MANAAKI WHENUA – LANDCAR

Rabbit haemorrhagic disease virus in New Zealand– impacts, spread and persistence of strains

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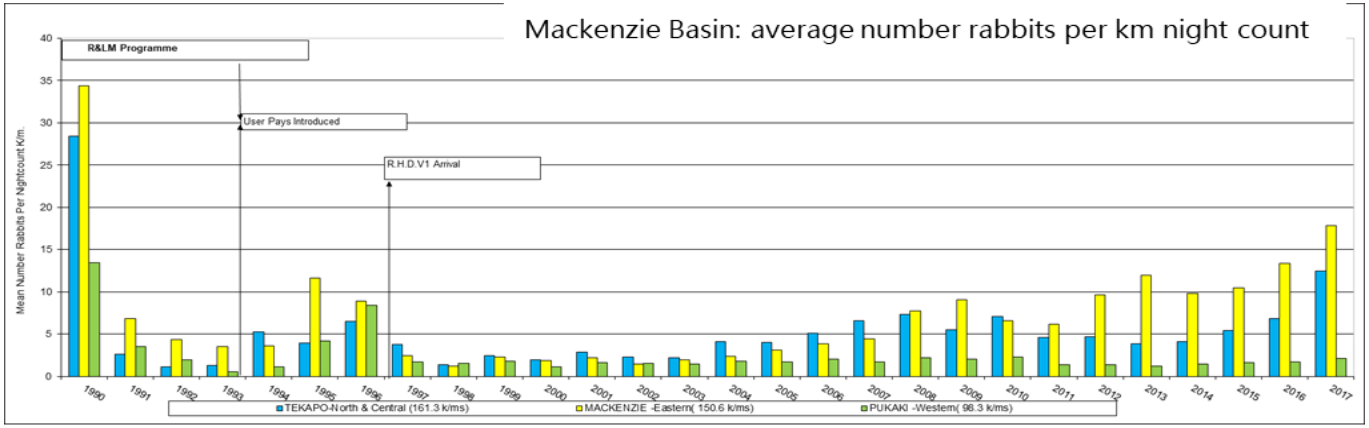
Rabbits and Rabbit Caliciviruses in New Zealand

- Rabbits introduced to New Zealand in 1830s
- Damaging periodic epidemics in 1880s, 1920s, 1940s and 1980s
- 1997 RHDV1 Czech release in New Zealand
- 2007 onwards increasing concern about rabbit numbers
- 2018 RHDV1 K5 nationwide release (March)
- 2018 RHDV2 detected

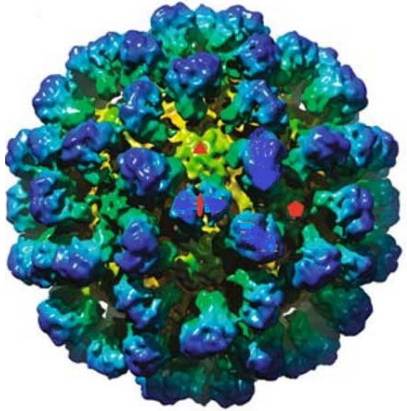


Rabbit caliciviruses in New Zealand

Pathogenic strains

- RHDV1 Czech (Gl.1) arrived in 1997
- RHDV1 K5 (Gl.1) released in 2018

- RHDV2 (Gl.2) discovered 2017/2018

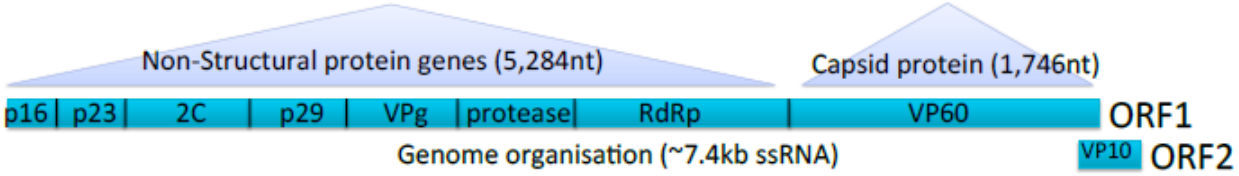


from Hu et al. 2010

Benign strains

- RCV – A1 (NZ variant 2016) (Gl.4) - suspect present since 1980's

Nomenclature of lagoviruses see Pendu et al. 2017



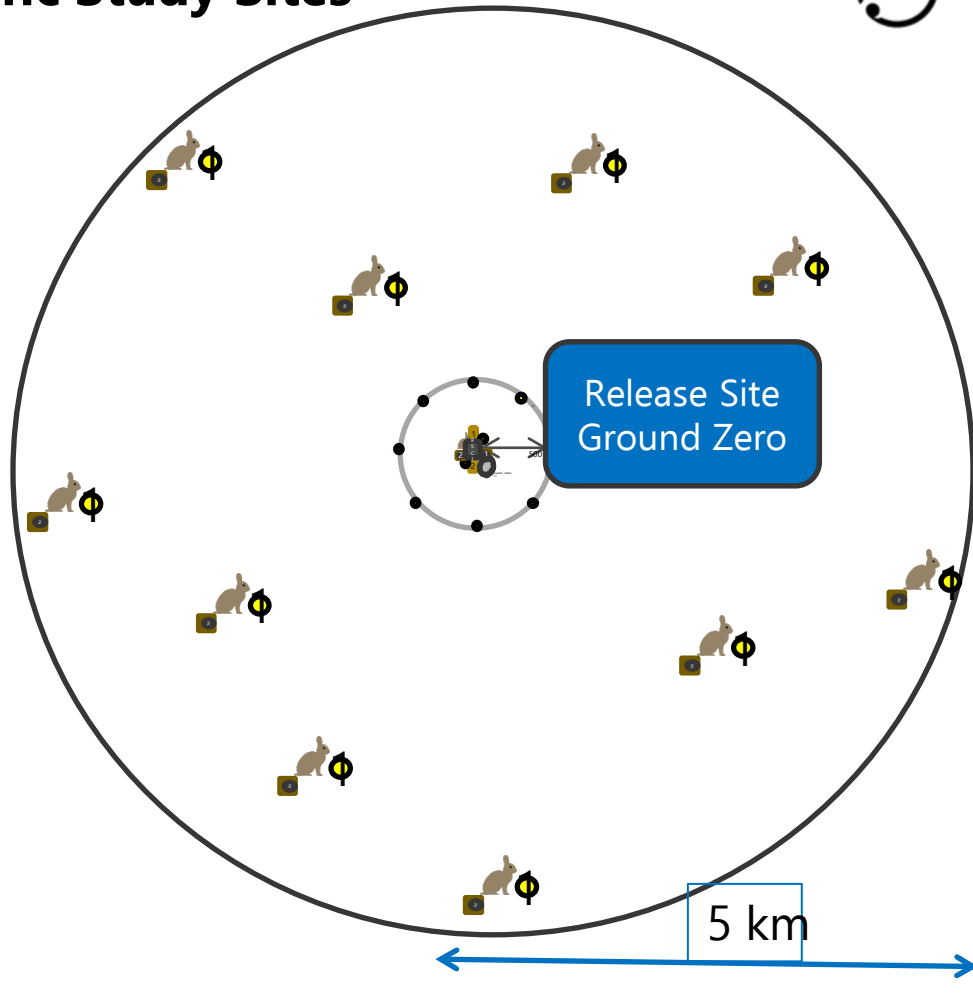
RHDV - adapted from Mahar et al. 2016

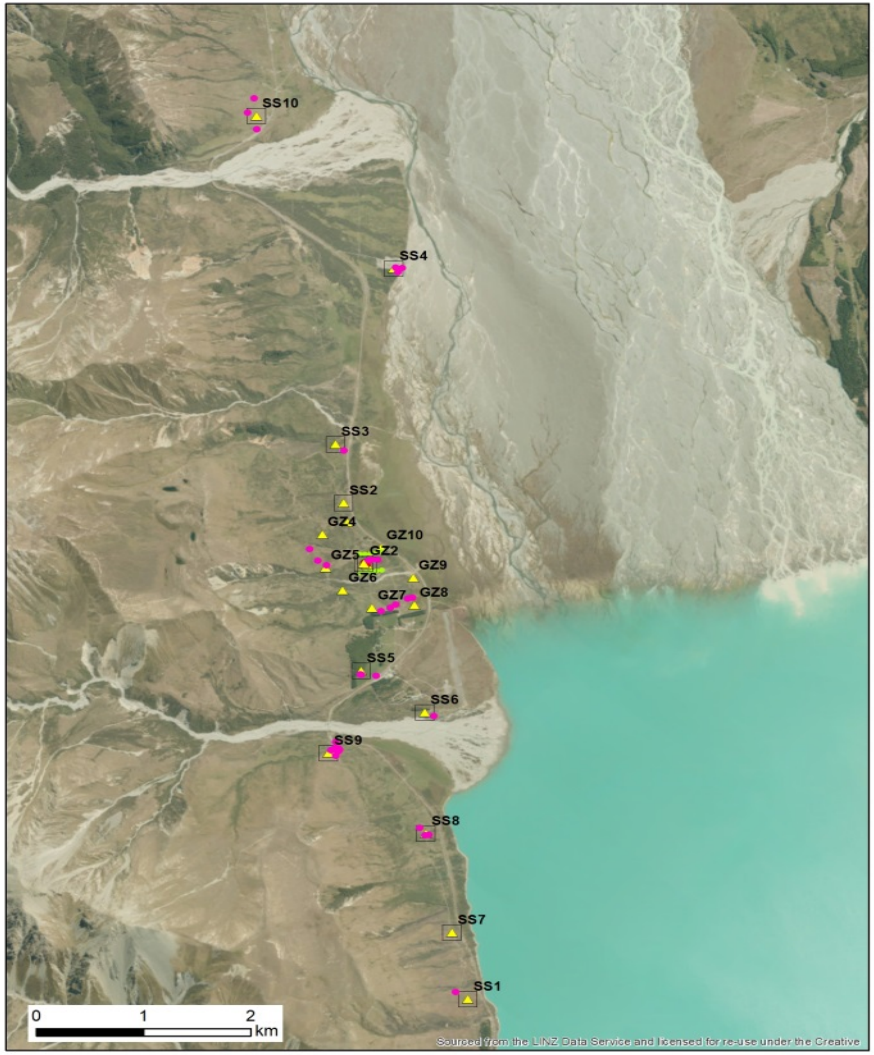
RHDV1 K5 Release –Science sites

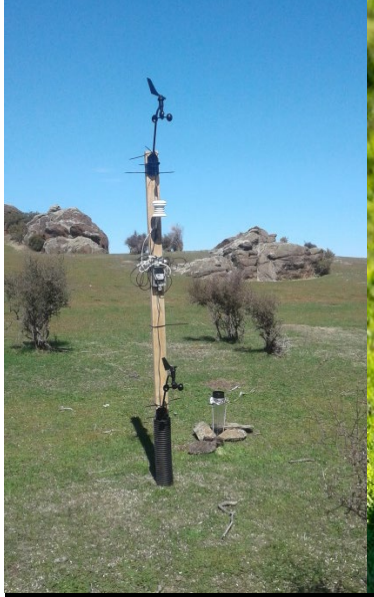
Four Scientific Study Sites

Monitored the release area and ten satellite sites within 5 km of release

- Surveyed for live and dead rabbits at each satellite site
- Used fly traps to collect and analyse viral RNA present on flies & flyspots
- Night spotlight counts pre and post treatment

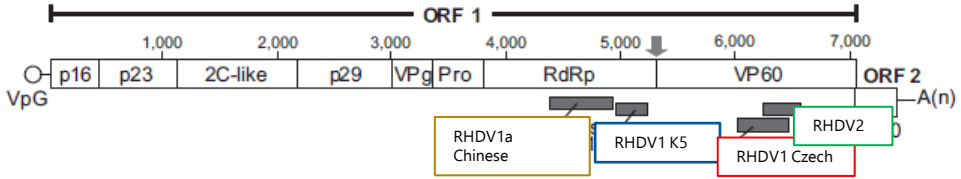


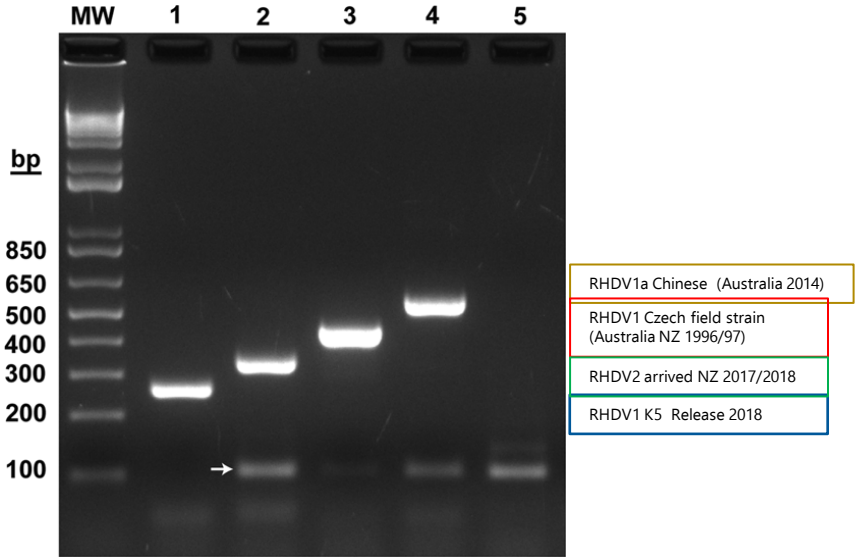




RHDV1 K5 Release – Science Site Glentanner

RHDV strain-specific multiplex RT-PCR (Tanja Strive's Group)





Adapted from Hall et al. 2017

RHDV1 in dead rabbits at science sites

43 rabbit carcasses recovered (excluding shot/very old (n=21))

- RHDV1 Czech present pre-release
- Carcasses hard to recover - lots of predators present (cats, ferrets, hawks)
- Post release carcasses: 64% RHDV1 K5, 36% RHDV1 Czech
- RHDV1 K5 in carcasses at 3 sites but not at Ida Valley
- RHDV1 K5 present in flies at all sites

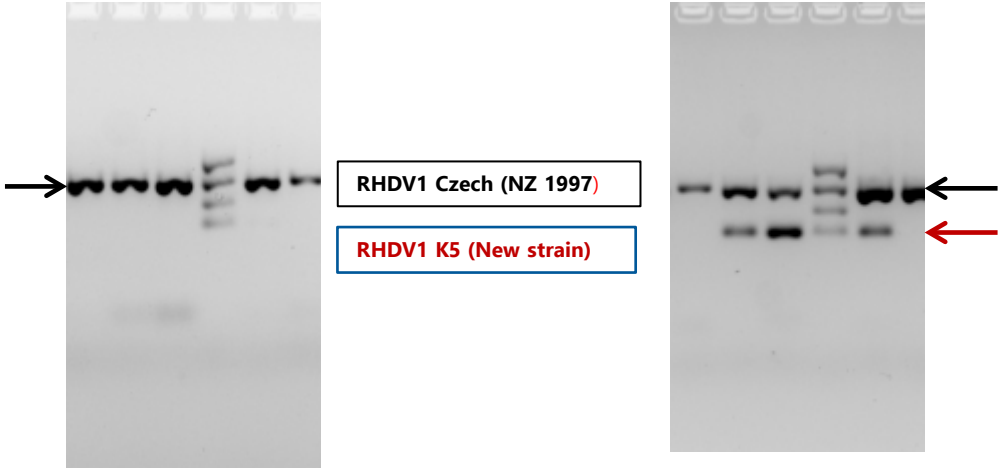
RHDV1 in flies and fly spots

- Fly trap was baited with minced liver and lined with a plastic acetate sheet
- Collected carrion flies and changed acetate sheet every 3-4 days over 8 weeks
- Acetates were swabbed with a cotton bud put in RNA preservative and stored -80°C
- Over 2000 samples were analysed - looking at rate of spread and persistence

RHDV in fly spots

1 week before RHDV1 K5 release

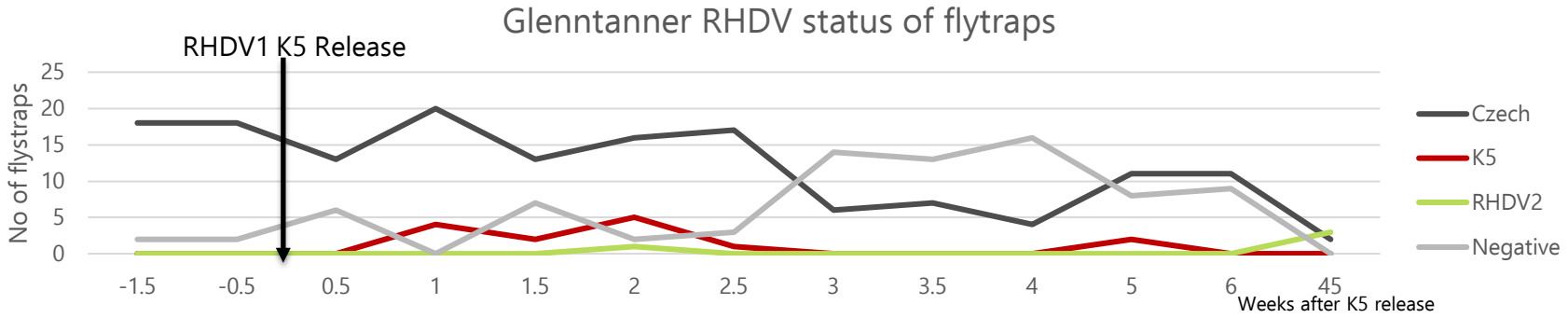
3 days after RHDV1 K5 release

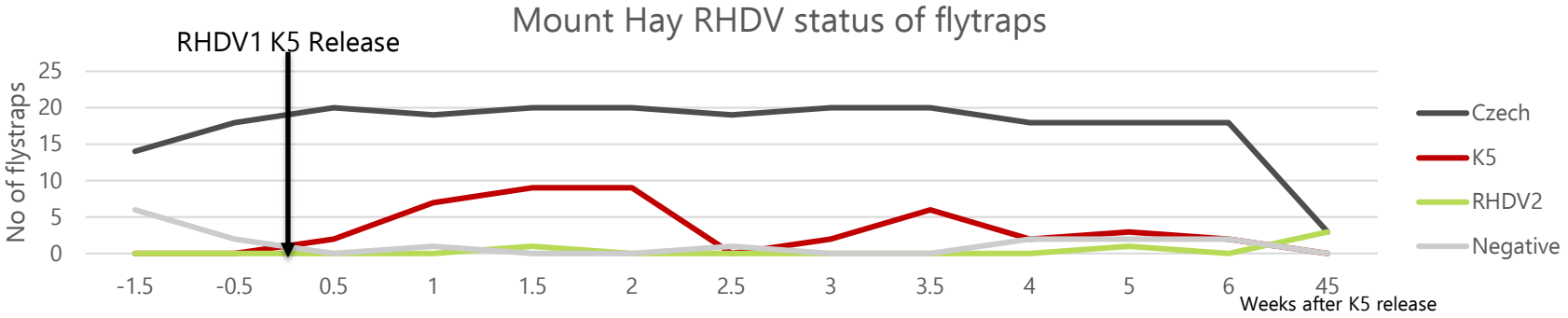


Release Site 4 Canterbury

- Original RHDV1 – Czech strain detected in flies at all sites prior to release
- Post release- RHDV1 K5 and Czech detected in flies at all sites

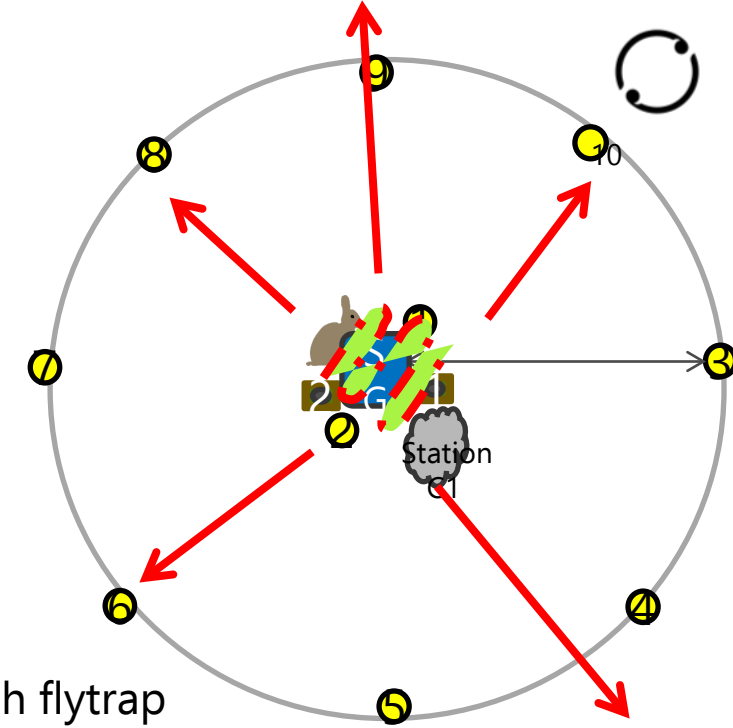
RHDV1 in flies - fly spots





RHDV1 K5 movement in flies

Site	n	Mean (km/month)	Range (km/month)
Glentanner	5	0.8 ±0.1	0.5-1.1
Mt Hayes	8	4.4 ±2.3	1.1-20.1
Ida Valley	4	3.9 ±3.2	0.4-13.3
Cardrona	6	4.4 ±1.7	0.4-9.5
Average	23	3.5 ±0.7	0.4-20.1



- Calculated time that RHDV1 K5 first recorded at each flytrap
- Individual virus movements varied greatly (0 – 700 m/day)
- Average rate of spread 3.5 km/month
- High rates of spread (9.5-20 km/month) at 3 sites

- Furthest movement detected at a regional site in carcass was ~25 km in 21 days

RHDV1 K5 Impacts

Night count summary- 6 weeks post release

	Night count pre-release	Night count Post-release	% reduction	Seropositive RHDV % Pre
RS1 Cardrona	107	94	12%	86 %
RS2 Ida Valley	68	35	48%	90 %
RS3 Glentanner	192	121	36%	68 %
RS4 Mount Hay	24	9.6	61%	52 %

- Overall 39% reduction
- Varied from 12% to 61% decrease
- Moderate to high immunity present
- Highest reduction associated with lowest % immunity

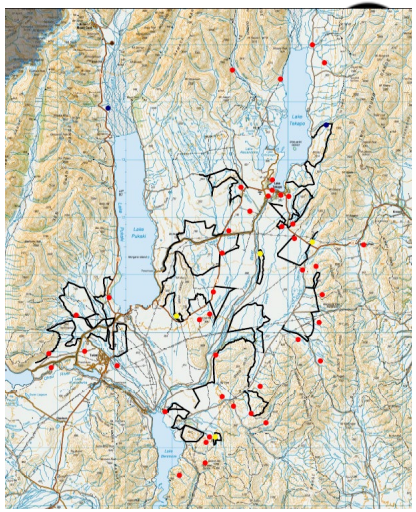
Results: Regional Night Counts

Six to eight weeks post-release night spotlight counts reflect combined impact of K5, Czech, natural mortality and any tradition control

Canterbury:

- Across the 129kms of transect in high-country stations the average reduction was 40%
- On a property basis the reduction ranged from 0%-70%

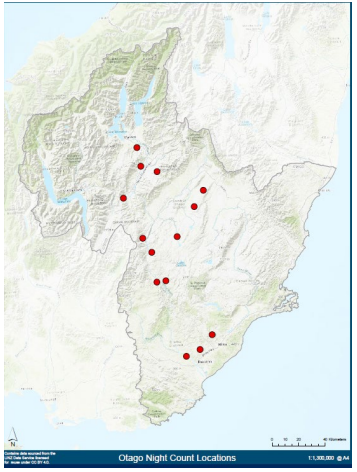
Graham Sullivan & Brent Glentworth, Environment Canterbury



Otago

- RHDV1 K5 monitored sites (n=14) average reduction 36-47%
- On a property basis the reduction ranged from 0%-80%

Otago Regional Council



Wild rabbit samples from councils & public:

n=43/88 RHDV positive

- 67% RHDV1 K5
- 26% RHDV1 Czech
- 6% RHDV2 (n=3 rabbits from 2 locations)

Outcomes RHDV1 K5 Release:

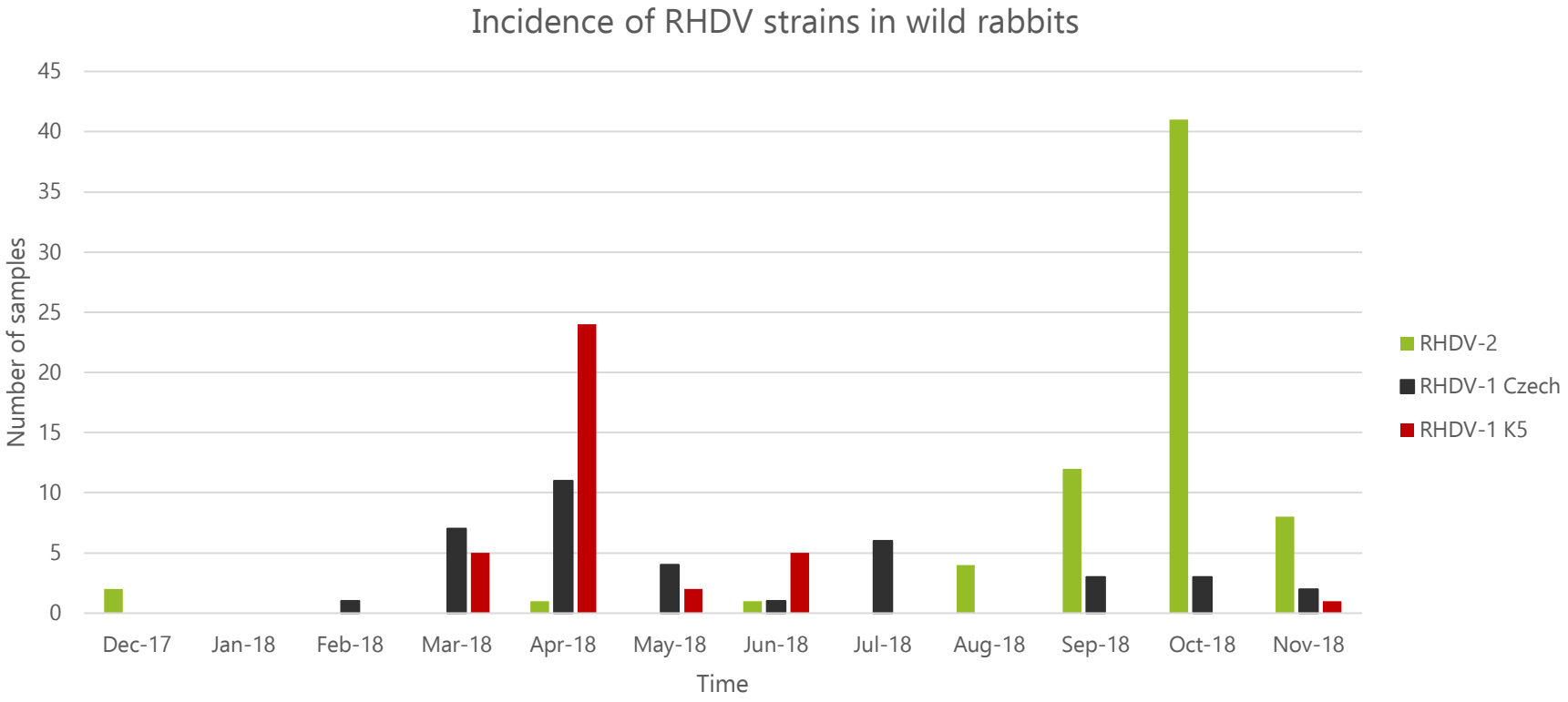
Post-release RHDV1 K5:

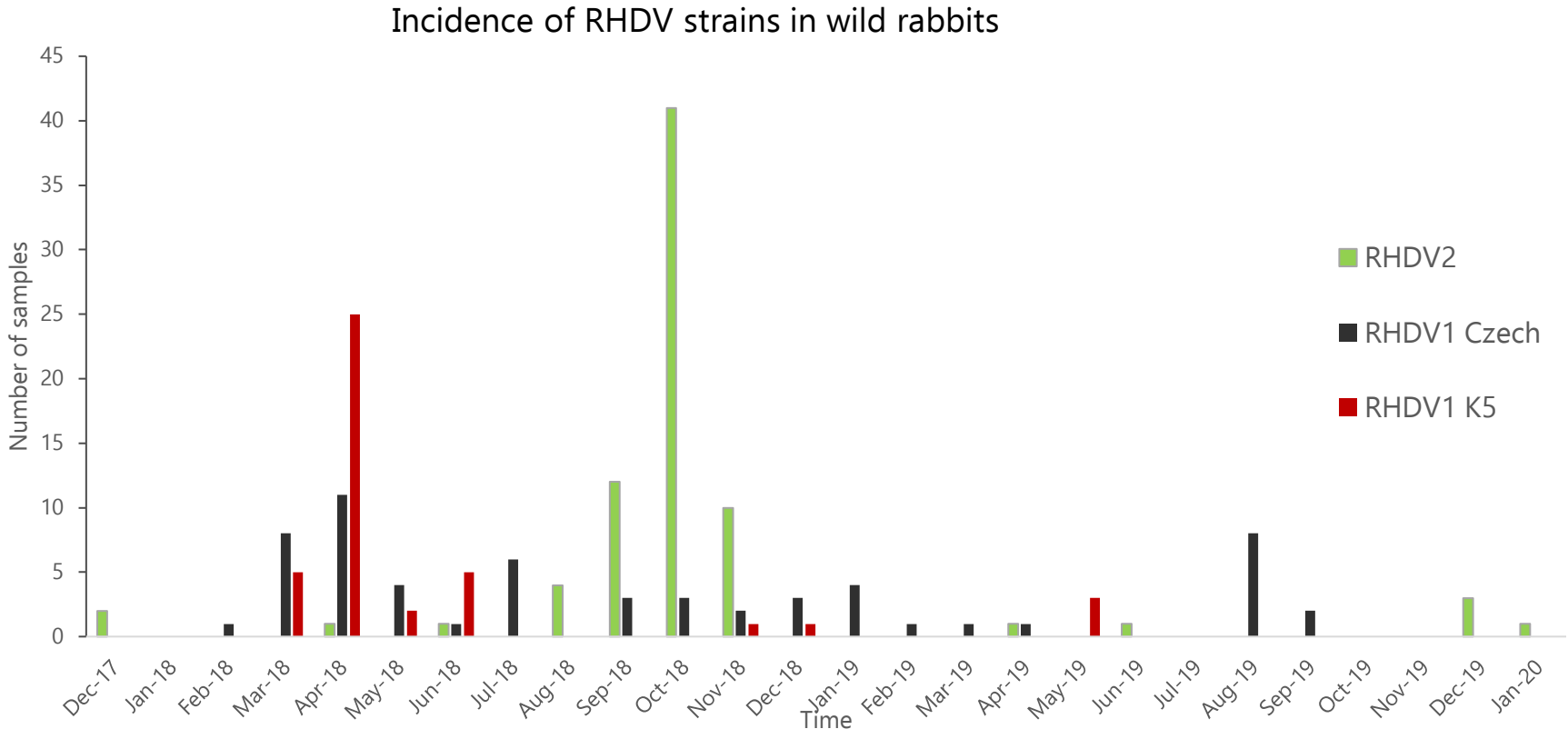
- 30-40% decrease in night counts
- 2/3 of RHDV deaths associated with RHDV1 K5

Rate of spread:

Virus spread in NZ 3-4 km per month on average but much larger distances in some places

- Slower than expected (7km/month)
    - Australia 20 ->100km per month
    - Spain 12-15km per month
- Widespread and active infections of RHDV1 Czech present prior to release


Incidence of RHDV strains in wild rabbits
Number of samples
45
40
35
30
25
20
15
10
5
0
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18
Jul-18
Aug-18
Sep-18
Oct-18
Nov-18
Time
RHDV-2
RHDV-1 Czech
RHDV-1 K5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Mar-19
Apr-19
May-19
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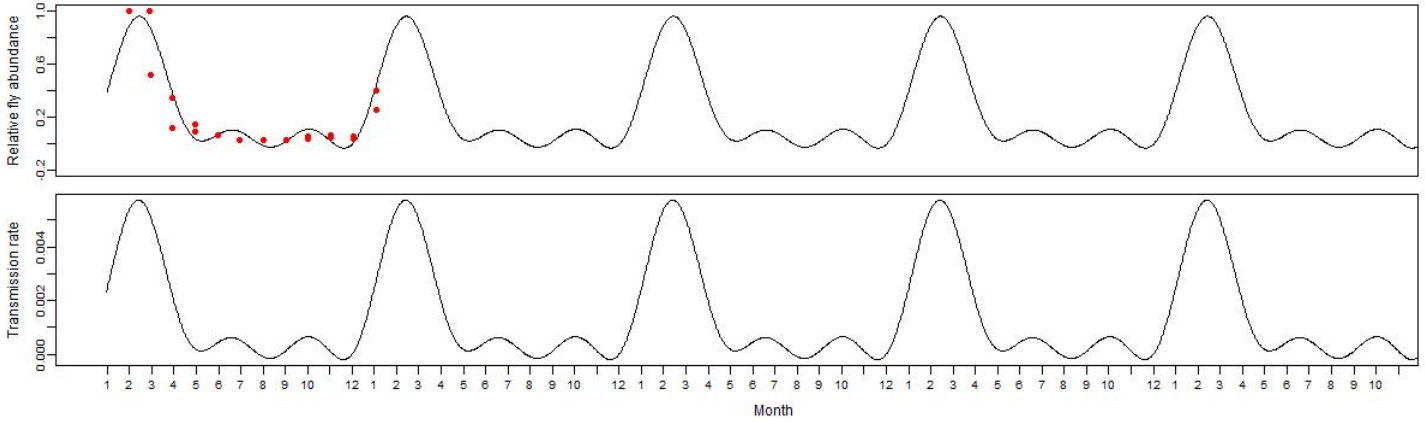
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
RHDV2
RHDV1 Czech
RHDV1 K5

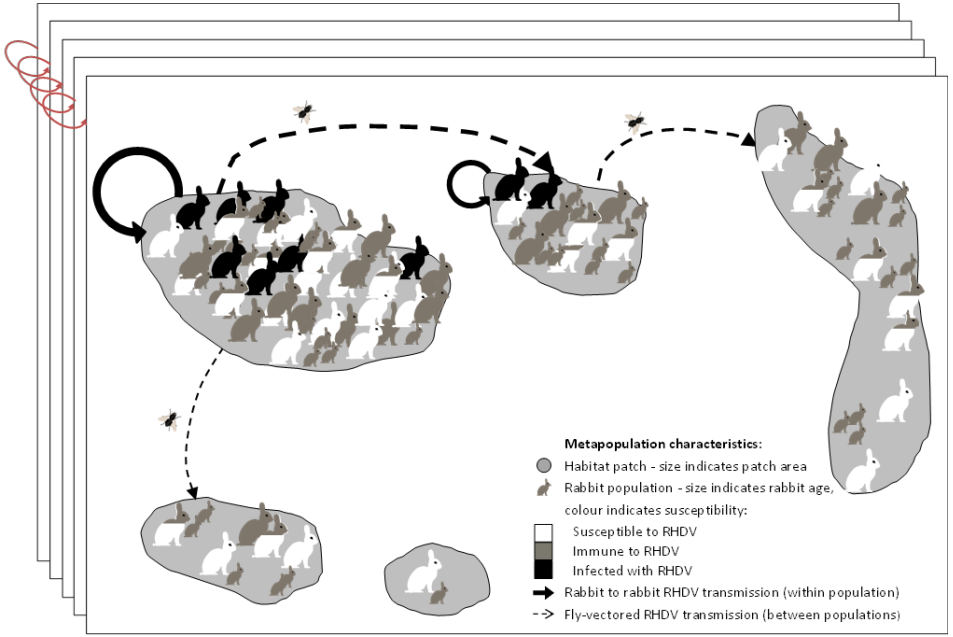
Developing a 3-strain model for rabbit calicivirus in New Zealand

- SIR Compartmental Model (Susceptable/Infected/Recovered) based on Barlow & Kean (1998) and Barlow et al. (2002), was extended to 3 strains: RCV-A1, RHDV1 Czech, RHDV1 K5.
- Includes seasonality in rabbit reproduction
- Seasonality in disease transmission rates added by modelling relative fly abundance as a function of time of the year.
- Fly abundance data was obtained from monthly samples taken in Central Otago and Makenzie Basin (Barratt et al. 2001)



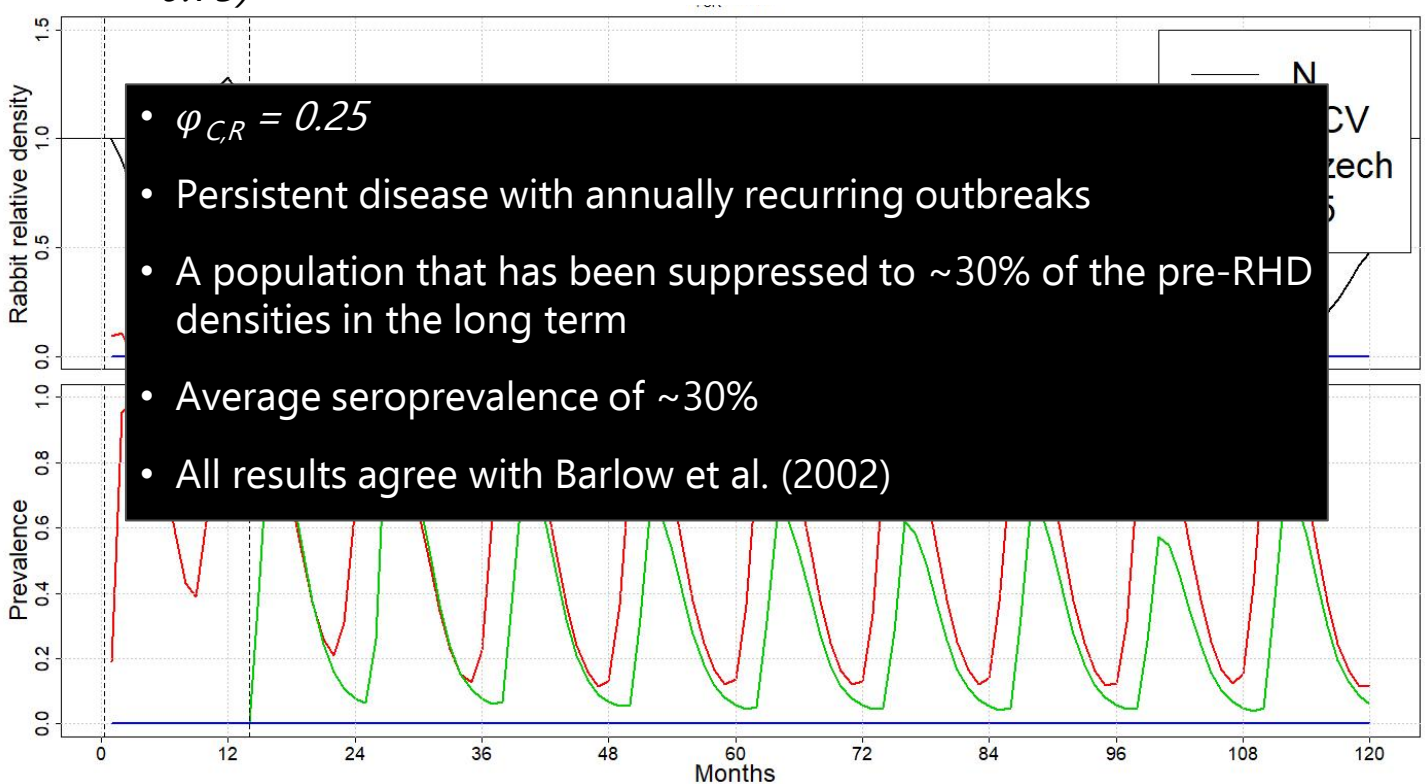
Basis of 3-strain metapopulation model

- Spatial structure added: virus particles (carried by flies) are coming from other populations and are being lost to other population



Step 1: Aspatial model with 2 strains (RCV-A1, RHDV1 Czech)

- To simulate different levels of cross-immunity ($\varphi_{C,R}$ = *0.25, 0.5, 0.75)*



- $\varphi_{C,R}$ = *0.25*
- Persistent disease with annually recurring outbreaks
- A population that has been suppressed to ~30% of the pre-RHD densities in the long term
- Average seroprevalence of ~30%
- All results agree with Barlow et al. (2002)

Step 2: Aspatial model with 3 strains (RCV-A1, RHDV1 Czech & K5)

- $\varphi_{C,R}$ = *(0.25)*, $\varphi_{K,R}$ = (0.0, 0.25, 0.5), $\varphi_{K,C}$ = (0.75, 1.0), $\varphi_{C,K}$ = (0.75, 1.0)
- $\varphi_{K,CR} = \varphi_{K,RC}$ = (0.75, 1.0)

$\varphi_{K,R} = 0$	$\varphi_{K,R} = \varphi_{C,R} = 0.25$	$\varphi_{K,R} = 0.5$
K5 replaces Czech	Co-existence between the 2 virulent strains	K5 goes extinct
K5 epidemics every 2 years	Yearly epidemics of both strains (but large ones only every 2 years)	Yearly epidemics of Czech
Rabbits suppressed to >>25% of pre-disease densities	Rabbits suppressed to ~25% of pre-disease densities	No observable effect of K5 on rabbit densities

E.g. cross-immunity ($\varphi_{C,R}$ =0.25) *Rabbits with prior exposure to benign RCV 0= fully susceptible and 1=fully protected*

Next step: Spatial model with 3 strains

1. Still need to simulate dynamics in multiple populations, using field data to inform parameters (rate of spread)
2. Contrast model outputs with field data obtained from the latest release (pre and post-release serology, percent reduction in rabbit numbers)
3. Modify models depending on susceptibility coefficients identified from animal challenge models

Cecilia Arienti-Latham – MWLR

Mandy Barron – previously MWLR

Amy Hurford, Memorial University of Newfoundland, Canada

Going forward

- Role of RHDV1 K5 as a biocide
  - worked well in peri-urban, semi-rural spaces
- Persistence and on-going impact of RHDV1 K5/Czech/RHDV2
  - RHDV in flies surveys
  - Rabbit susceptibility/immunity
- Impact of RHDV2
  - lack knowledge on lethality and cross-protective immunity
- Highlights complexity of rabbit control and management
- Importance of nationally co-ordinated and ongoing partnership approaches to rabbit issues

Acknowledgements

- MWLR Field Team: Sam Brown, Grant Morriss, Morgan Coleman, Gretchen Brownstein, Hayley Ricardo, Florian Chazottier, Dave Latham, Oscar Pollard
- Rabbit Coordination Group
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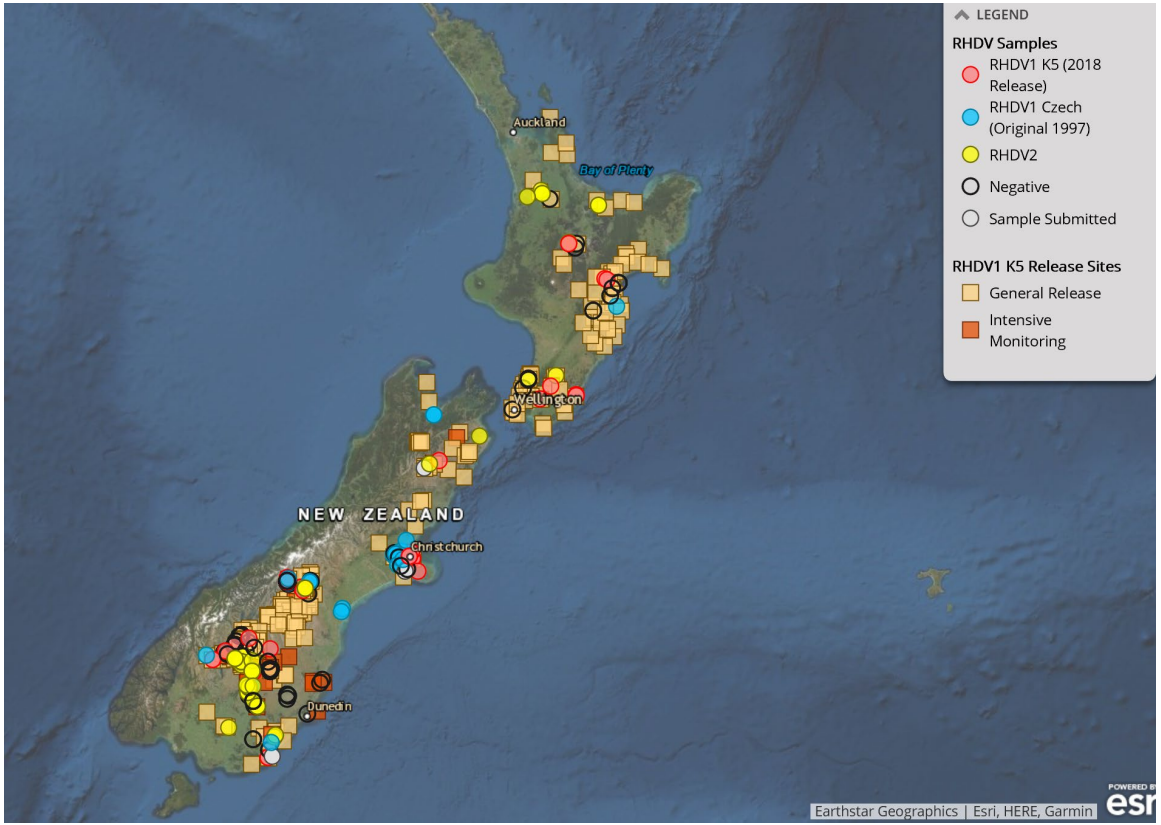
- Landowners providing access and local knowledge; many others including contractors and members of the public
- Australian research teams: IA CRC; Tanja Strive, CSIRO; Andrew Read, DPI
- Funders: MPI, Sustainable Farming Fund, MBIE

Next step: Role of rabbit caliciviruses as biocontrol agents



NZ RHDV Rabbit Tracker

LINZ & MWLR