: No Place for Gene Drives in Conservation

**New technologies have played an important role in protecting life on earth, and we the undersigned support innovation and science in conservation. However, we believe that a powerful and potentially dangerous technology such as gene drives, which has not been tested for unintended consequences nor fully evaluated for its ethical and social impacts, should not be promoted as a conservation tool.**

From the climate impact of the internal combustion engine to the synthetic chemicals that have poisoned the web of life, we have learned some lessons. We now understand the serious need for precaution when radical new technologies arise, especially with gene drives, which change the rules of genetics and inheritance and have consequences beyond our comprehension.

Gene drives have the potential to dramatically transform our natural world and even humanity's relationship to it. The invention of the CRISPR-CAS9 tool and its application to gene drives (also known as a "mutagenic chain reaction") gives technicians the ability to intervene in evolution, to engineer the fate of an entire species, to dramatically modify

***Founding signatories include:***

***Dr Jane Goodall***

Scientists and environmental experts and organizations from around the globe have advocated for a halt to proposals for the use of gene drive technologies in conservation. Announced today, a long list of environmental leaders, including **Dr. Jane Goodall, DBE**, genetics professor and broadcaster **Dr. David Suzuki**, **Dr. Fritjof Capra**, entomologist **Dr. Angelika Hilbeck**, Indian environmental activist **Dr. Vandana Shiva** and organic pioneer and biologist **Nell Newman**, have lent their support to the

2017

PLOS | BIOLOGY

PERSPECTIVE

# Conservation demands safe gene drive

**Kevin M. Esvelt**[1]*, **Neil J. Gemmell**[2]*

1 MIT Media Lab, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States of America, 2 Department of Anatomy, University of Otago, Dunedin, New Zealand

* esvelt@media.mit.edu (KME); neil.gemmell@otago.ac.nz (NJG)

## Abstract

Interest in developing gene drive systems to control invasive species is growing, with New Zealand reportedly considering the nascent technology as a way to locally eliminate the mammalian pests that threaten its unique flora and fauna. If gene drives successfully eradicated these invasive populations, many would rejoice, but what are the possible consequences? Here, we explore the risk of accidental spread posed by self-propagating gene drive technologies, highlight new gene drive designs that might achieve better outcomes, and explain why we need open and international discussions concerning a technology that could have global ramifications.

Check for updates

OPEN ACCESS

**Citation:** Esvelt KM, Gemmell NJ (2017) Conservation demands safe gene drive. PLoS Biol 15(11): e2003850. https://doi.org/10.1371/journal.pbio.2003850

ABSTRACTIONS BLOG

## New Model Warns About CRISPR Gene Drives in the Wild

3

*Two new papers urge caution in using powerful genome-editing technology against invasive species: Models show that evolving resistance won't stop aggressive standard gene drives from spreading.*

Go Back: Home > Earth Island Journal > Latest News > Post and Comments

## Latest News

## Letting Gene Drives Loose Outside Labs is Too Risky, says Scientist Who Promoted Idea

BY PAUL KOBERSTEIN – DECEMBER 21, 2017

**But other advocates of controversial genetic engineering technology are moving ahead with plans to conduct field trials in a few years**

Noble et al. eLife 2018;7:e33423. DOI: https://doi.org/10.7554/eLife.33423

2018

eLIFE
elifesciences.org

RESEARCH ARTICLE

# Current CRISPR gene drive systems are likely to be highly invasive in wild populations

Charleston Noble[1,2,3†], Ben Adlam[1,4†], George M Church[2,3], Kevin M Esvelt[5*], Martin A Nowak[1,6,7*]

## Discussion

Our results suggest that current first-generation CRISPR-based gene drive systems for population alteration are capable of far-reaching—perhaps, for species distributed worldwide, global—spread, even for very small releases. A simple, constitutively expressed CRISPR nuclease and guide RNA cassette targeting the neutral site of insertion—an arrangement that could occur accidentally—may be capable of altering many populations of the target species depending on the homing efficiency of the organism in question. More generally, resistance can be problematic for intentional applications of gene drives, but we find that it is not a major impediment to invasion of unintended populations.

https://targetmalaria.org/our-work/

## Our Goal

## How it Works

## Biasing the Sex Ratio

## Focus on Mosquito Female Fertility


ISLAND CONSERVATION
Preventing Extinctions

LANDCARE RESEARCH
MANAAKI WHENUA

NC STATE UNIVERSITY

CSIRO

THE UNIVERSITY of ADELAIDE

USDA

ATM

# *Eradication of Invasive Quagga and Zebra Mussels using Engineered Disseminated Neoplasia*

**Steve Suhr and Marie-Claude Senut**

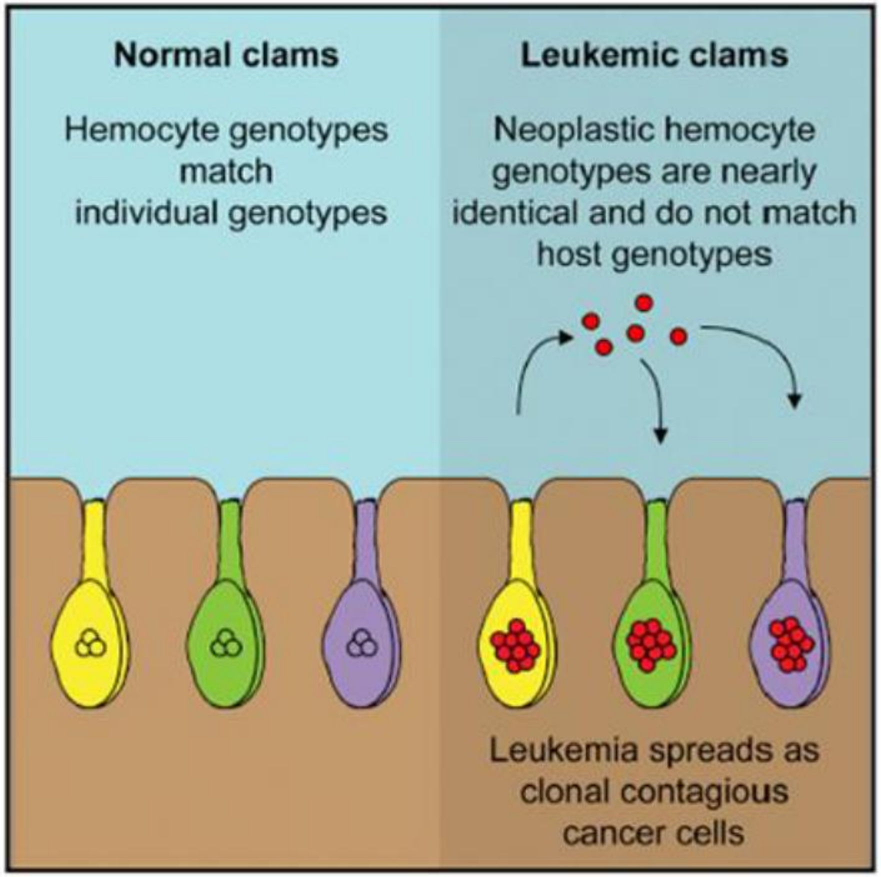
**Biomilab LLC**

**4209 S. Pennsylvania, Lansing MI 48910**

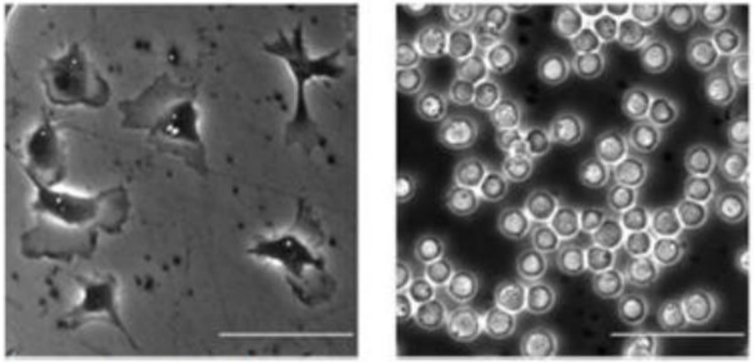
**office@biomilab.com**

**517-492-9900**

# Bivalve Transmissible Neoplasia




**_Metzger et al. (2015) Horizontal transmission of clonal cancer cells causes leukemia in soft-shell clams. Cell. 161:255-263_**



**_Metzger et al. (2015)_**

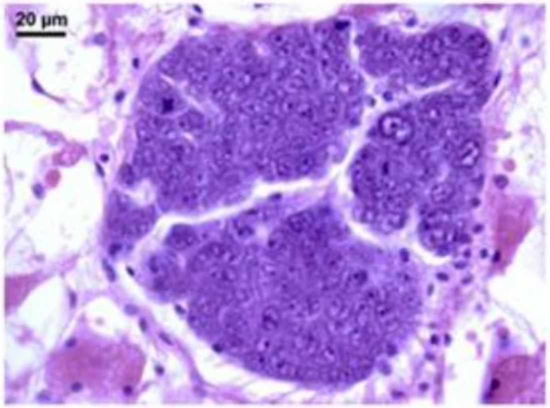
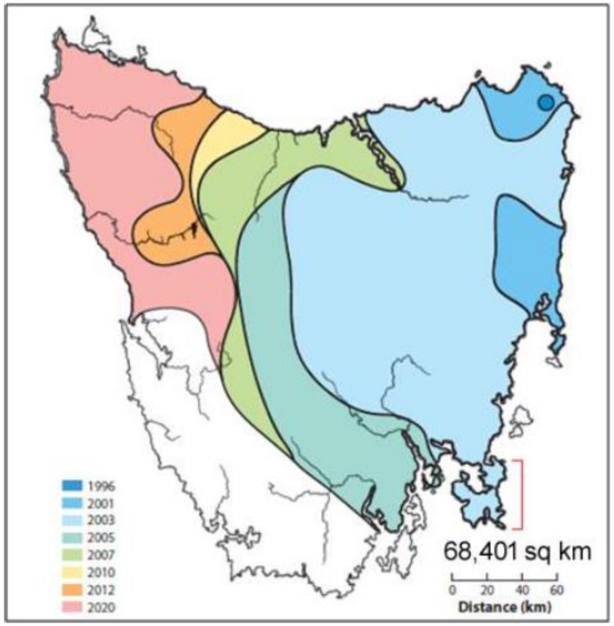
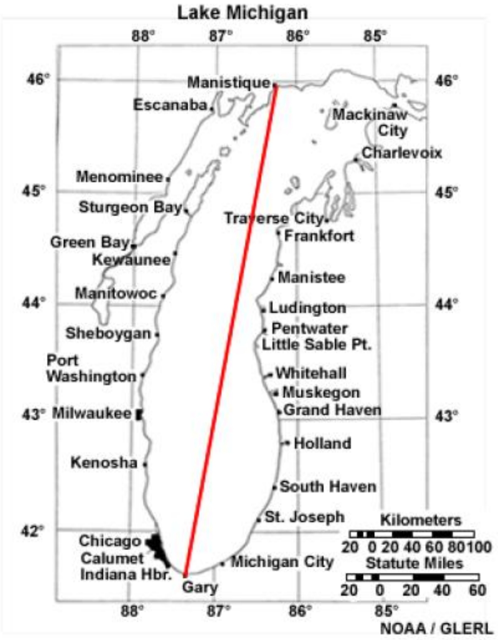



Fig. 6. Light micrograph of a histological section through the mantle of a mussel *Mytilus galloprovincialis* showing a gonad follicle filled with neoplastic cells.

**_Carballal et al. (2015) Neoplastic diseases of marine bivalves. J. Invertebr. Pathol.; 131:83-106._**

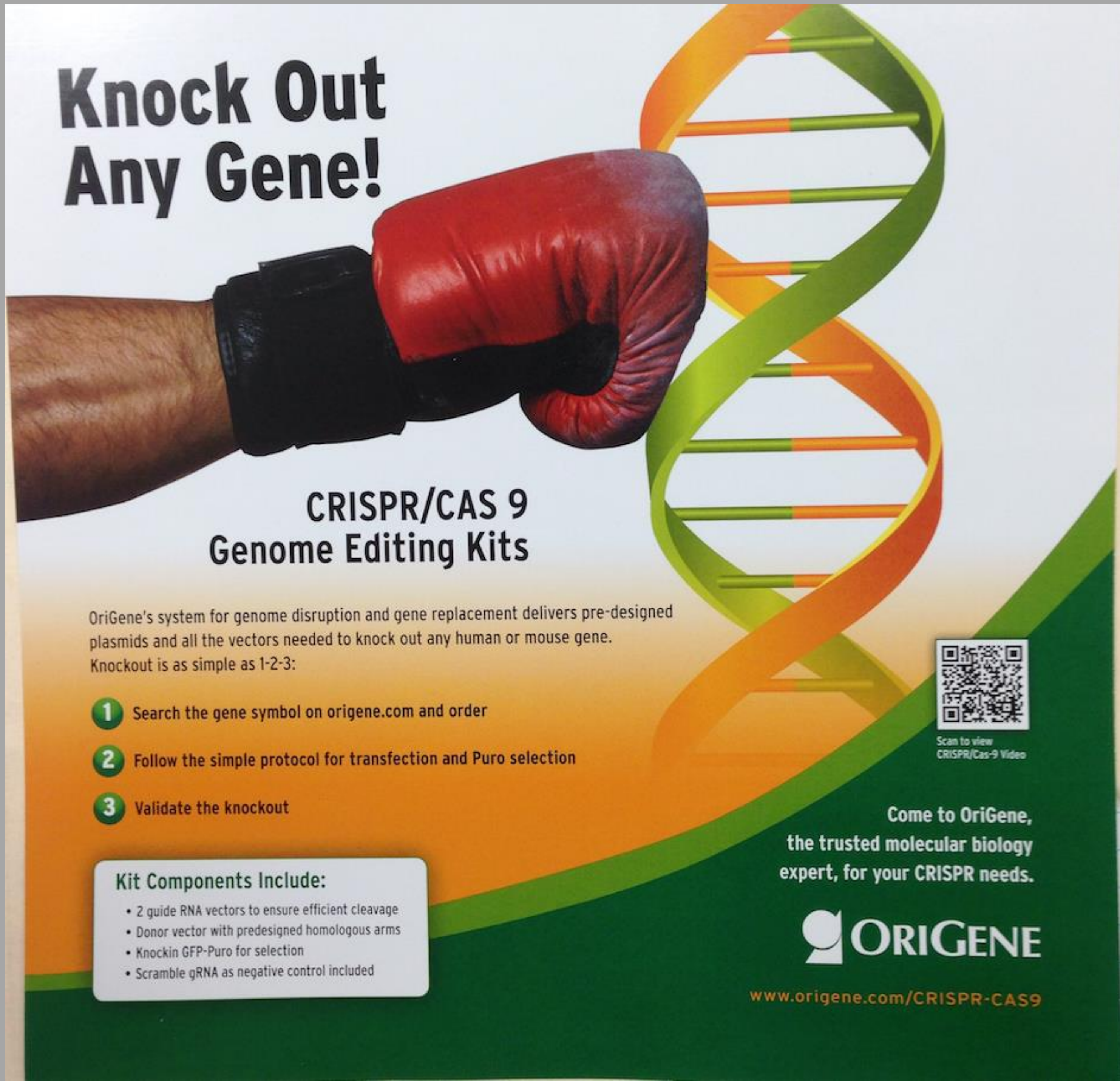
# Devil Facial Tumor Disease




## >90% decline in devil population since 1996 and extinction by 2026.

*Stammnitz et al. (2018) Cancer Cell 33, 607–619 April 9, 2018*
*Bender et al. (2014) Ann. Rev. Anim. Biosci. 2014; 2: 165-187.*


Knock Out Any Gene!
CRISPR/CAS 9
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OriGene's system for genome disruption and gene replacement delivers pre-designed plasmids and all the vectors needed to knock out any human or mouse gene. Knockout is as simple as 1-2-3:
1 Search the gene symbol on origene.com and order
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Kit Components Include:
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Scan to view CRISPR/Cas-9 Video
Come to OriGene, the trusted molecular biology expert, for your CRISPR needs.
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May 14, 2018
The New York Times
As D.I.Y. Gene Editing Gains Popularity, 'Someone Is Going to Get Hurt'
After a virus was created from mail-order DNA, scientists are sounding the alarm about the genetic tinkering carried out in garages and living rooms.

Science 354:541 2016

# A reporter does CRISPR

*By* **Jon Cohen**

I speak biology fluently, but the molecular complexities of the novel genome-editing tool called CRISPR left me as befuddled as when I peruse descriptions of the inflationary universe. So I decided to test what one investigator told me: CRISPR (for "clustered regularly interspaced short palindromic repeats") may sound intimidating, but it is so simple to use that "any idiot" could do it.

I would give it a try.


Biologist Roland Wagner (left) watches as Jon Cohen attempts a key pipetting step in creating a CRISPR construct.

***Can any idiot do it?***

I've already learned that any idiot cannot do CRISPR: It takes, at least, basic laboratory skills.

Michael McWilliams, 2016, Tasmania

"The Usurpers"

# QUESTIONS?