Managing invasions on land and in water: What's worked and what hasn't

Dan Simberloff
University of Tennessee

Is management hopeless?

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.”

in Vince 2011, Science 331:1383-1384

Rubus niveus

Early detection/rapid response = EDRR

persistent problem: insufficient resources

not enough personnel ⟶

one response: educated citizenry and iPhones https://www.eddmaps.org/

Early detection/rapid response = EDRR

persistent problem: insufficient resources
not enough personnel ⟶

one response: educated citizenry and iPhones
another response: trained and organized volunteers

IPANE
Invasive Plant Atlas of New England

weed spotters

Victoria, Australia

EDRR

EARLY DETECTION
& RAPID RESPONSE
NETWORK ONTARIO

https://edrrontario.ca/

Beetle Busters

Chicago Asian Longhorned Beetle Eradication Program

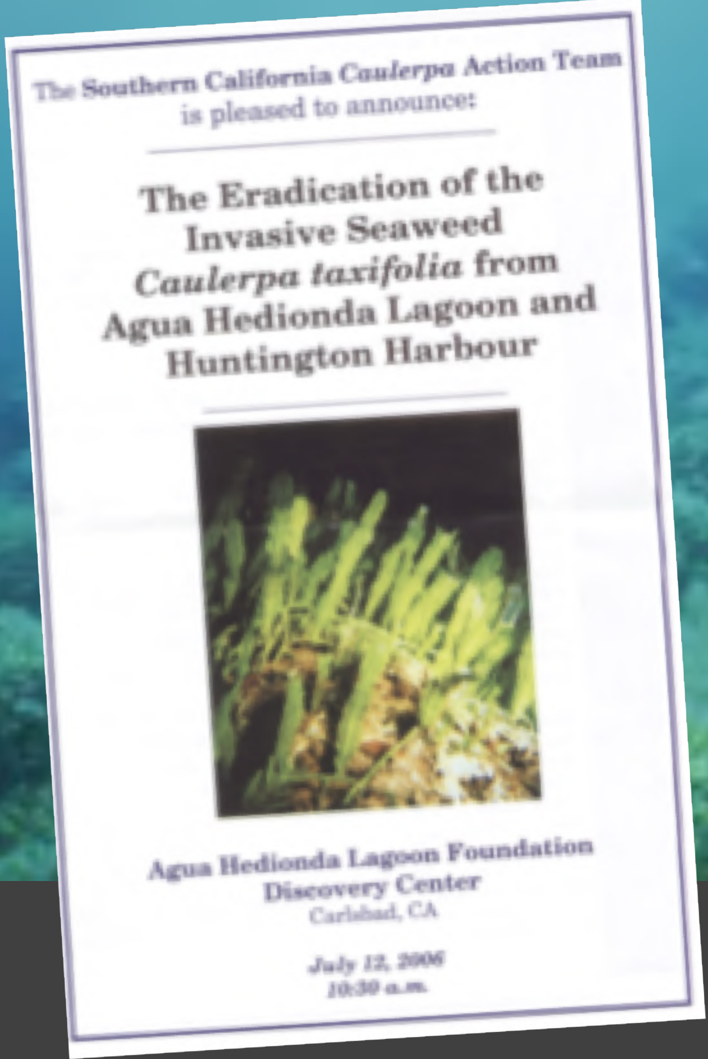
The Challenge

Illinois can claim one of the few victories in the war against invasive insects. Since the discovery of Asian Longhorned Beetle in Chicago in 1998, collaboration between the Forest Service, Animal and Plant Health Inspection Service, the state of Illinois and city of Chicago has accomplished an exciting achievement. The Chicago ALB Eradication Program is ready to declare the beetle eradicated from the city. All of the quarantine areas were deregulated in the spring of 2005, and during 2006 the Forest Service continued to work with the other cooperators to promote the successful completion of the two years of negative surveys required for a declaration of eradication.

The Solution

The U.S. Forest Service assumed a partnership role with APHIS in their "Beetle Busters" campaign to reach out to the public and the media in publicizing this effort. Outreach tools such as the ALB Identification card were

As part of the "Beetlebusters" campaign, Chicago schoolchildren learn to recognize ALB damage and the insect itself. Above, a US Forest Service smokejumper who

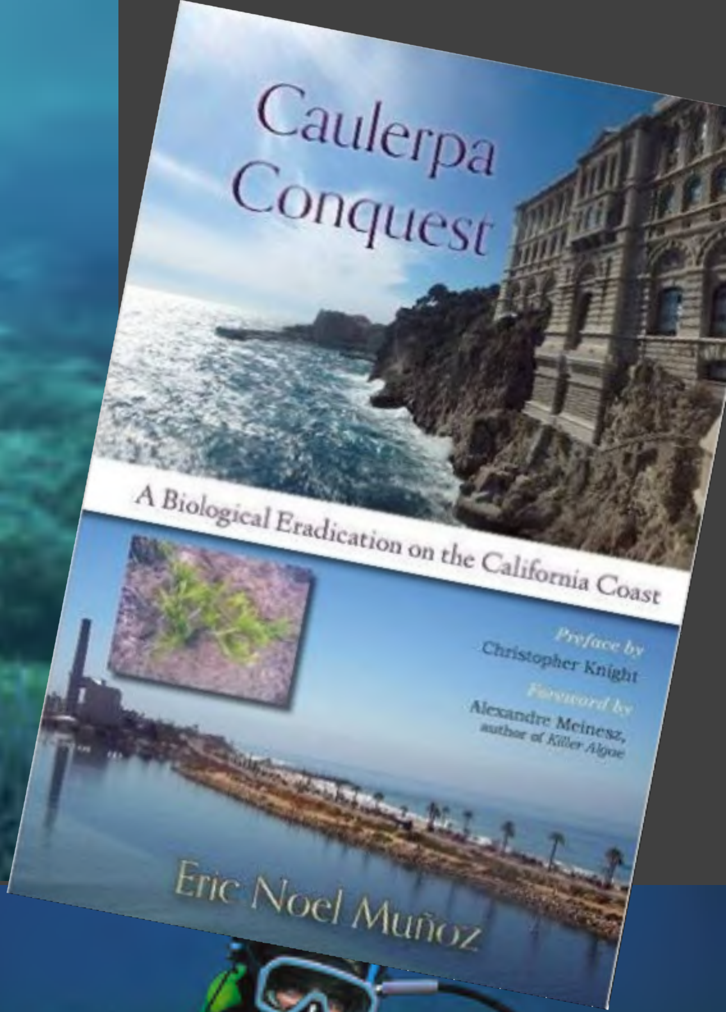


The Southern California *Caulerpa* Action Team
is pleased to announce:

The Eradication of the Invasive Seaweed *Caulerpa taxifolia* from Agua Hedionda Lagoon and Huntington Harbour

Agua Hedionda Lagoon Foundation
Discovery Center
Carlsbad, CA

July 12, 2006
10:30 a.m.



Caulerpa taxifolia

California

Courtesy CSIRO Marine Research Division

An Australian Government Initiative

THE NATIONAL SYSTEM FOR THE PREVENTION AND MANAGEMENT OF MARINE PEST INCURSIONS

Australian Emergency Marine Pest Plan

(EMPPlan)

Rapid Response Manual

Mytilopsis sallei

and

Perna viridis

Version 1.0, 2015

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

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

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]

[1]Department of Biology, McGill University, Montreal, Quebec, Canada H3A 1B1; email: melania.cristescu@mcgill.ca

[2]Centre for Biodiversity Genomics and Department of Integrative Biology, University of Guelph, Ontario, Canada N1G 2W1

PLOS | ONE

Evaluation of the Environmental DNA Method for E... 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/jo...

NRC Research Press
RAPID COMMUNICATION

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

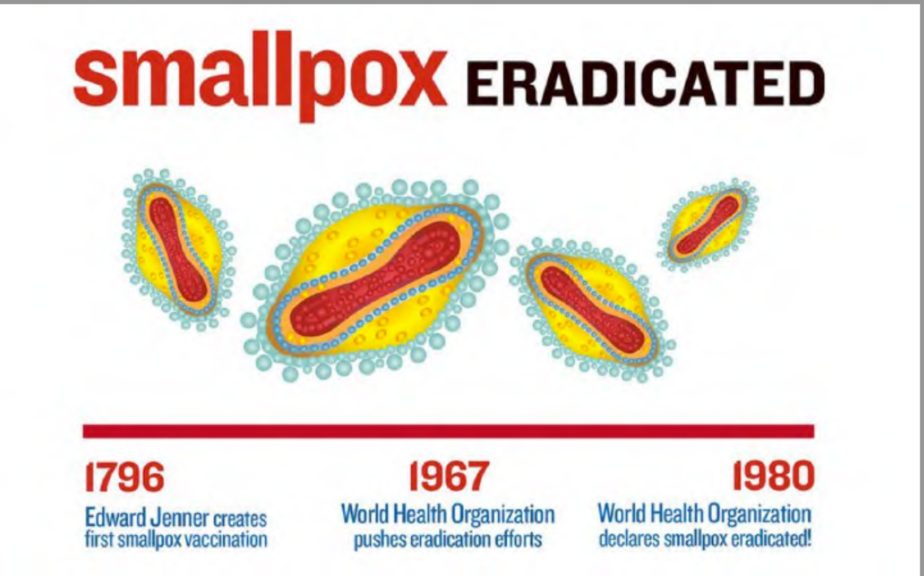
Christopher L. Jerde, W. Lindsay Chadderton, Andrew R. Mahon, Mark A. Renshaw, Joel Corush, Michelle L. Budny, Sagar Mysorekar, and David M. Lodge

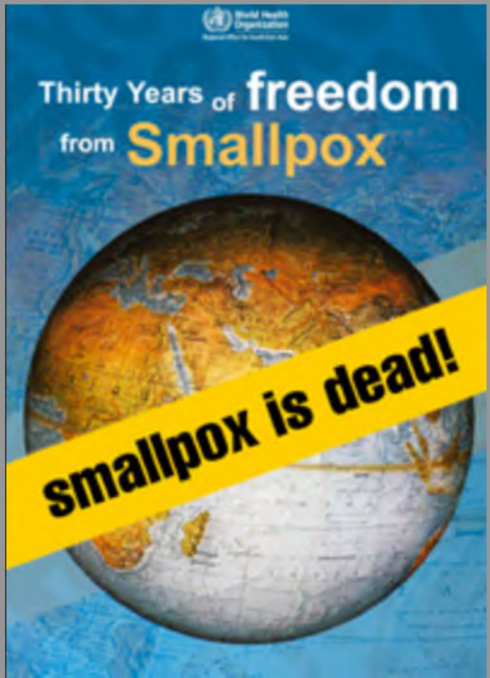
eradication = total elimination of
population(s) from a
discrete, separate region

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, Man Adapting



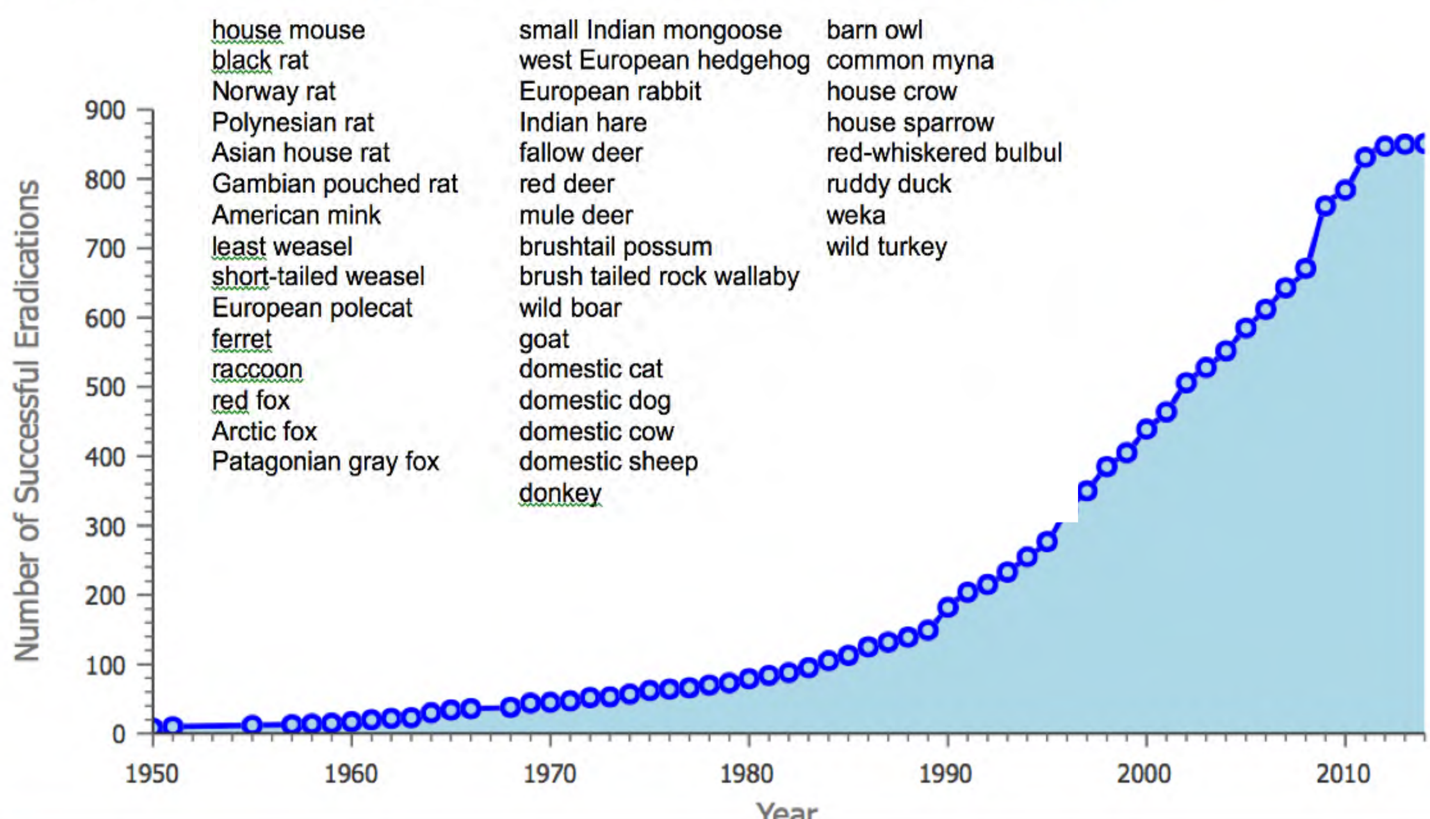


http://diise.islandconservation.org/

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

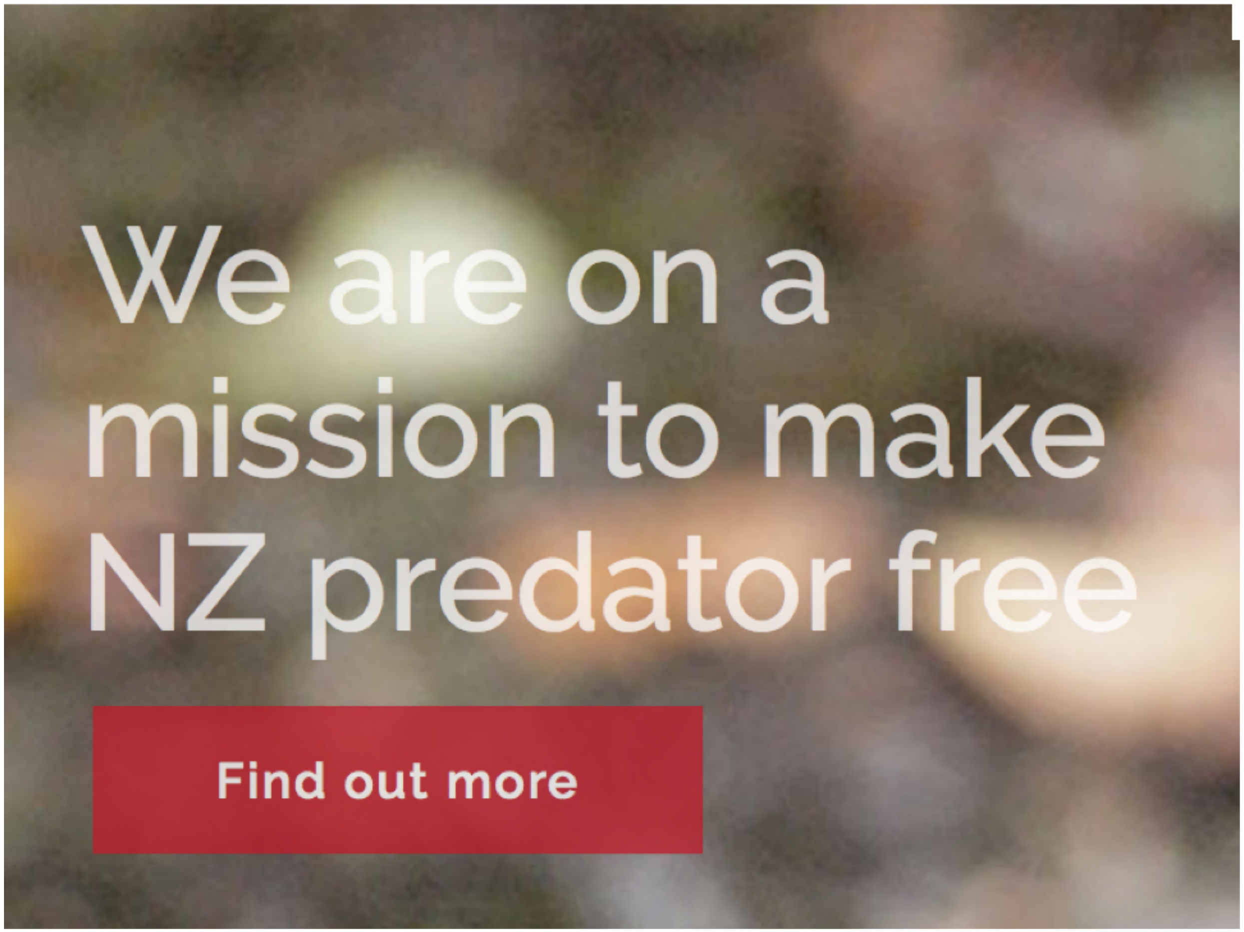
rats:	Macquarie Island		12,873 ha
	Campbell Island		11,330 ha
	South Georgia Island		352,758 ha
house mouse:	Macquarie Island		12,873 ha
carnivore (mink):	Hiiumaa Island (Estonia)		102,560 ha
boar	Santiago (Galapagos)		58,041 ha
goat	Isabela (Galapagos)		458,812 ha

---

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.

PREDATOR Free NZ



predatorfreenz.org

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

g@rda
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**

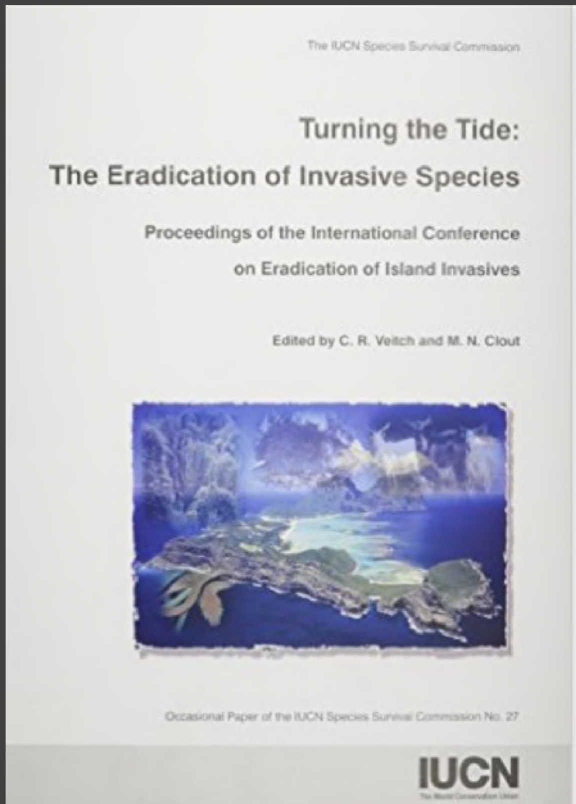
Rinderpest, Scourge of Cattle, Is Vanquished

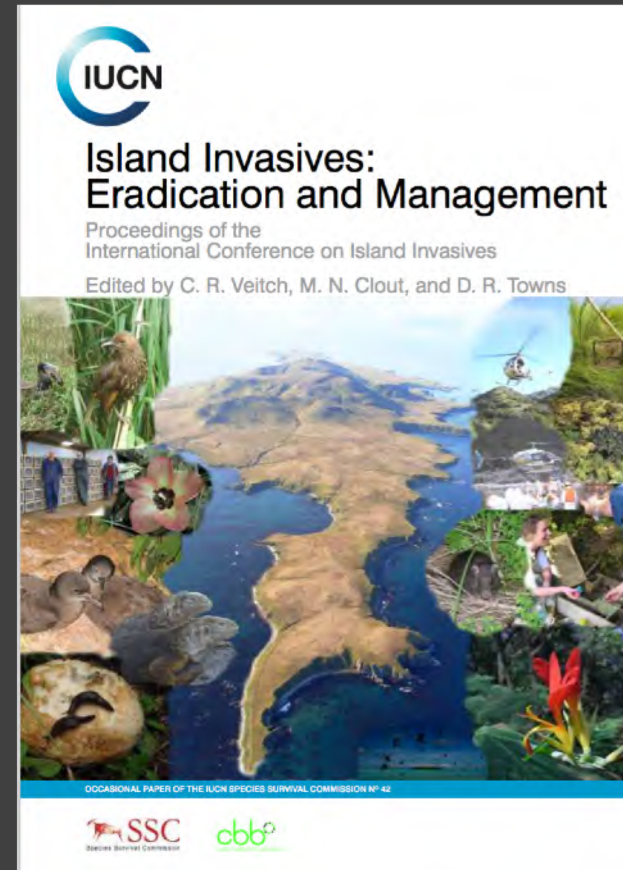
2011

F. Paladini

BEGONE Dr. William P. Taylor, in 1987 in Sudan, examined a cow for rinderpest. The United Nations is announcing this week that the disease has been wiped off the face of the earth.

2002		2011	





animals	plants	animals	plants
59	14	129	8

Kochia scoparia in Western Australia

1990 – introduced

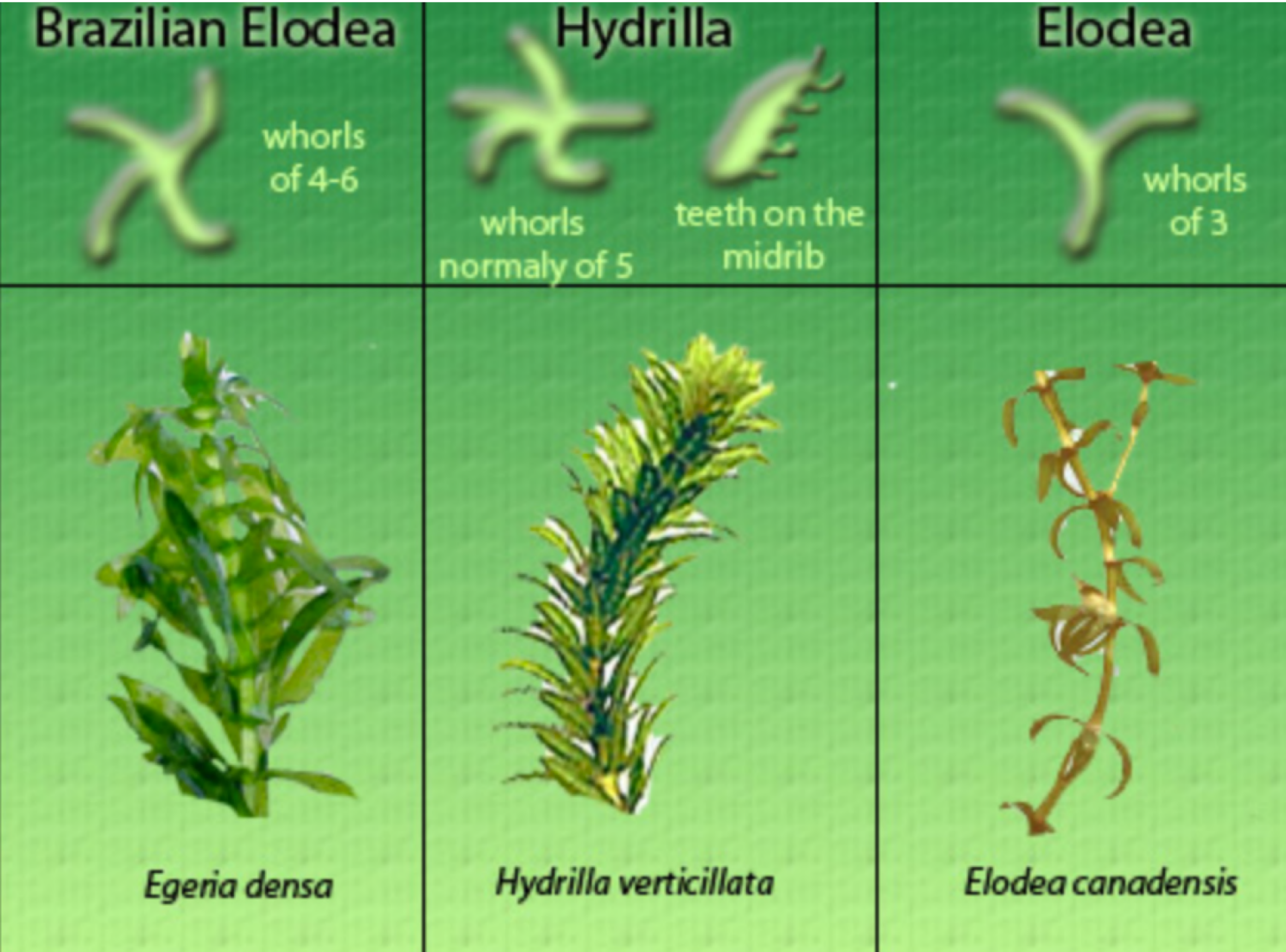
1992 – eradication campaign begun

1993 – 3,200 ha over 900 km

1995 – 139 ha

1999 – 5 ha

2000 - eradicated


Brazilian Elodea
Hydrilla
Elodea
whorls
of 4-6
whorls
normaly of 5
teeth on the
midrib
whorls
of 3
Egeria densa
Hydrilla verticillata
Elodea canadensis

Environ. Rev. 27: 71–94 (2019) dx.doi.org/10.1139/er-2018-0049

71

NRC Research Press

REVIEW

The effectiveness of non-native fish removal techniques in freshwater ecosystems: a systematic review

Trina Rytwinski, Jessica J. Taylor, Lisa A. Donaldson, J. Robert Britton, David R. Browne, Robert E. Gresswell, Mark Lintermans, Kent A. Prior, Marlow G. Pellatt, Chantal Vis, and Steven J. Cooke

77 attempted eradications, mostly successful, including:

- Gambusia in Australia
- carp in Spain
- spotted bass in South Africa
- trout in Sierra Nevada
- etc., etc., etc.

methods:

- rotenone
- antimycin
- electrofishing
- netting
- etc.

Aquatic Invasions (2010) Volume 5, Issue 1: 75-81
This is an Open Access article; doi: 10.3391/ai.2010.5.1.9

Proceedings of the 16th International Conference on Aquatic Invasive Species (19-23 April 2009, Montreal, Canada)

Research article

Eradication of introduced signal crayfish *Pasifastacus leniusculus* using the pharmaceutical BETAMAX VET.®

Roar Sandodden[1*] and Stein Ivar Johnsen[2]

[1]*National Veterinary Institute, Section for Environmental and Biosecurity Measures. Tungasletta 2. NO-7485 Trondheim, Norway*
[2]*Norwegian Institute for Nature Research (NINA). Fakkelgården, N-2624 Lillehammer, Norway*
E-mail: roar.sandodden@vetinst.no (RS), stein.ivar.johnsen@nina.no (SI.J)

Figure 1. Treatment of pond 5 with BETAMAX VET.® using a pump to disperse the chemical. Photo by Roar Sandodden.

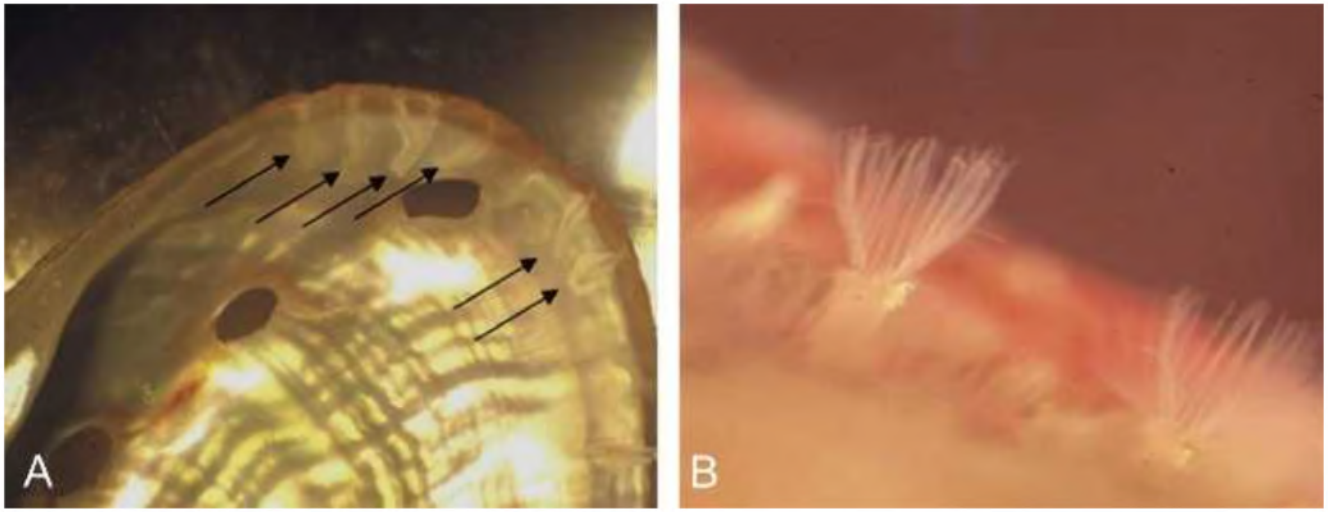
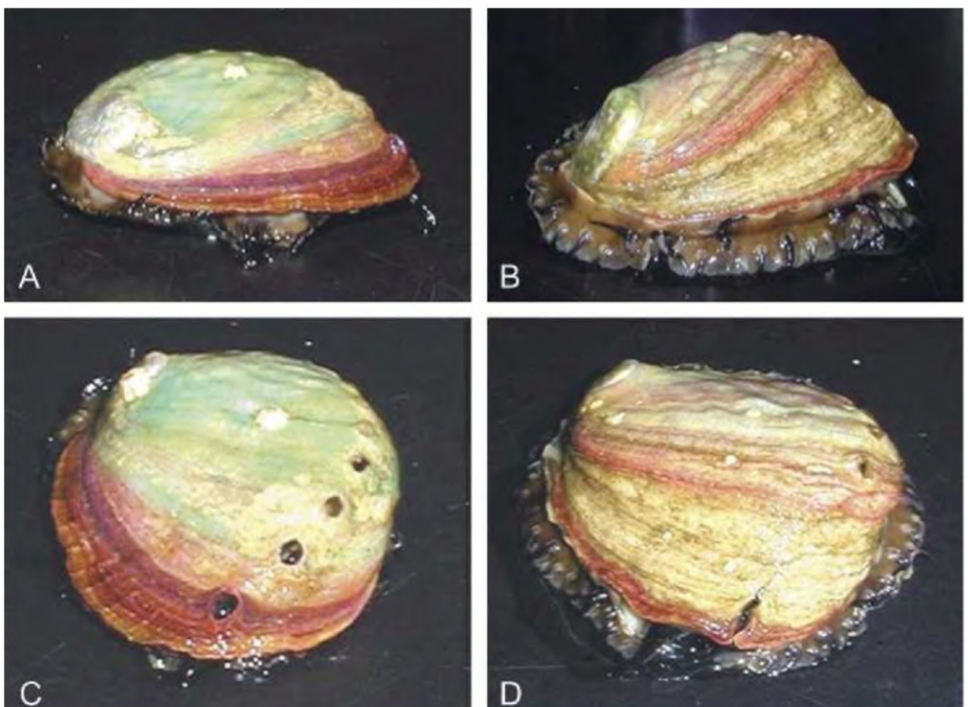


Figure 1. *Terebrasabella heterouncinata* infesting farmed red abalone *Haliotis rufescens*. A: Ventral view of lightly-infested juvenile *H. rufescens* shell with soft tissues removed. Arrows point to tubes of recently settled *T. heterouncinata*. B: Crowns of adult *T. heterouncinata* emerging from burrows on the dorsal surface of *H. rufescens* shell.



J.D. Moore et al. 2007. Journal of Shellfish Research 26(3):869-876.

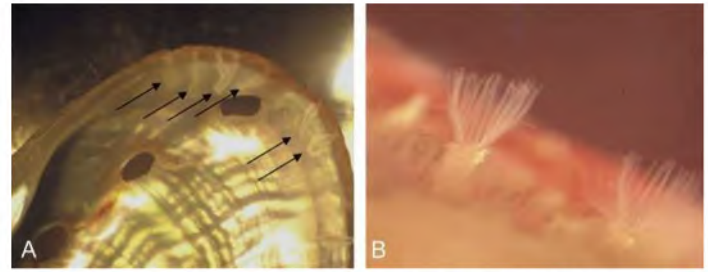
Biological Invasions **2:** 245–253, 2000.

The apparent eradication of a locally established introduced marine pest

Carolynn S. Culver* & Armand M. Kuris
*Ecology, Evolution & Marine Biology and the Marine Science Institute, University of California, Santa Barbara, CA 93106, USA; *Author for correspondence (e-mail: c_culver@lifesci.ucsb.edu; fax: +1-805-893-8062)*

Received 3 June 1999; accepted in revised form 12 September 2000

Key words: abalone, aquaculture, eradication, management, molluscs, polychaete, sabellid



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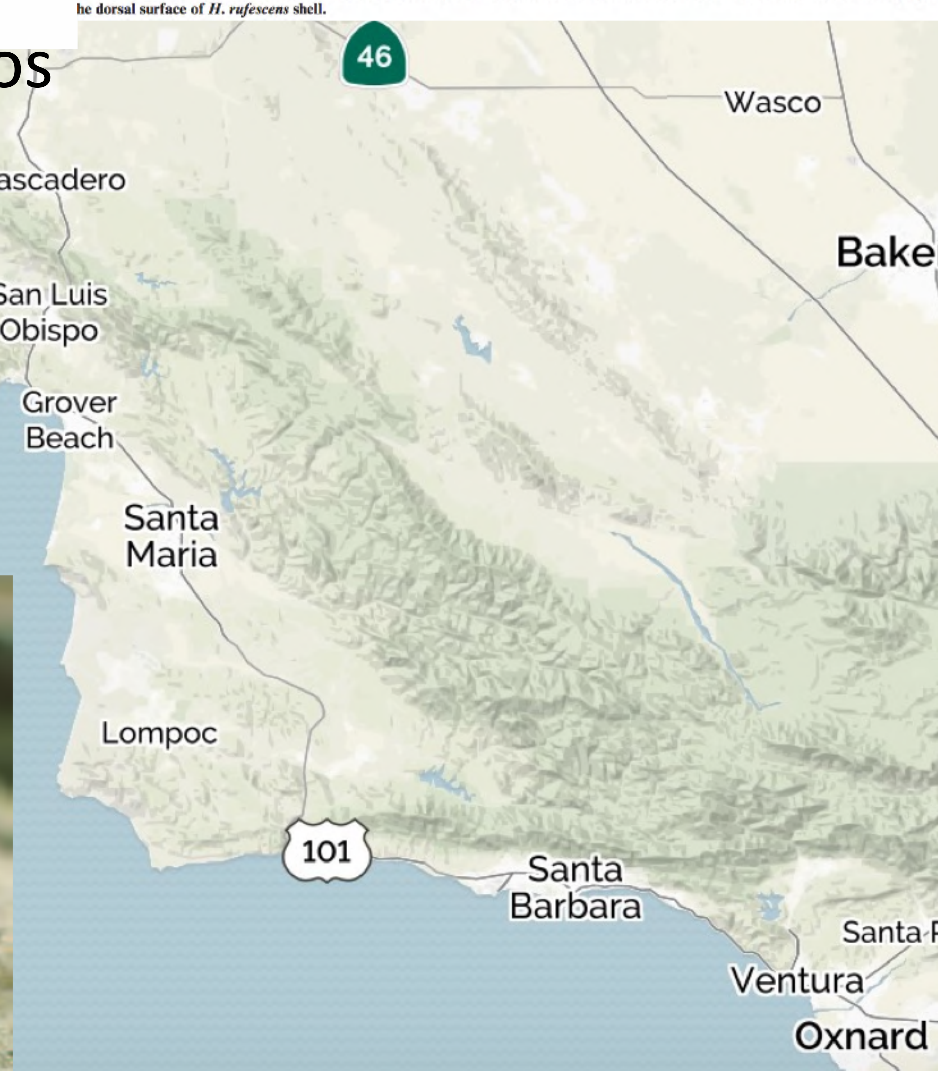


Tegula funebralis

Journal of Applied Ecology

British Ecological Society

Journal of Applied Ecology 2011, **48**, 424–431 doi: 10.1111/j.1365-2664.2010.01941.x

Successful eradication of a non-indigenous marine bivalve from a subtidal soft-sediment environment

Grant A. Hopkins[1]*, Barrie M. Forrest[1], Weimin Jiang[1] and Jonathan P. A. Gardner[2]

[1]*Cawthron Institute, Private Bag 2, Nelson 7010, New Zealand; and* [2]*Centre for Marine Environmental & Economic Research, School of Biological Sciences, Victoria University of Wellington, PO Box 600, Wellington, New Zealand*

Fig. 1. Location of the defouling site in Tasman Bay (41°S, 173°E), New Zealand. Water depth at the site ranged between 42 and 44 m.

Perna perna = brown mussel

FIG. 1. Locations of intertidal surveys in San Francisco Bay (California, USA) completed between 1 June 2001 and 20 September 2002. The black circle marks the location of *Ascophyllum nodosum*, and white circles indicate locations that were surveyed but where *A. nodosum* was not detected.

MAINTENANCE MANAGEMENT

physical and mechanical control

chemical control

biological control

sterile male, mating disruption, etc.

volunteers

GRAND CANYON WILDLANDS COUNCIL

www.grandcanyonwildlands.org

tamarisk removal

Lee's Ferry, 2 years after tamarisk cleared. Fremont cottonwood, Gooding's willow, four-winged saltbush, inkweed GCWC

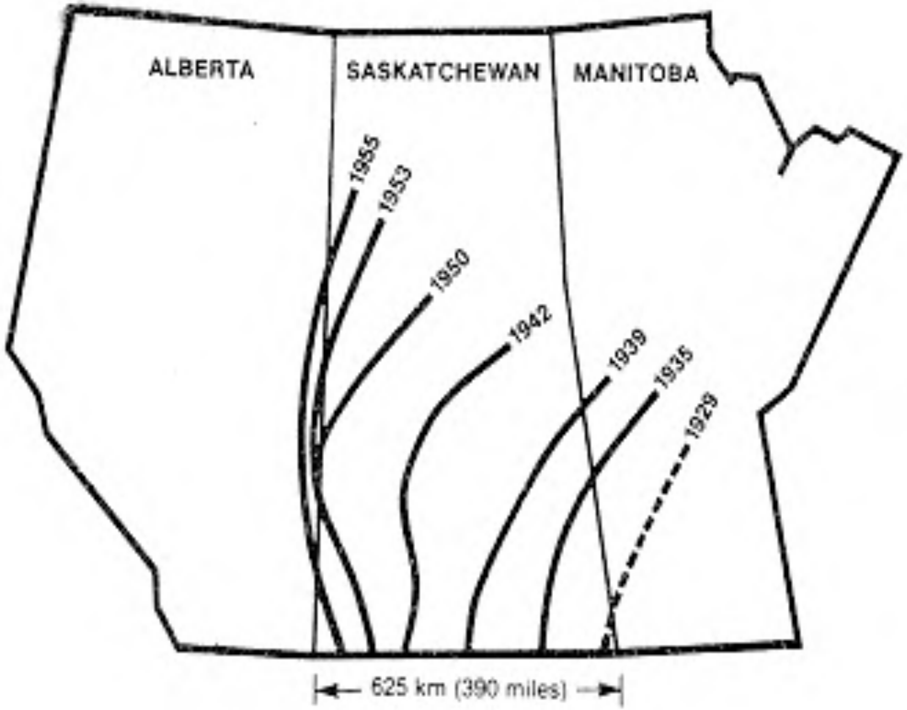
1) Physical/mechanical control:

New Brontosaurus Eats Up Exotic Vegetation

Machine maintains lands of preservation

By Kevin Lollar, klollar@news-press.com

westward movement of the Norway rat across the prairies



Any season is open season for these hunters

LARRY WONG, THE JOURNAL

Alberta Rat Control officers, from left, Orest Popil, Bruce Alexander and Bill Kloeckes check out a farm field for rats near Kitscoty. The Norway rat on the bale of hay in the foreground has been stuffed.

Dedicated patrol scours the border to keep Alberta rat-free

JEFF HOLUBITSKY
Journal Staff Writer
KITSCOTY, ALTA.

The good: The rat patrol — a magnificent seven rodent-savvy hunters armed with shotguns, poison bait and an iron will to destroy every rat crossing Alberta's border with Saskatchewan, from Montana to the boreal forests north of Cold Lake, at a cost of about $250,000 a year.

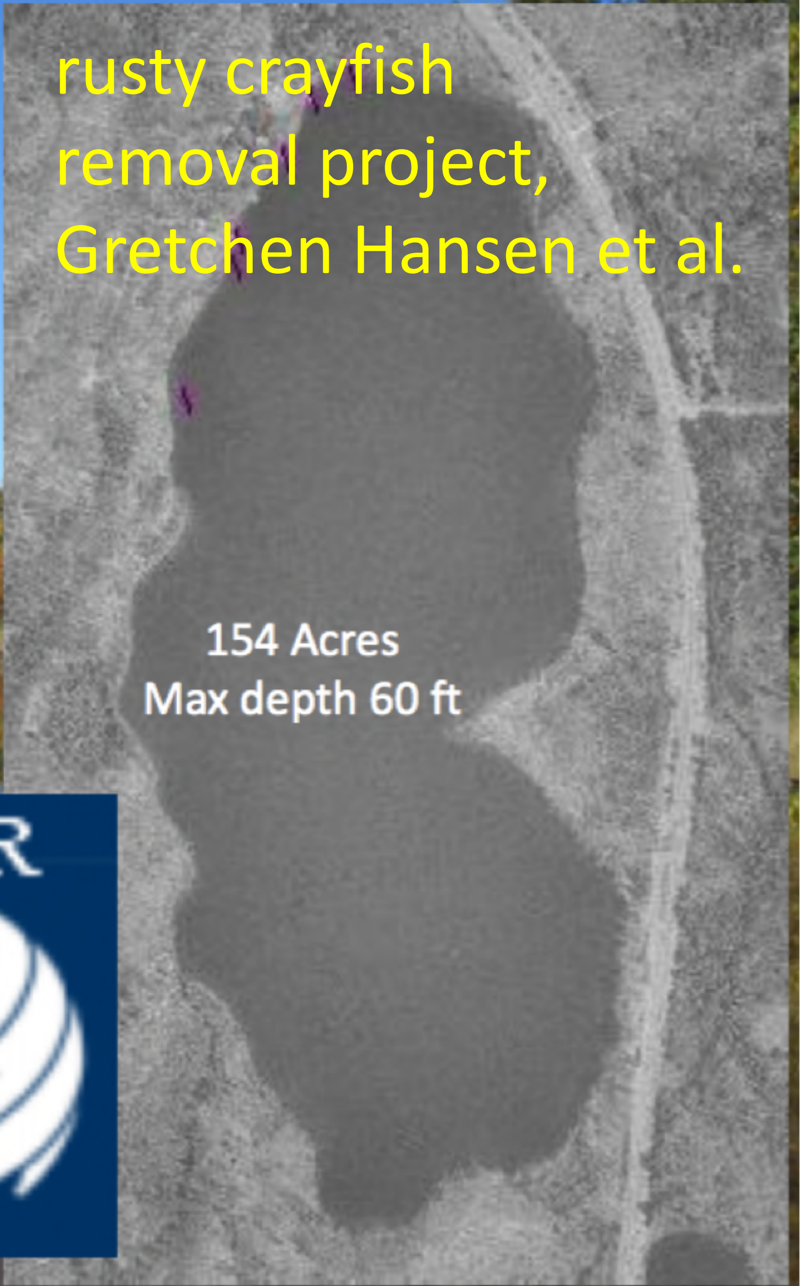
The bad: The Norway rat — weighing about half a kilogram, this tropical animal originally from the jungles of Southeast Asia has spread to nearly every corner of the earth. Completely dependent on man for food and shelter, it is intelligent and can reproduce at astounding rates. In one year, a pregnant female could be the foundation of a colony of 10,000 reproducing offspring.

The ugly: A threat to Alberta's sales pitch of clean grain. Albertans won't find rat droppings in their bread and morning cereal unless it's imported. Rats could bring an end to this peculiar Alberta advantage and cost the agriculture industry an estimated $50 million a year in lost crops and sales.

See RATS / A7

Sparkling Lake

rusty crayfish removal project, Gretchen Hansen et al.



LTER

Trapping effort was high

- Intensively trapped June-August, 2001-2008
- 100-300 traps per day
- 1,300-15,000 "trap days" per year
- 91,930 crayfish removed


“High crayfish”
“Low crayfish”

Environ. Rev. 27: 71–94 (2019) dx.doi.org/10.1139/er-2018-0049

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NRC Research Press

REVIEW

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69 attempted maintenance management projects, mostly successful, including:

- lake trout in Yellowstone Lake
- Atlantic brown trout in France
- topmouth gudgeon in Great Britain
- tilapia in Australia
- etc., etc., etc.

methods:

- rotenone
- antimycin
- electrofishing
- netting
- biocontrol
- etc.


Conveyor # 15 removing water hyacinth
from Caloosahatchee River - 1939
Courtesy U.S. Army Corps of Engineers
Jacksonville Archives

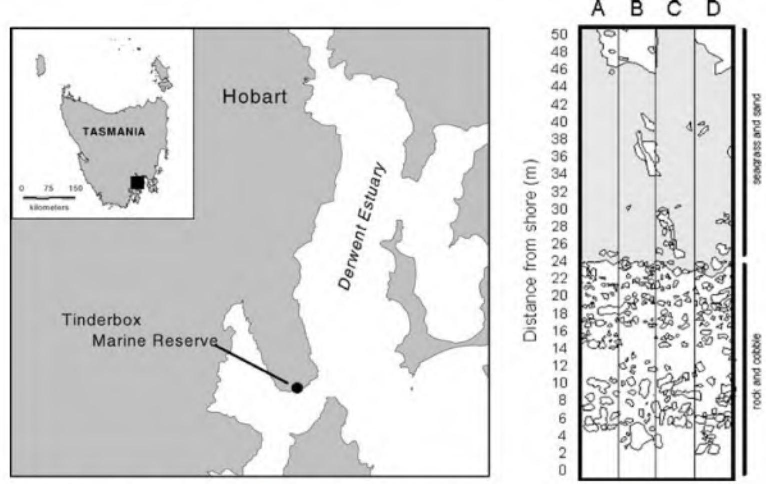


Figure 1. (a) Location of Tinderbox Marine Reserve in relation to Hobart, Tasmania; (b) habitat map of the four removal transects. Transect orientation is southeast (147°) from shore. Rocky platform extends from 0 m to ca. 24 m; grey shading represents sandy habitat with seagrass; white represents rock and cobble.

Undaria pinnatifida

C.L. Hewitt et al. 2005
Biol. Inv. 7:251-263

Vol. 22: 175–182, 2013
doi: 10.3354/esr00542
ENDANGERED SPECIES RESEARCH
Endang Species Res
Published online December 2

Effectiveness of lionfish removal efforts in the southern Caribbean

Ramón de León[1], Kim Vane[2], Paulo Bertuol[1], Valérie C. Chamberland[2,3], Fernando Simal[1], Eseld Imms[4], Mark J. A. Vermeij[2,3,*]

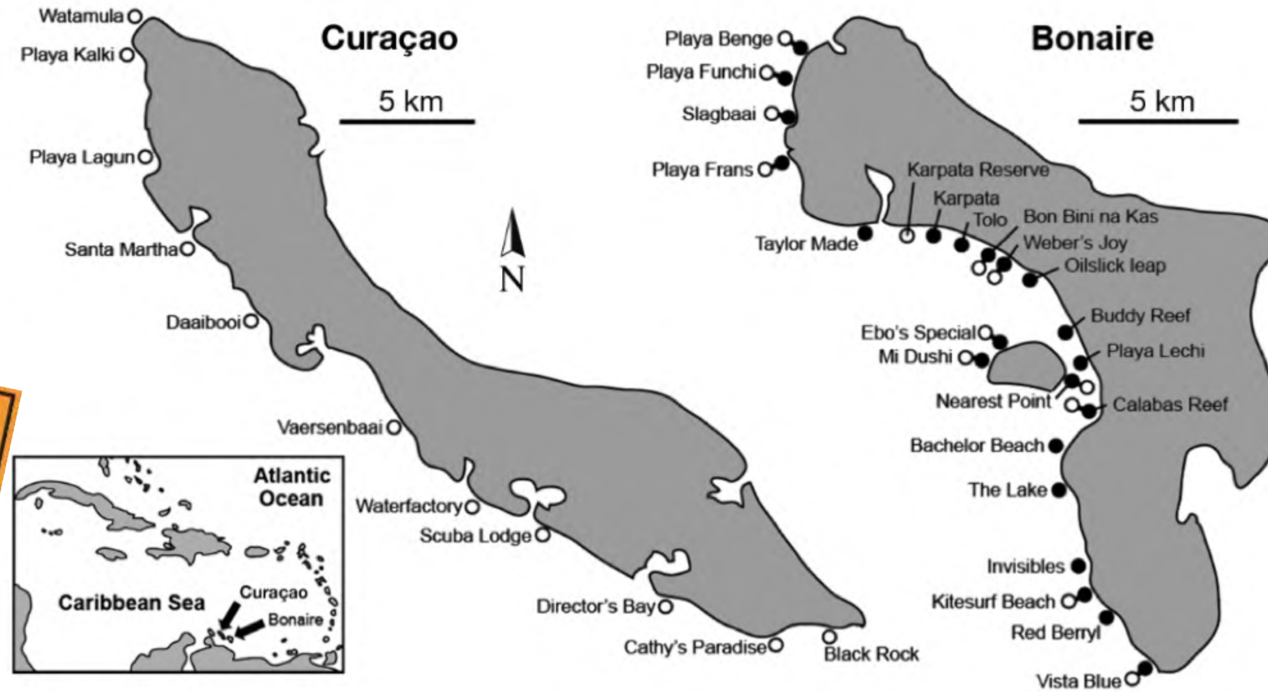
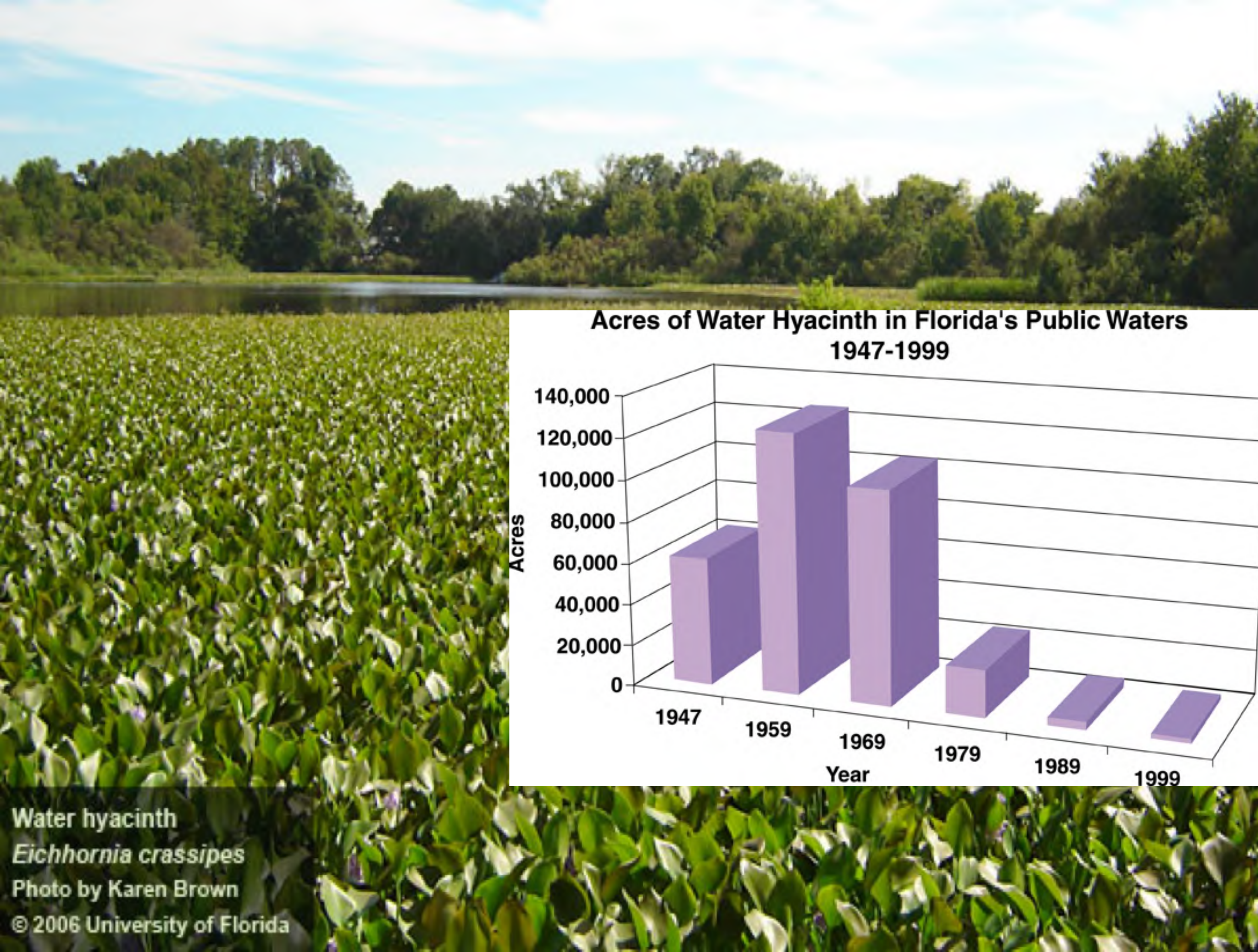


Fig. 1. Surveyed locations on the leeward side of Curaçao and Bonaire. Open circles indicate locations where lionfish were not fished in 2011; closed circles indicate fished locations. Neighbouring black and white circles at certain locations on Bonaire indicate that surveys at 1 location were conducted at a fished site and an unfished site nearby (>200 m)



Water hyacinth
Eichhornia crassipes
Photo by Karen Brown

Hydrilla verticillata

Environ. Rev. 27: 71–94 (2019) dx.doi.org/10.1139/er-2018-0049

71

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- tilapia in Australia
- etc., etc., etc.

methods:

rotenone	biocontrol
antimycin	etc.
electrofishing	
netting	

Microencapsulated BioBullets for the Control of Biofouling Zebra Mussels

DAVID C. ALDRIDGE,*[,†]
PAUL ELLIOTT,[†] AND
GEOFF D. MOGGRIDGE[‡]
Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, U.K., and Department of Chemical Engineering, University of Cambridge, Pembroke Street, Cambridge CB2 3RA, U.K.

The widespread invasion of freshwaters by the zebra mussel, *Dreissena polymorpha*, during the last 2 decades has made it one of the world's most economically and ecologically important pests. Since arriving in the North American Great Lakes in the 1980s, zebra mussels have become a major biofouler, blocking the raw water cooling systems of power stations and water treatment works and costing U.S. $1−5 billion per year. Despite the development of numerous control methods, chlorination remains the only widespread and licensed technique. Zebra mussels are able to sense chlorine and other toxins in their surrounding environment and respond by closing their valves, thus enabling them to avoid toxic effects for up to 3 weeks. Furthermore, prolonged dosing of chlorine in raw water produces ecotoxic trihalomethanes (THMs) by reaction with organic material in the water. We have developed a novel, environmentally safe, and effective method for controlling the zebra mussel: the BioBullet. Our method uses the encapsulation of an active ingredient (KCl) in microscopic particles of edible material. The mussels' natural filtering ability then removes and concentrates the particles from the water, without stimulating the valve-closing response. By using the mussels' filtering behavior to concentrate BioBullets the absolute quantity of active ingredient added to the water can be reduced substantially. Our approach allows us to engineer the particles to break up and dissolve completely within a few hours, thus eliminating the risk of polluting the wider ecosystem. We demonstrate that the effectiveness of a toxin in the control of biofouling filter-feeders can be enhanced greatly by using our technique. This paves the way for a new approach to the control of some of the world's most important economic pests.

Introduction

The introduction of nonnative taxa into novel localities represents one of the greatest threats to the world's ecosystems and economies (*1*−*3*). One of the most well-known examples comes from the invasion of the zebra mussel, *Dreissena polymorpha*, into the Laurentian Great Lakes of North America during the 1980s (*4*). Zebra mussels are unusual among freshwater bivalves in possessing byssus which enables them to attach to hard substrates and form encrustations many individuals deep (*5*). Rapid population growth and invasion is assisted by high fecundities and the possession of planktonic veliger larvae that can disperse passively in the water column for up to 4 weeks before settling (*6*).

Zebra mussels can lead to system-level changes in invaded ecosystems and have led to local extirpation of some species of North American unionid mussels (*7, 8*). For industry, zebra mussel biofouling of pipelines that carry raw water can be devastating. In North America, numerous power plants have experienced fouling and blockage of the heat exchange pipes, screenhouses, steam condensers, and trash bars (*9*). In Britain, the recent spread of zebra mussels (*10*) has resulted in many water treatment works experiencing blockage of microstrainers and pumps, the occlusion of pipes, and the compromising of filter bed efficiency (*11*). In Spain, where zebra mussels were discovered in the Ebro River in 2001 (*12*), many thousands of kilometers of irrigation pipeline are threatened by zebra mussel fouling (J. Insausti, Government of Aragon, Spain, 2003, personal communication). In North America alone, zebra mussels are estimated to cost industry ca. U.S. $1−5 billion ($10^9$) each year (*1, 13*).

Considering the immense economic cost of zebra mussels, it is unsurprising that much effort has been put into developing control strategies (*6*). Physical removal, generally using high-pressure water jets, is only feasible within sections of industrial facilities where ready access is possible. Antifoulant coatings (e.g., copper-based) may offer practical preventative measures for new facilities or retrofitted screens but are difficult to apply to existing pipelines. Biological control using natural enemies offers an attractive option, and while fish and crayfish can regulate zebra mussel populations under some circumstances (*14, 15*), there appear to be no grounds for expecting the development of a practicable biological control method in the foreseeable future. Chemical control options are favored by industry because treatment can be applied throughout the entire facility from a single dosing point. Many chemicals will kill zebra mussels given sufficient concentration and contact time, but the suitability of a particular chemical is determined by considerations of water quality (e.g., residual concentrations, byproducts), cost, and practicality. Chemicals which have been tested to some success include chloramines, chlorine dioxide, ozone, hydrogen peroxide, potassium permanganate, pH adjustment, and inorganic salts, such as KCl (*6*).

While numerous physical and chemical techniques have been proposed and tested, chlorination remains the only widespread and licensed option (*6*). However, chlorination poses a number of problems for industry and regulators. First, chlorine reacts with organic material in the water to produce trihalomethanes (THMs) which are toxic to humans and other animals. This restricts greatly the chlorine doses that can be applied to water in infested water treatment works. Second, zebra mussels respond to unfavorable environmental conditions by closing their valves for prolonged periods (*6*). This means that control agents, such a chlorine in the form of sodium hypochlorite, must be dosed continuously for up to 3 weeks to have their desired effects. Third, hypochlorite is rather expensive and hazardous to transport, store, and handle. Fourth, chlorine dosed into pipelines that exit into open ecosystems can impact deleteriously on nontarget biota in the recipient waters. Indeed, many of the chemicals used

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[†] Department of Zoology.
[‡] Department of Chemical Engineering.

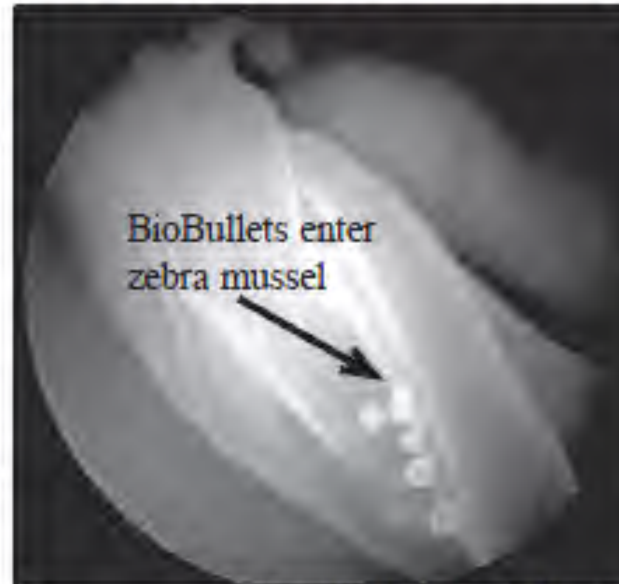
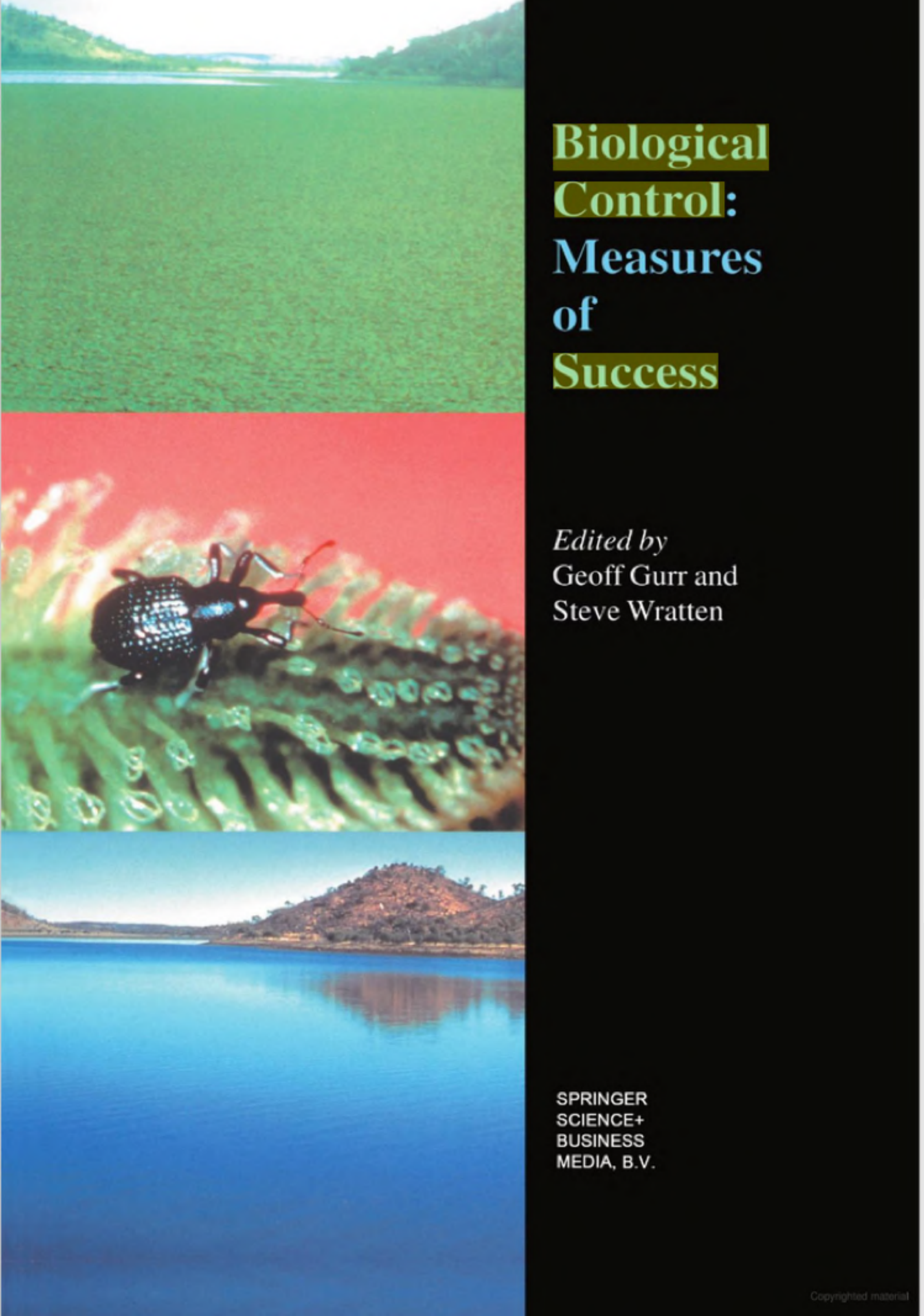


Photo by David Aldridge, University of Cambridge

BioBullets being transported along the gill of a live zebra mussel. The mussel has been fooled into treating the bullets as food, and will ingest their toxic payload.

2000



2018

BioControl (2018) 63:319–331
https://doi.org/10.1007/s10526-018-9890-8

CrossMark

REVIEW

Biological control of weeds: an analysis of introductions, rates of establishment and estimates of success, worldwide

M. Schwarzländer · Hariet L. Hinz · R. L. Winston · M. D. Day

For control of plants, ca. 2/3 survived, of which ca. 1/2 conferred at least some control.

2016

BioControl (2016) 61:349–363
DOI 10.1007/s10526-016-9726-3

CrossMark

REVIEW

Trends in the classical biological control of insect pests by insects: an update of the BIOCAT database

Matthew J. W. Cock · Sean T. Murphy · Moses T. K. Kairo · Emma Thompson · Rebecca J. Murphy · Antonio W. Francis

For control of insects, ca. 1/3 survived, of which ca. 1/3 conferred at least some control.

Annu. Rev. Entomol. 1995. 40:475–92

BIOLOGICAL CONTROL OF THE WINTER MOTH

Jens Roland
Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2E9

Douglas G. Embree
Canadian Forest Service, Maritimes Region, PO Box 4000, Fredericton, New Brunswick, Canada E3B 5P7

Winter moth *Operophtera brumata*

Cyzenis albicans

Agrypon flaveolatum

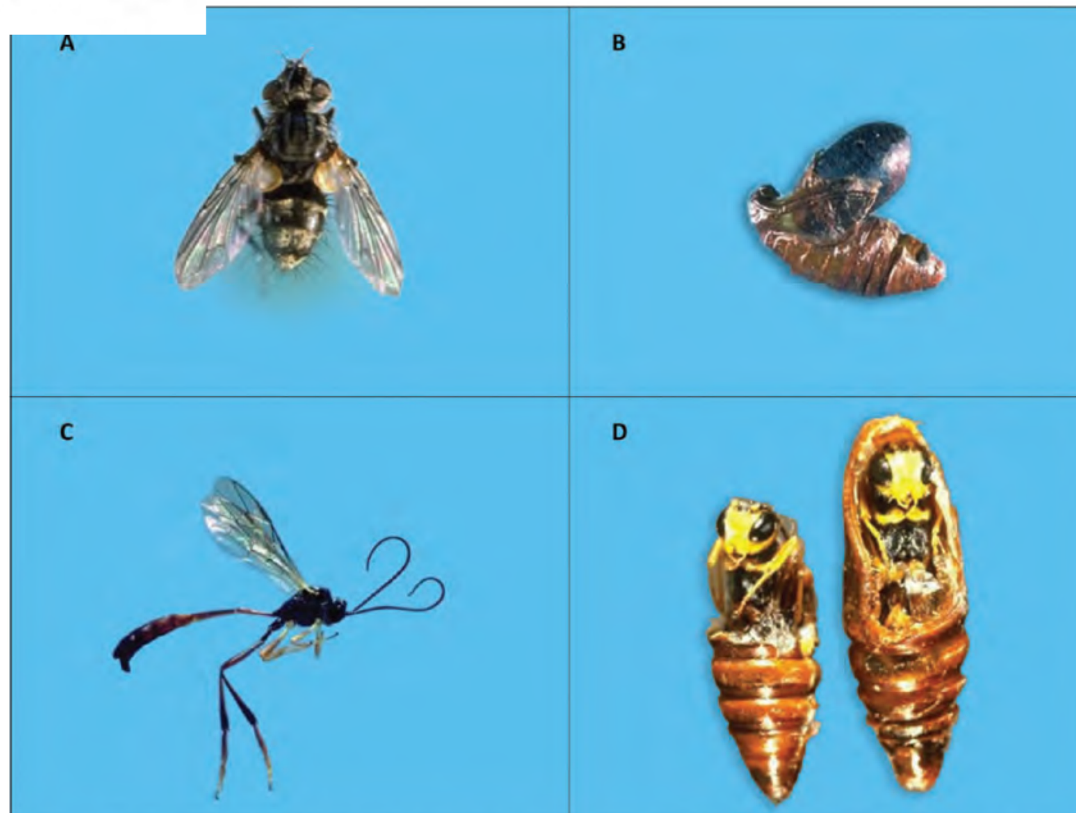
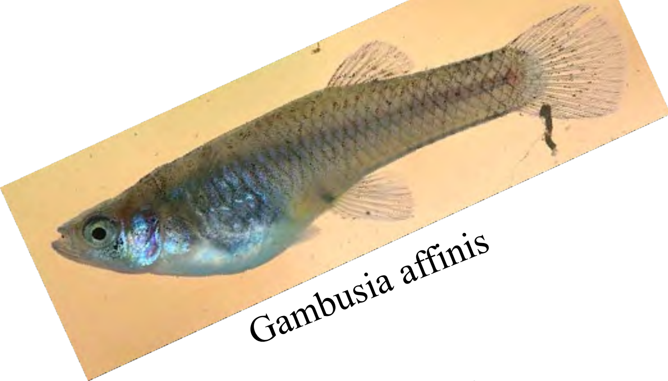


Figure 8 **A)** Adult *Cyzenis albicans*, **B)** *C. albicans* puparium inside winter moth pupa, **C)** adult *Agrypon flaveolatum*, **D)** pharate adult *A. flaveolatum* inside winter moth pupae (photos by Nicholas Condor).



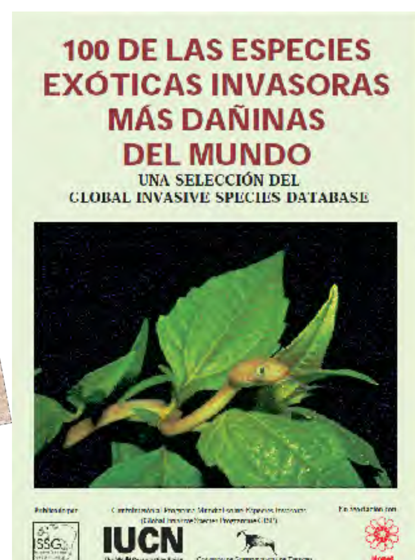
Gambusia affinis

Mustela erminea

Herpestes auropunctata

Acridotheres tristis

Platyhdemus manokwari

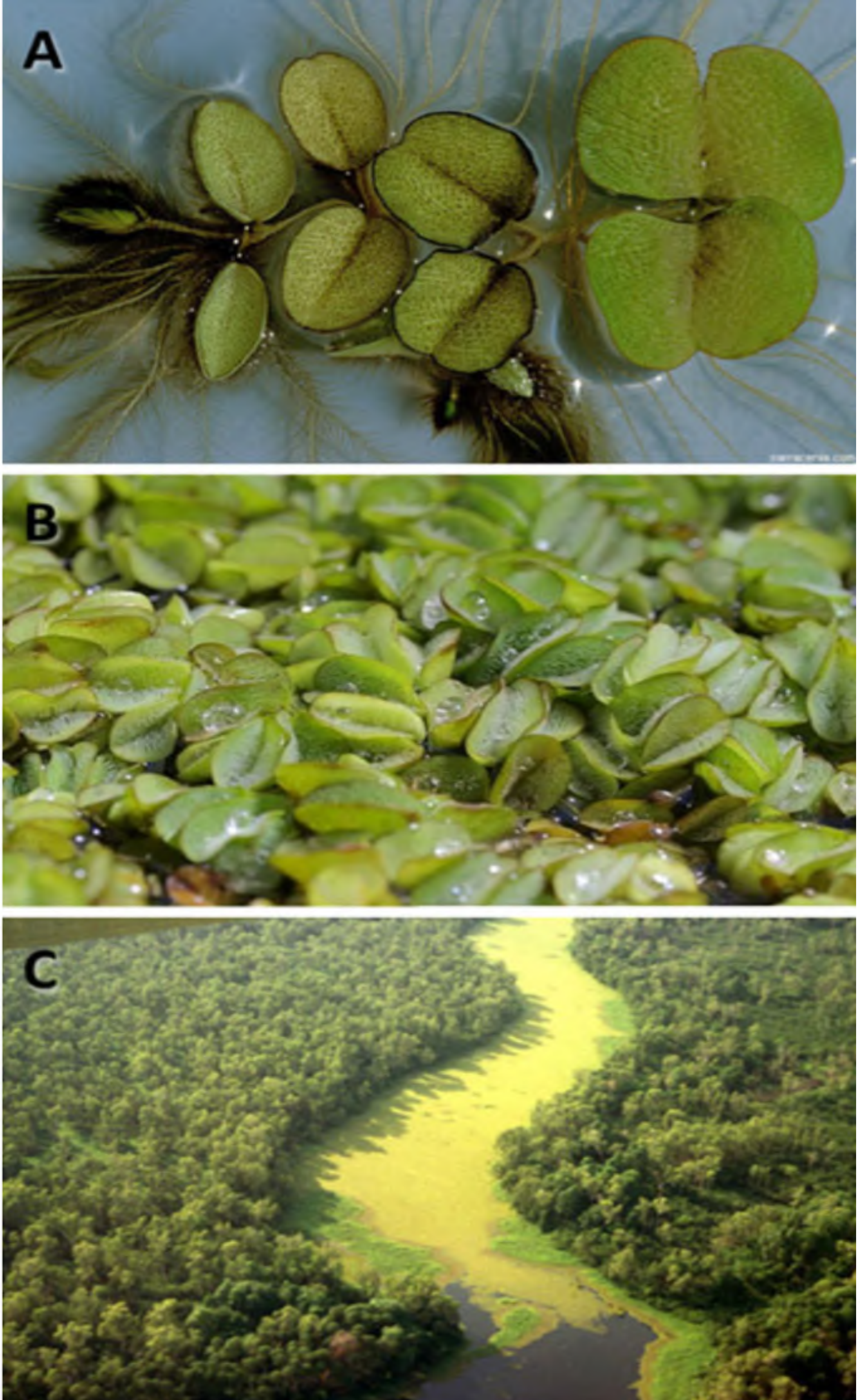


Rhinella marina

Lissachatina fulica

Euglandina rosea

alligatorweed flea beetle, *Agasicles hygrophila*



The weevil *Cyrtobagous salviniae* on a leaf of *Salvinia molesta*. Photo: S. Bauer.

Neochetina – 2 species

water hyacinth

grass carp (Ctenopharyngodon idella)

Annu. Rev. Ecol. Evol. Syst. 2008. 39:171–91

Plague Minnow or Mosquito Fish? A Review of the Biology and Impacts of Introduced *Gambusia* Species

Graham H. Pyke

Australian Museum, Sydney, NSW 2010, Australia; email: Graham.Pyke@austmus.gov.au

G. affinis

G. holbrooki

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PLOS | ONE

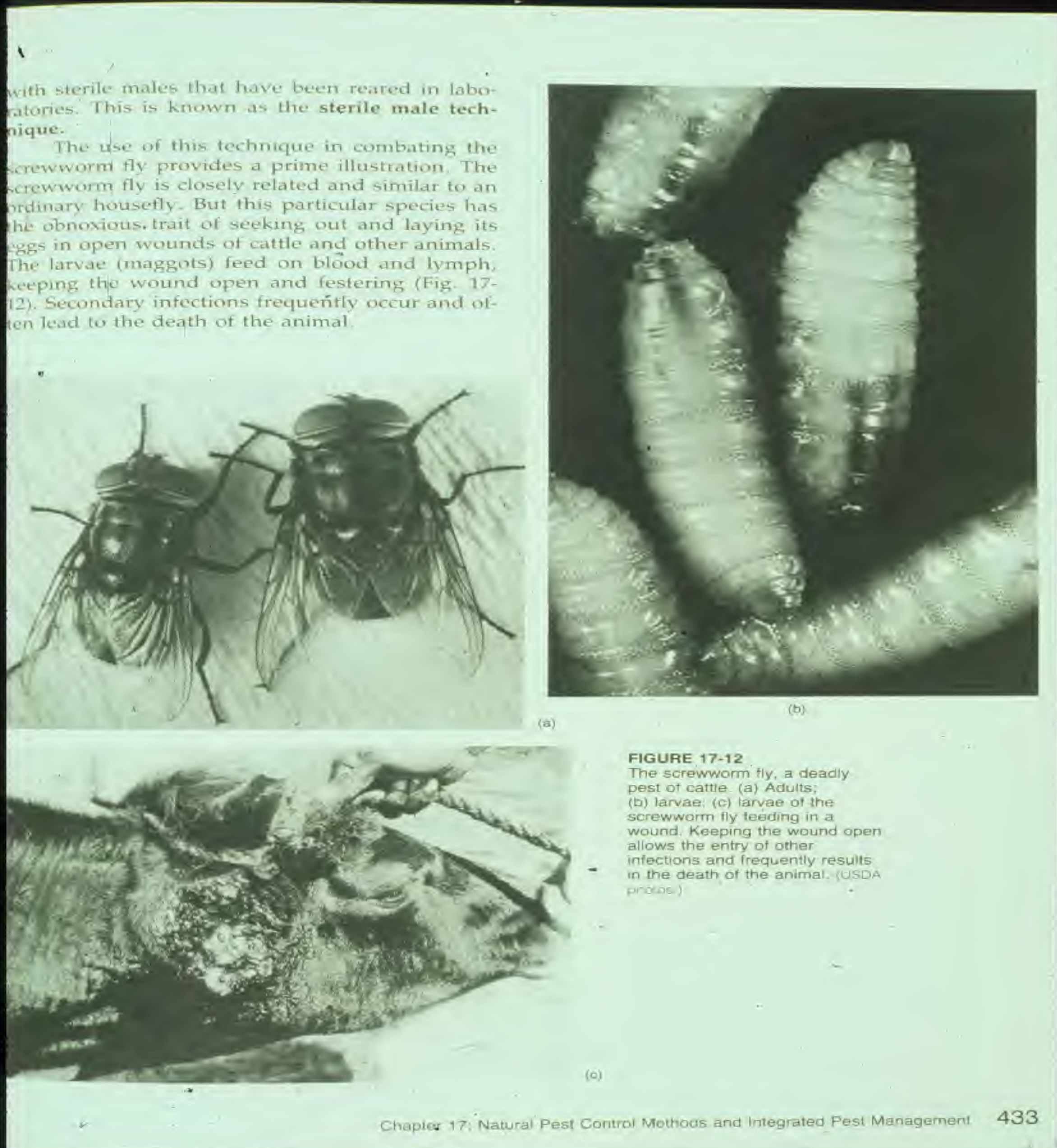
Augmentative Biocontrol in Natural Marine Habitats: Persistence, Spread and Non-Target Effects of the Sea Urchin *Evechinus chloroticus*

Javier Atalah*, **Grant A. Hopkins**, **Barrie M. Forrest**

Cawthron Institute, Nelson, New Zealand

Abstract

Augmentative biocontrol aims to control established pest populations through enhancement of their indigenous enemies. To our knowledge, this approach has not been applied at an operational scale in natural marine habitats, in part because of the perceived risk of adverse non-target effects on native ecosystems. In this paper, we focus on the persistence, spread and non-target effects of the sea urchin *Evechinus chloroticus* when used as biocontrol agent to eradicate an invasive kelp from Fiordland, New Zealand. Rocky reef macrobenthic assemblages were monitored over 17 months in areas where the



with sterile males that have been reared in laboratories. This is known as the **sterile male technique.**

The use of this technique in combating the screwworm fly provides a prime illustration. The screwworm fly is closely related and similar to an ordinary housefly. But this particular species has the obnoxious trait of seeking out and laying its eggs in open wounds of cattle and other animals. The larvae (maggots) feed on blood and lymph, keeping the wound open and festering (Fig. 17-12). Secondary infections frequently occur and often lead to the death of the animal.

(a)

(b)

(c)

FIGURE 17-12
The screwworm fly, a deadly pest of cattle. (a) Adults; (b) larvae; (c) larvae of the screwworm fly feeding in a wound. Keeping the wound open allows the entry of other infections and frequently results in the death of the animal. (USDA photos.)

Chapter 17: Natural Pest Control Methods and Integrated Pest Management 433

sterile male technique-

screwworm eradication

1954
Curaçao 444 km^2

Edward Knipling

International Atomic Energy Agency

IAEA

Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

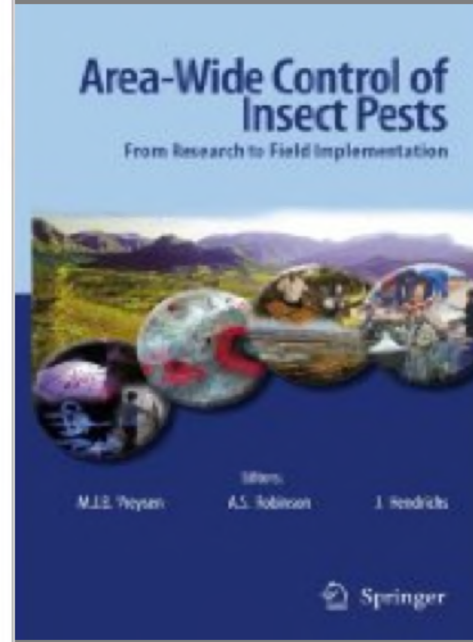
Insect & Pest Control Newsletter

http://www-naweb.iaea.org/nafa/index.html
http://www.fao.org/ag/portal/index_en.html
ISSN 1011-274X
No. 86, January 2016

Contents

To Our Readers

Images of representatives of each the four tephritid fruit fly cryptic species complexes studied to delimit species boundaries to overcome constraints to Sterile Insect Technique (SIT) application and international trade. A Anastrepha fraterculus, *B* Ceratitis rosa *(R2 type), C* Zeugodacus cucurbitae, *D* Bactrocera dorsalis *(Photo credits: A Michal Hoskovec, B and C Antoine Franck, D Ana Rodriguez).*



Annu. Rev. Entomol. 2008. 53:503–22

Codling Moth Management and Chemical Ecology

Peter Witzgall,[1] Lukasz Stelinski,[2] Larry Gut,[3] and Don Thomson[4]

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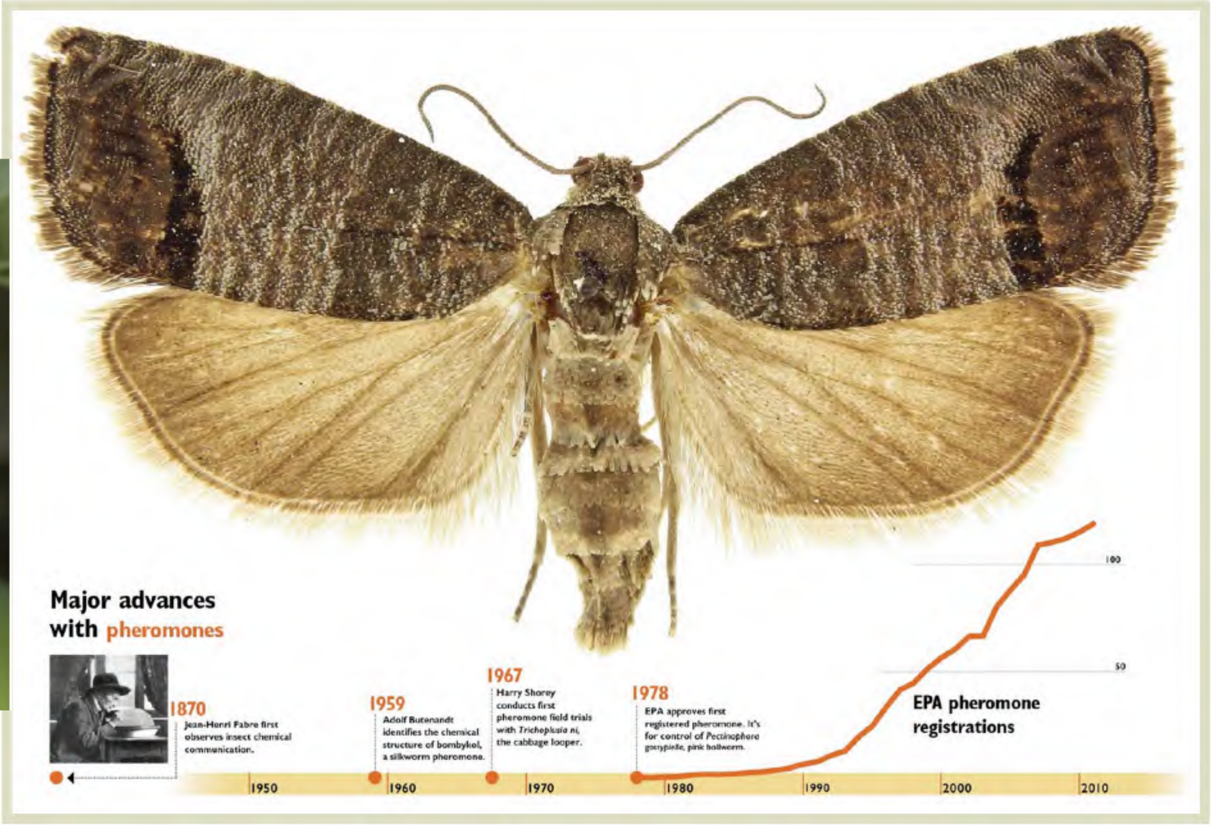
Key Words

pheromone, kairomone, sexual communication, integrated pest management



The Christian Science Monitor

How to beat the sea lamprey with its own pheromones, bile salts

Researchers are now closer to using the invasive species's predilection for bile salts against it.

By **Elizabeth Barber**, Contributor | OCTOBER 11, 2013

Save for later

John Flesher/AP | View Caption

Science AAAS

Though sea lampreys may be known for their sharp, pointy teeth, their sense of smell is highly sensitive. T. Lawrence/ GLFC

So long suckers! Sex pheromone may combat destructive lampreys

By Kerry Klein | Jan. 20, 2016 , 1:30 PM

Terrestrial

Many successes in both eradication and maintenance management
Improved technologies, mostly incremental advances, some totally new approaches

Aquatic

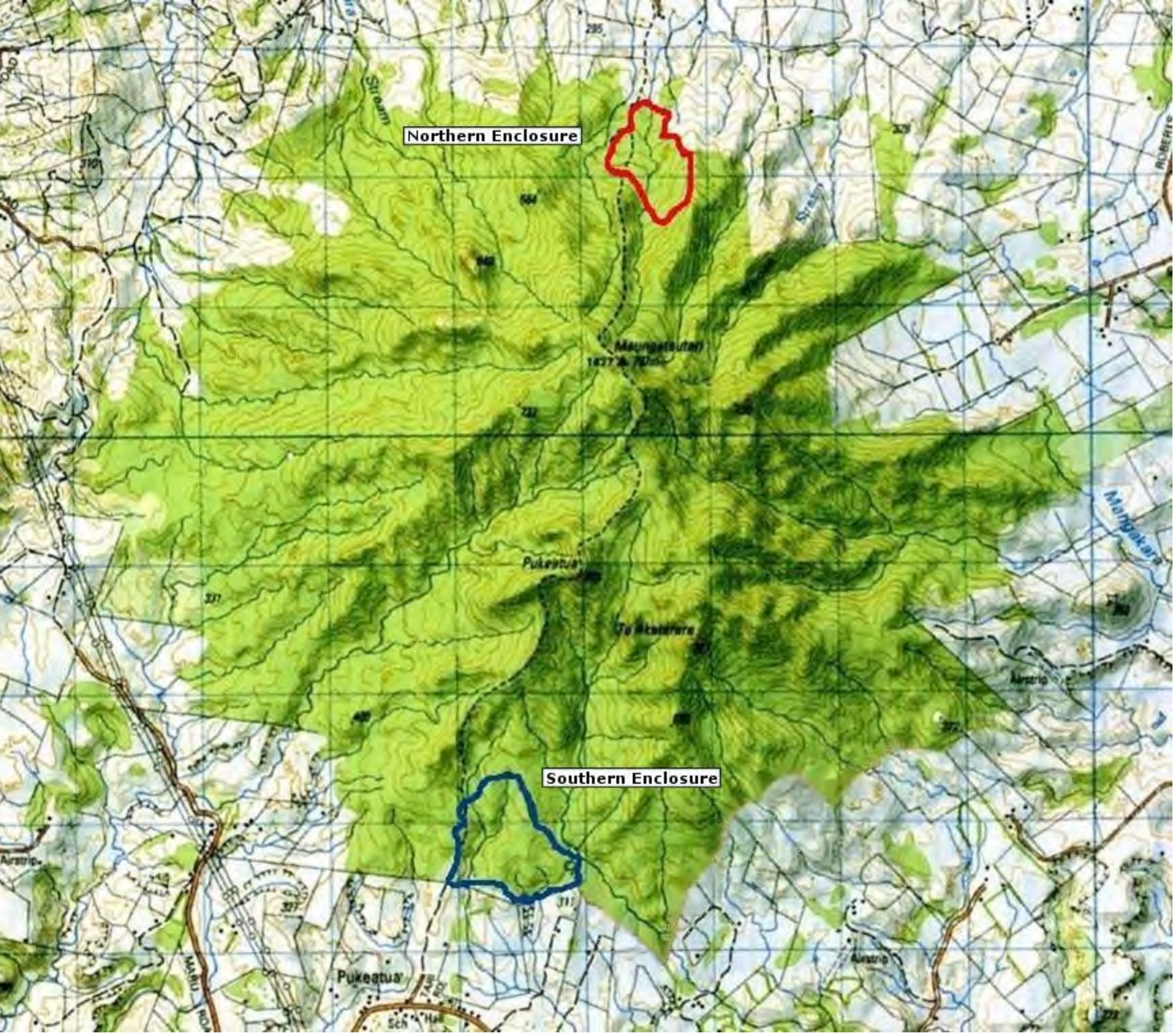
Increasing number of successes in both eradication and maintenance management, primarily in small, enclosed systems

Marine

Few successes in either eradication or maintenance management
Almost all intertidal

1) Difficult to see underwater, thus to detect and to determine success

2) Difficult to work underwater



“mainland Islands”

http://www.maungatrust.org/home/index.asp

Maungatautari