MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HIKINA WHAKATUTUKI

Landcare Research
Manaaki Whenua

Pest Control via "Trojan Female Technique"

Research Update and Next Steps

Dan Tompkins

Talk outline

- The issue – pest impacts and management costs
- The concept – what makes the TFT different?
- MBIE Smart Ideas Phase 1 (2013-15) plan
- Progress to date
  - Towards invertebrate 'proof-of-concept'
  - Towards vertebrate 'proof-of-utility'
  - Assessing social acceptability
  - Pathways to market
- MBIE Smart Ideas Phase 2 (2015-17) plan
- Other initiatives

Research Team

University of Otago
Te Whare Wānanga o Otāgo
New Zealand

Monash University

The AgriBusiness Group

agresearch
Farming, Food and Health. First™
Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi

Landcare Research
Manaaki Whenua

Department of Environment and Primary Industries

State Government Victoria

Advisory Group

Ministry for Primary Industries
Manatū Ahu Matua

TBfree New Zealand

beef+lamb new zealand

Environmental Protection Authority
Te Mana Rauhī Taiao

Department of Conservation
Te Papa Atawhai

Agriculture cost of pests

- **Globally: $ billions p.a. (e.g. 30% SE Asia rice crop)**
- **Nationally:**

Total Annual Defensive Expenditure ($ million)	
Regional Councils	36.9
Central Government	299.6
Private Sector	407.0
Total (GST exclusive)	**743.5**
Total (GST inclusive)	836.4
Defensive expenditure as a % of GDP (2008)	0.47%

Total Output Losses ($ million)	Plant	Animal & invertebrate	Total Impacts
Agriculture	202	635	837
Horticulture		25	25
Forestry	37	227	264
Marine		15	15
Other	63	88	151
Total Output Losses	**302**	**885**	**1292**

Nimmo-Bell 2009. Economic costs of pests to New Zealand. MAF(BNZ) report. 84pp

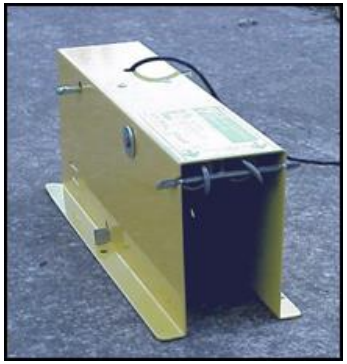
Biodiversity cost of pests

- **Globally:**
  - **key driver of biodiversity decline**
  - **ecosystem-wide consequences for:**
    - **species interaction networks**
    - **community composition**
    - **ecosystem services such as nutrient cycling and carbon sequestration**
  - **loss of biodiversity has equal or larger effects than climate change**
- **Nationally:**
  - **key driver of animal and plant biodiversity loss**
  - **impacting biological heritage values:**
    - **Taonga and other harvested natural resources**
    - **access to nature and associated leisure pursuits**
    - **tourism industry**
  - **international conventions and obligations**

Hooper (2012) A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature 486: 105-108

Issues of conventional control

- **Usually involves lethal control techniques:**
  - **poisoning, trapping or shooting vertebrates**
  - **chemical application for invertebrates**


- **Issues:**
  - **Cost of repeat application**
  - **Limited effectiveness at low density**
  - **Non-target effects on other species**
  - **Environmental contamination**
  - **Animal welfare**
  - **Evolution of resistance**


The promise of fertility control…

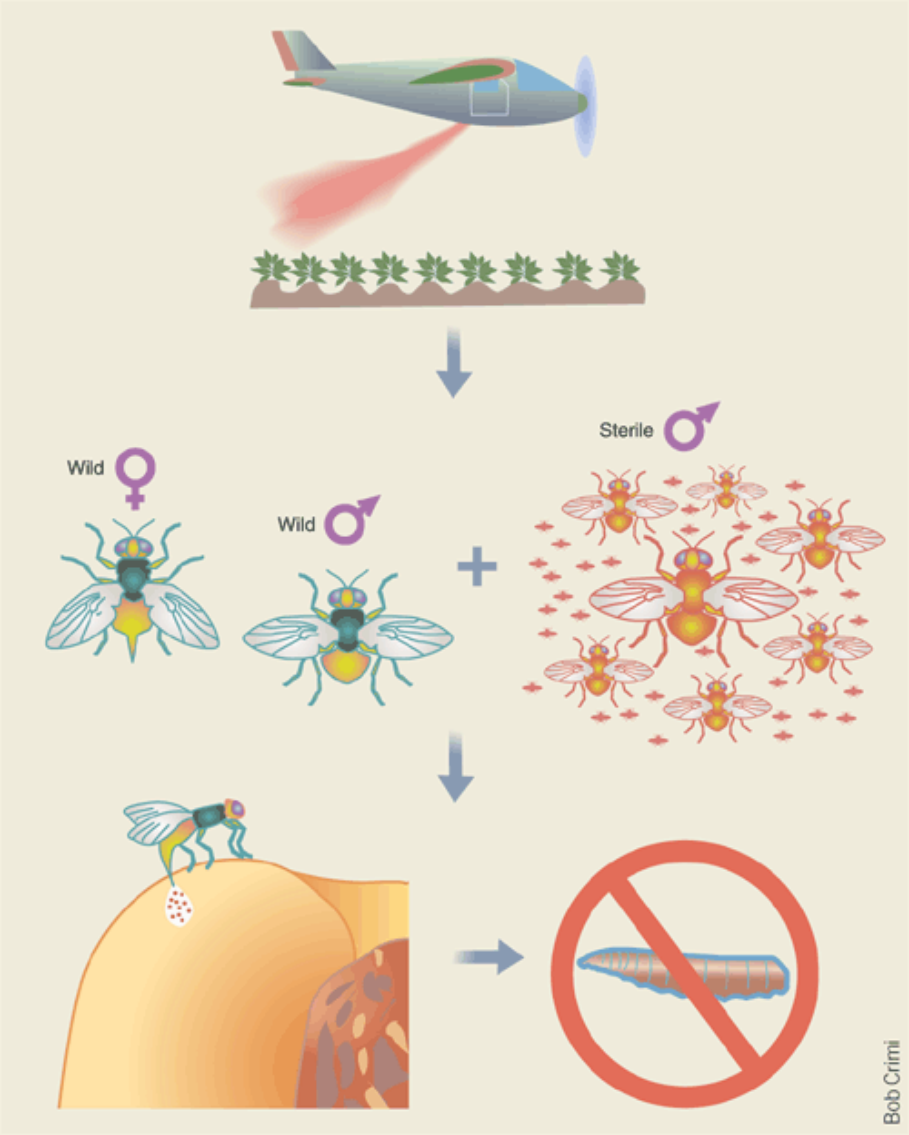
- **Management via control of reproductive output an optimal solution?**
  - **humane**
  - **specifies specific**
  - **self-disseminating**

- **Past efforts not successful**
  - **Possum Biocontrol OBI**
    - **Efficacy not high enough**
    - **Non-target concerns**
    - **GMO concerns**
  - **Mouse cytomegalovirus**
    - **Unable to transmit**
    - **GMO concerns**
    - **Potential evolution of resistance**

But when it works...

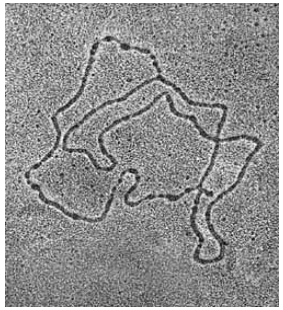
- **Sterile Insect Technique**
  - sterile males released each generation
  - successfully applied to many insect species in many countries
  - e.g. screwworm fly eradication saves USA alone US$796 million p.a.
  - but cost can be prohibitive

- **The TFT is a new twist on this paradigm**
  - potentially cost-effective for a far greater range of pest species

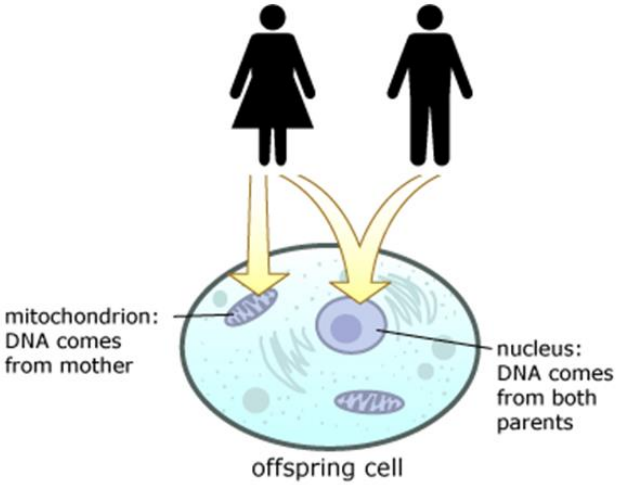


So what is the TFT?

- **Based on the mitochondria – the "batteries" of the cells;**

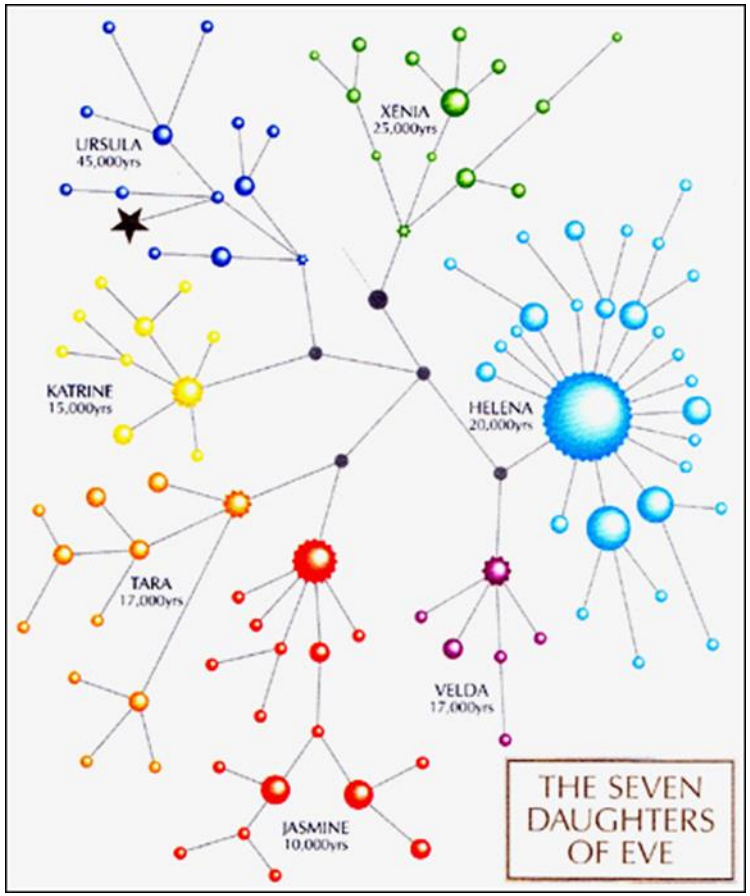


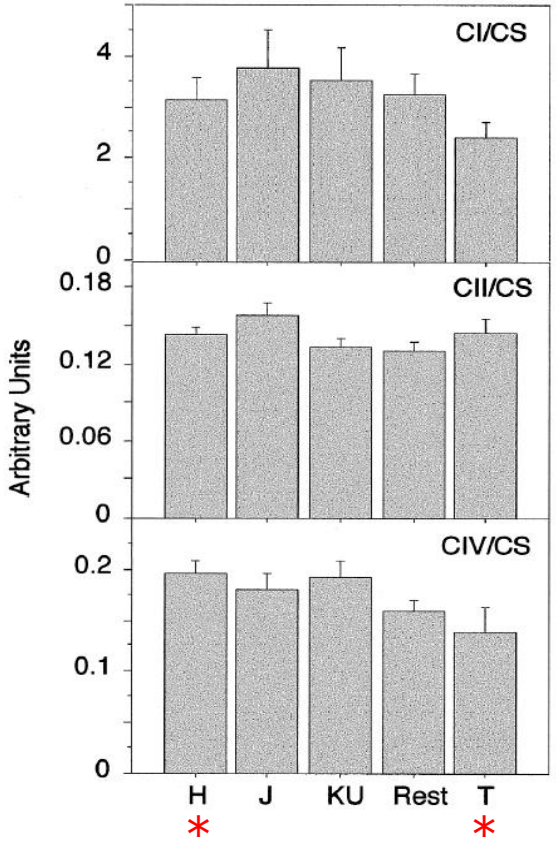
- **Naturally occurring variation in the mtDNA causes variation in the energy output of these batteries; this variation is maternally inherited;**



What does this variation do?

- **Substantial decreases in energy output cause mitochondrial diseases such as MERRF syndrome;**
- **Minor decreases have no general fitness effects:**





What does this variation do?

- **But, minor decreases in energy output can impact male fertility:**



- **Identified as a cause of male fertility issues in people, and a threat to small populations of endangered species (because not selected against);**
- **Here we're attempting to use to purposively control populations of pest species.**

What makes the TFT different?

PROCEEDINGS OF THE ROYAL SOCIETY B

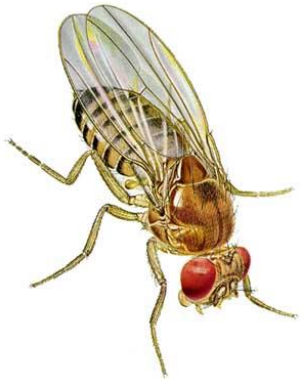
rspb.royalsocietypublishing.org

The Trojan female technique: a novel, effective and humane approach for pest population control

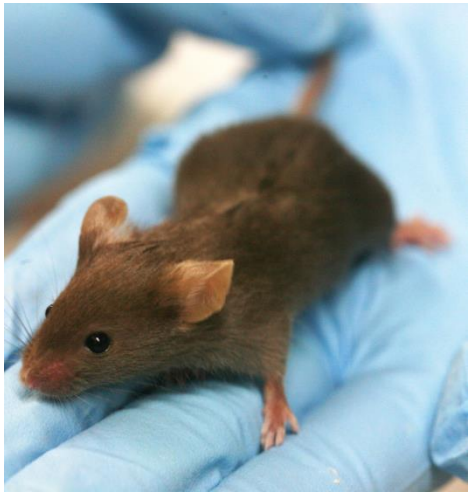
Neil J. Gemmell[1], Aidin Jalilzadeh[2], Raphael K. Didham[3], Tanya Soboleva[4] and Daniel M. Tompkins[5]

- **Predicted the potential for population scale control over a wide range of pest life histories**
- **Because the impacts are to male fertility, and mitochondria are maternally inherited, under most circumstances the responsible mtDNA variation is not selected against and thus persists over multiple generations**

MBIE Smart Ideas Phase I



- October 2013 – September 2015
- RA 1.1 Invertebrate proof-of-concept
  - Demonstrate in the lab that the TFT can regulate populations
- RA 1.2 Vertebrate proof-of-utility
  - Demonstrate that suitable mtDNA variation can be identified in the lab



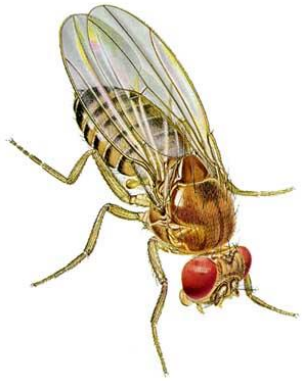
- RA 1.3 Social acceptability
  - Determine how socially acceptable the TFT is as a form of pest control
- RA 1.4 Pathways to market
  - Construct credible pathways for TFT application to address real-world pest issues

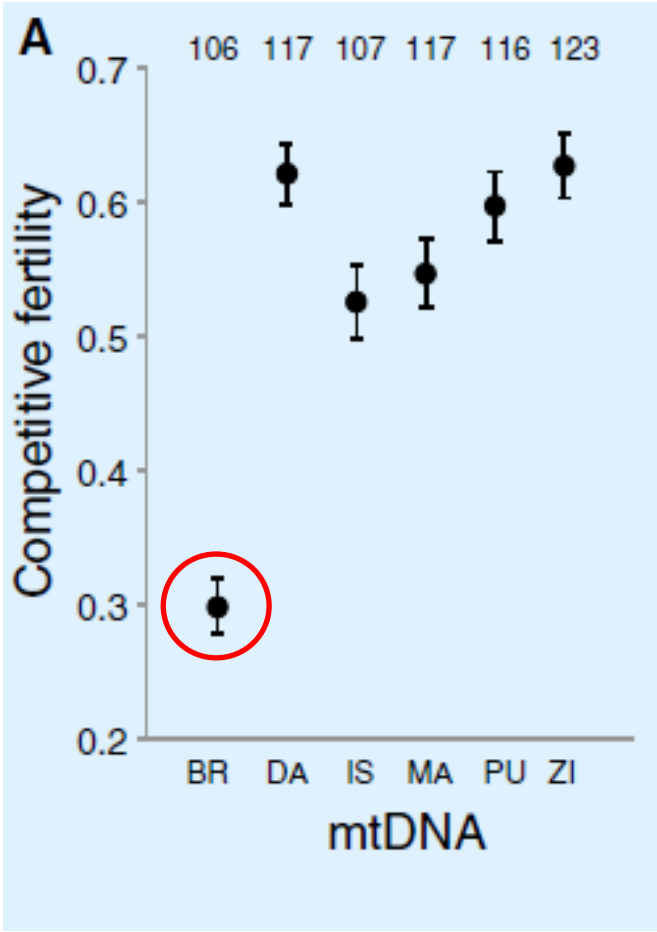
RA 1.1 Invertebrate proof-of-concept

Goal: Demonstrate in the lab that the TFT can regulate populations

<u>Prior to Phase 1</u>

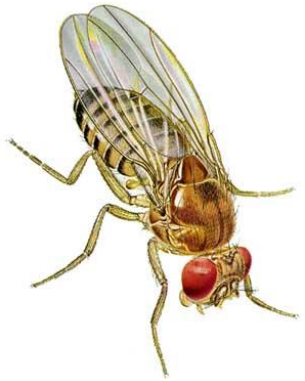
Demonstration that certain mtDNA haplotypes have reduced male fertility





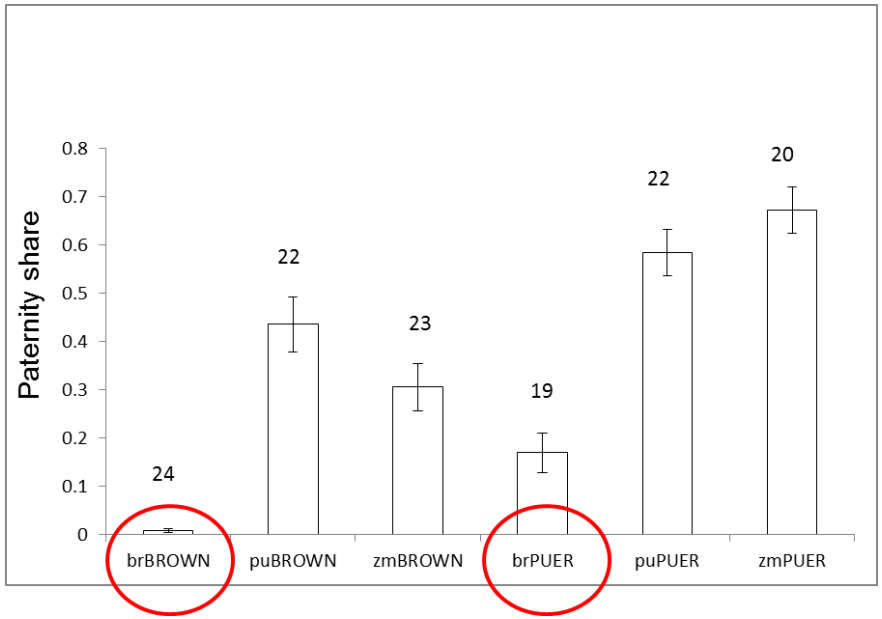
RA 1.1 Invertebrate proof-of-concept

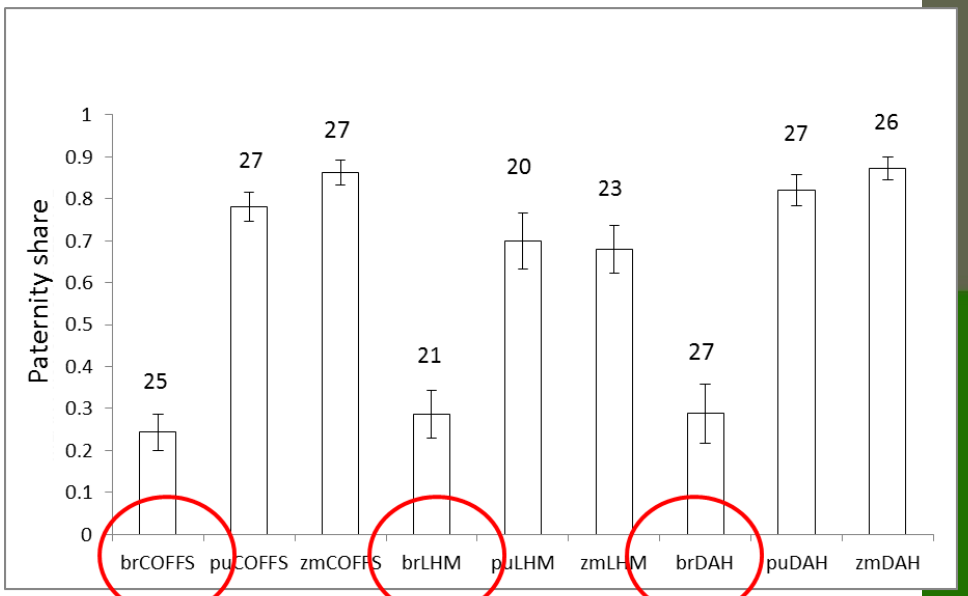
Goal: Demonstrate in the lab that the TFT can regulate populations



Progress 1

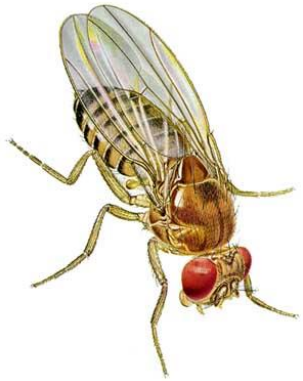
Confirmation that the effect consistently reduces breeding success across genotypes





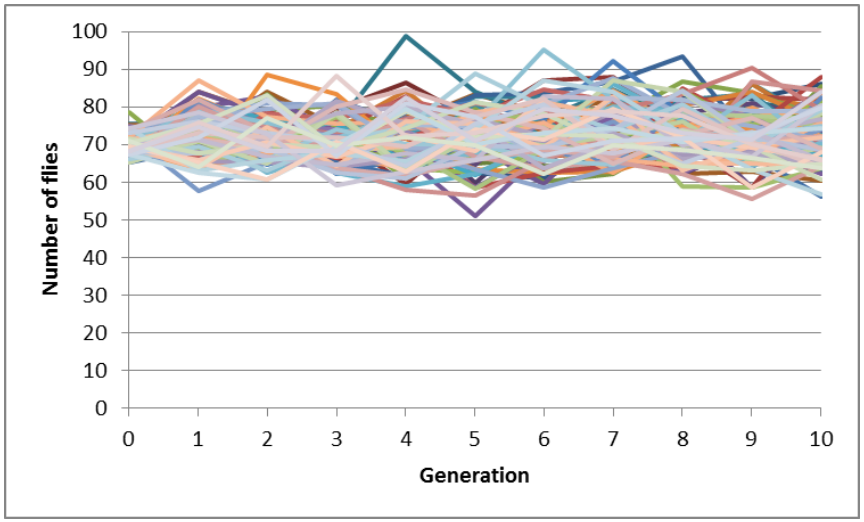
RA 1.1 Invertebrate proof-of-concept

Goal: Demonstrate in the lab that the TFT can regulate populations

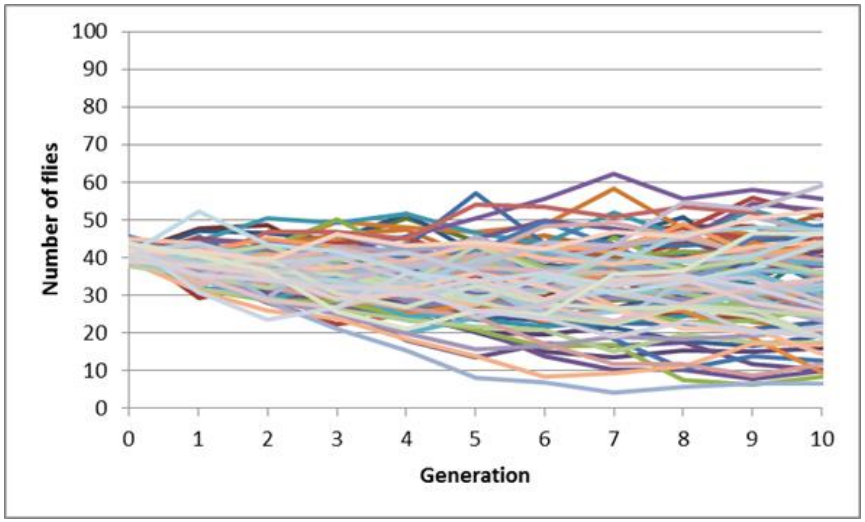


Progress 2

Modelling predicting that these effects will result in population regulation in the lab



Wildtype populations



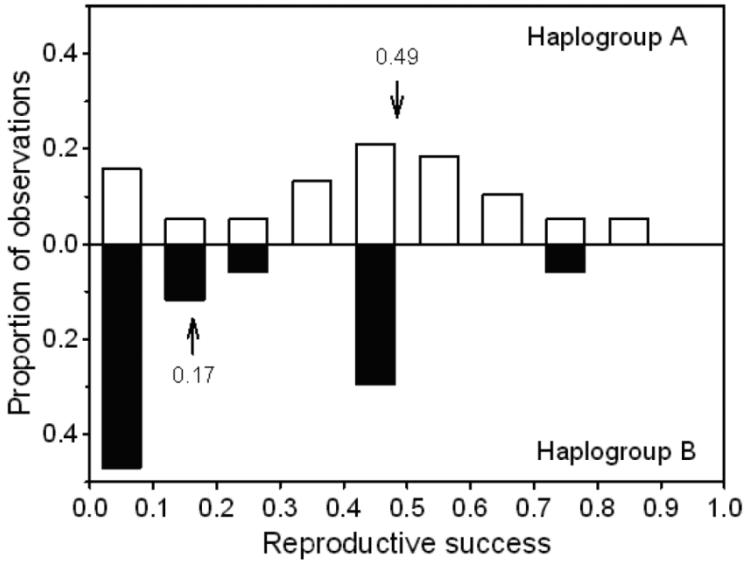
Single TFT release

RA 1.2 Vertebrate proof-of-utility

Goal: Demonstrate that suitable mtDNA variation can be identified in the lab

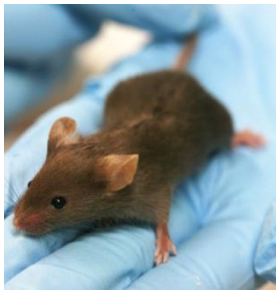
<u>Prior to Phase 1</u>

Demonstration of mtDNA linked reductions in male fertility in a captive colony of European hares (with no other detectable effects)



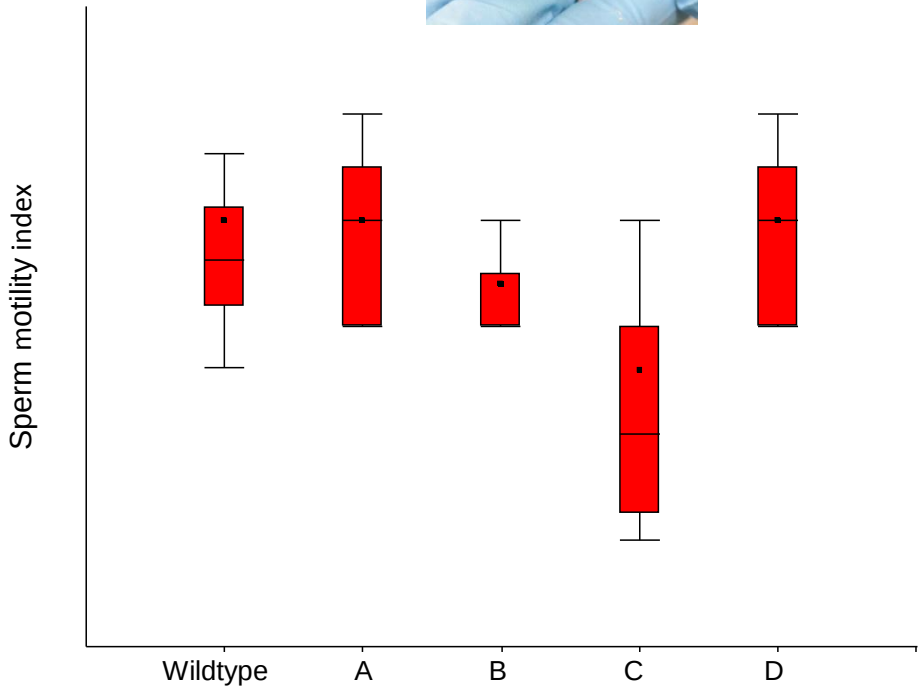
RA 1.2 Vertebrate proof-of-utility

Goal: Demonstrate that suitable mtDNA variation can be identified in the lab



Progress 1

Differences in male fertility indices among mouse mtDNA lineages demonstrated



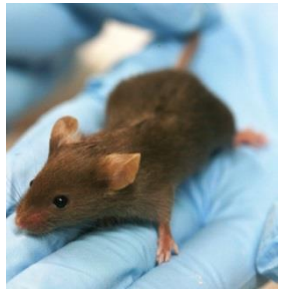
RA 1.2 Vertebrate proof-of-utility

Goal: Demonstrate that suitable mtDNA variation can be isolated in the lab

<u>Progress 2</u>

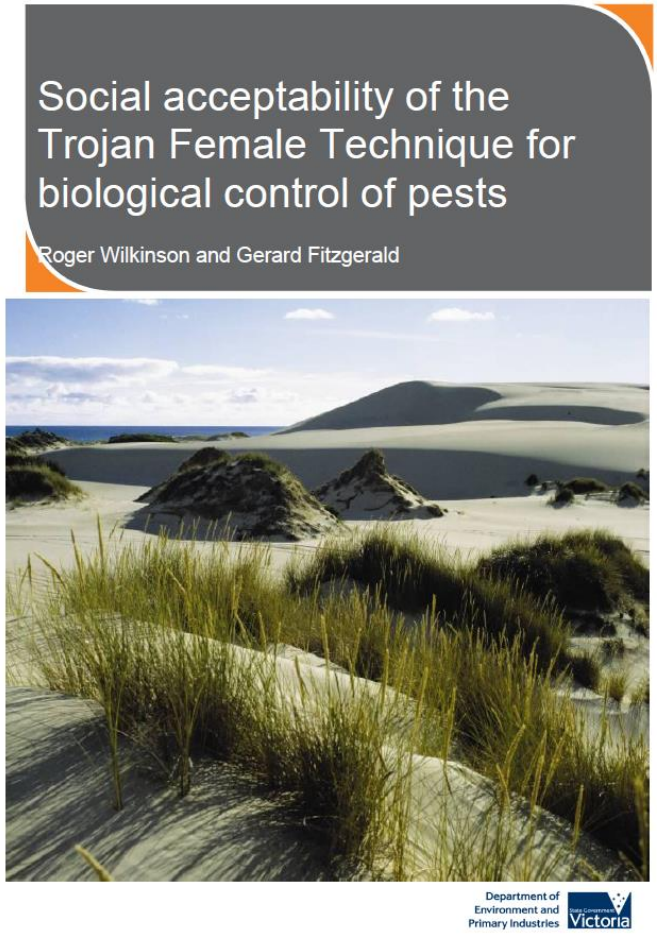
Establishment of mtDNA variant mouse lineages at the University of Otago

- **Import of heterozygous PolG mice**
- **Generation of PolG homozygous individuals**
- **Creation of mtDNA variant lines (9/12 generated)**
- **Backcross to remove the PolG component**
- **Fertility/breeding assessment and mtDNA sequencing**



RA 1.3 Social acceptability

Goal: Determine how socially acceptable the TFT is as a form of pest control



Used focus groups to identify:

- **Drivers of the social acceptability of pest management approaches**
- **The acceptability of the Trojan Female Technique specifically**

Focus groups:

- **Urban men (Christchurch)**
- **Urban women (Wellington)**
- **Rural public including farmers (Geraldine)**
- **Maori (Northland)**
- **Animal welfare (Christchurch)**
- **Environmentalists (Christchurch)**
- **Scientists (Lincoln)**
- **Pest managers (Palmerston North)**

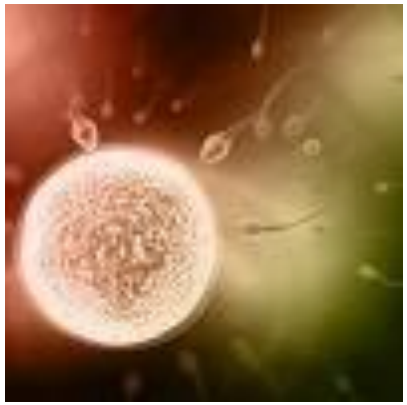
RA 1.3 Social acceptability

- There is cautious support for the TFT
  - Existing methods not working or inhumane. TFT sounds promising on both counts
- Several side risks need to be addressed
  - Main ones are ecosystem effects, effect on genetically similar non-target species, uncontrollability once released
- Public is happy for research to continue
  - Suggestion that the stated goal of field use by 2020 is too optimistic
- Less trust if perceived to be a 'money spinner'
- Need ongoing communication and transparency
- Call for a robust decision process for any field use

"... fundamentally I think it's a sound idea so long as the risks are identified and managed ... just about all of the concerns that were raised immediately when you broached the idea were around the periphery and the management of side risks, rather than the core activity of what was going on. That signals to me that the core activity is socially acceptable so long as risks around it are managed." (Rural public group)

Favourable media coverage

- Radio New Zealand morning report
- Radio New Zealand 'our changing world'
- ABC News
- Otago Daily Times
- New Zealand Herald
- The Southland Times
- And multiple on-line news websites



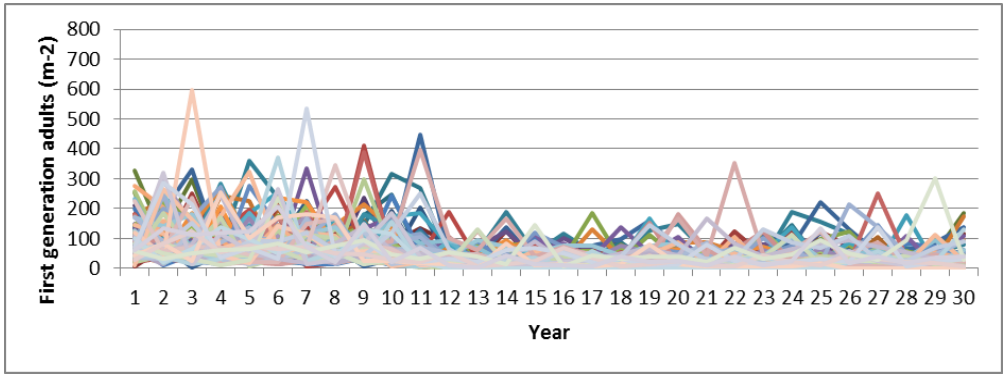
- Publically supported by both Federated Farmers and Forest & Bird in the same RNZ segment and news articles!
- $20k contribution by a member of the public – used as honours and summer bursaries for an undergraduate student.

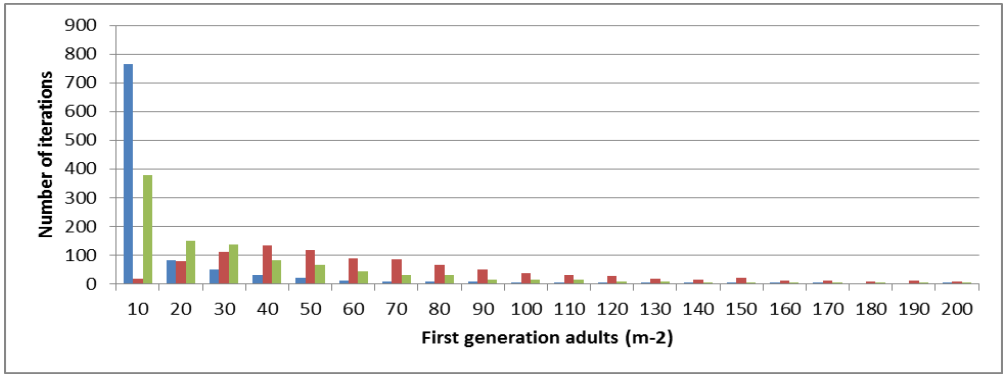
RA 1.4 Pathways to Market

Goal: Construct credible pathways for TFT application to address real-world pest issues

Progress 1

Modelling feasibility studies demonstrating potential effectiveness for controlling some invertebrate pests (e.g. pasture weevils) but not others (e.g. varroa mite)



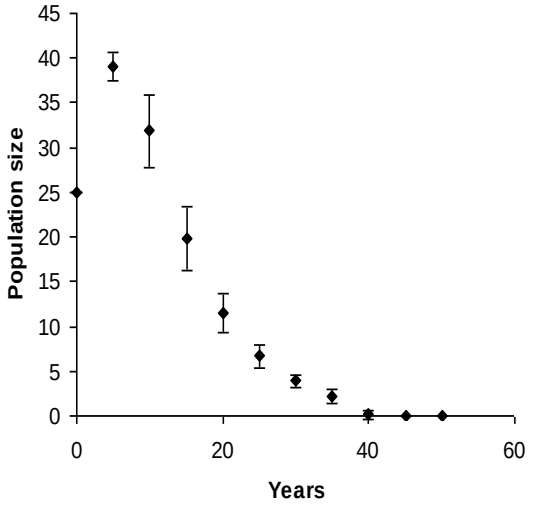


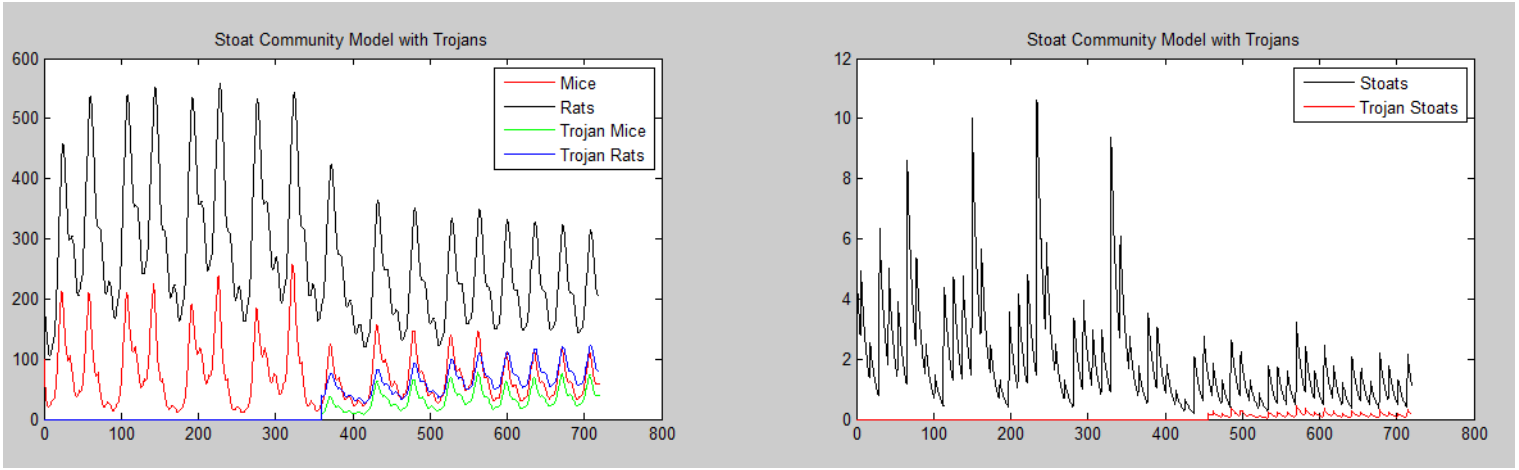
RA 1.4 Pathways to Market

Goal: Construct credible pathways for TFT application to address real-world pest issues

Progress 2

Modelling feasibility studies demonstrating range of potential effectiveness for also controlling vertebrate pests





Commercialisation potential

Isaac Bentwich:

- **(TFT) commercialisation provides a difficult challenge;**
- **Agree with previous assessments of no IP;**
  - **No novel process in identifying TFT lineages;**
  - **Patenting of certain lineages could be bypassed by competitors using different lineages;**
  - **Once in the wild, TFT lineages could easily be picked up by others;**
- **'Methodology' patents are dramatically weaker than 'composition of matter' ones.**

Commercialisation potential

Isaac Bentwich:

- **Would not encourage IP-based commercialisation;**
- **Do not recommend an emphasis on trying to build a service;**
- **Should focus on the non-profit route, pursuing suitable grants and philanthropic funding;**
- **Build robust business cases for non-profit broad-scale deployment.**

MBIE Smart Ideas Phase II

- October 2015 – September 2017
- Moving from 'proof-of-concept' to 'proof-of-application'
- Logical shift in focus from fundamental to applied science
- Application of the TFT technology platform to economically important pests
  - Primary focus on application for pasture weevil control
  - Secondary exploration of utility for possum management
- Underpinning activity
  - Communication and Education
  - Proof-of-concept for application to vertebrates
  - Increase understanding of the mtDNA variation involved

“Real-world” pests for Phase II

Wasp may be losing its pasture pest battle
Last updated 06:00 29/06/2014
Scientists are finding signs that a successful biocontrol agent might be losing its battle against a pest feeding on farming pastures. A South American wasp could be a victim of its own success against the Argentine stem weevil with initial evidence pointing to its numbers declining and the host gaining the upper hand….

Possum purge dents TB rate
Last updated 05:01 07/09/2014
Possum control operations are making inroads into the most inhospitable bush and swamps in the challenging upper South Island area to protect cattle and deer herds from bovine tuberculosis (TB). Of the 68 herds infected with TB nationally, 44 are in the West Coast, Tasman, Marlborough and Canterbury north of the Rangitata River. Southland, Otago and Canterbury south of the Rangitata have 15 infected herds and nine remain in the North Island.

MBIE Smart Ideas Phase II

- October 2015 – September 2017
- RA 1.1 Develop for pasture weevils
  - Identify suitable mtDNA variants
  - Demonstrate effectiveness of fertility males in field trials

- RA 1.2 Assess for 'real' vertebrates
  - Identify potentially suitable variants
  - Model appropriate tactics for use
- RA 1.3 Underpinning science
  - Proof-of-concept for vertebrates (mice)
  - Better understanding of mtDNA variation & effects (flies)
- RA 1.4 Communication and Education
  - Respond to the findings of the Phase 1 acceptability survey
  - Build a rigorous decision process for TFT use

Pathway to application

GLOBAL AGRICULTURAL LOSSES TO INSECTS/MITES = US$33 BILLION PA[46]

NZ AGRICULTURAL LOSSES TO CRW= NZ$312 MILLION PA[11]

PATHWAY TO MARKET	CRITICAL HURDLES	MITIGATION ACTIONS	ESTIMATED PROBABILITY SUCCESS	TIMELINE
Current Smart Ideas Phase 1 project, TFT "proof-of-concept"	Technology platform development	See current application	90%	2013
	Industry relations	User Needs Analysis; links from day 1 with sectors & service providers	90%	2015
Smart Ideas Phase 2 project, TFT "proof-of-application"	Specific technology development	"Multiple candidate approach"; best-capabilities team	60%	
	Social/stake-holder/policy acceptability	Regulatory authority engagement from day 1; social research; project Transparency	90%	2017
Industry and Regional Council roll-out	Large-scale application logistics	Government, industry, NGO & public collaboration	60%	2025
GOAL – AGRICULTURAL LOSSES REDUCED TO NZ$156 MILLION PA				2030

Research community technology sharing

Global reputation building

Overseas provision of research support

Overseas provision of application support

GLOBAL BENEFITS

Pathway to application

GLOBAL AGRICULTURAL LOSSES = US$1.6 BILLION PA[46]

NZ AGRICULTURAL LOSSES = NZ$50 MILLION PA[11]

PATHWAY TO MARKET	CRITICAL HURDLES	MITIGATION ACTIONS	ESTIMATED PROBABILITY SUCCESS	TIMELINE
Current Smart Ideas Phase 1 project, TFT "proof-of-concept"	Technology platform development	See current application	80%	2013
	Industry relations	User Needs Analysis; links from day 1 with sectors & service providers	80%	2015
Smart Ideas Phase 2 project, TFT "proof-of-application"	Specific technology development	"Multiple candidate approach"; best-capabilities team	30%	
	Social/stake-holder/policy acceptability	Regulatory authority engagement from day 1; social research; project Transparency	80%	2020
Industry and Regional Council roll-out	Large-scale application logistics	Government, industry, NGO & public collaboration	30%	2025
GOAL – AGRICULTURAL LOSSES REDUCED TO NZ$25 MILLION PA				2030

Research community technology sharing

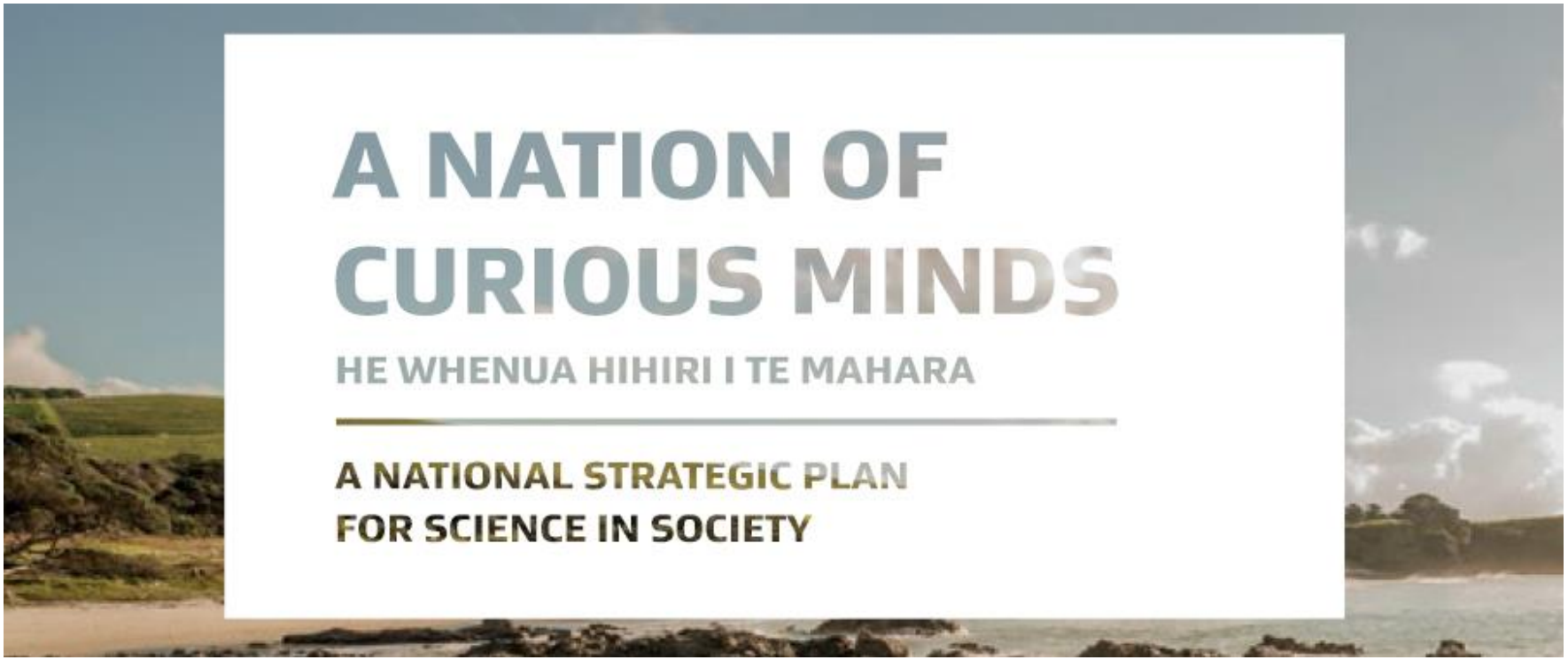
Global reputation building

Overseas provision of research support

Overseas provision of application support

GLOBAL BENEFITS


NEW ZEALAND'S
BIOLOGICAL
HERITAGE
Ngā Koiora
Tuku Iho
National
SCIENCE
Challenges


A NATION OF
CURIOUS MINDS
HE WHENUA HIHIRI I TE MAHARA
A NATIONAL STRATEGIC PLAN
FOR SCIENCE IN SOCIETY