

Supplementary Material

Identification and characteristics of refuges for the threatened swamp antechinus (*Antechinus minimus maritimus*) under climate change; targeted surveys across the Otway Ranges, south-east Australia

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Table S1. Summary of Otways camera trapping January 2018 – December 2023

Region Site	Number cameras	Start date	Number survey nights	Total trap nights
Eastern Otways				
Flaxbourne	1	20/04/2018	6	6
Forest rd east	2	20/04/2018	12	24
Bald Hills Rd Grid B	2	12/06/2018	19	38
Pipeline	2	12/06/2018	18	36
Urquharts Bluff	2	13/06/2018	18	36
Hutt Gully	1	13/06/2018	36	36
EC Tk BH Rd	1	15/06/2018	36	36
EC Tk Kylie	1	18/06/2018	13	13
EC Tk Hagg G	1	18/06/2018	13	13
Hutt Gully	1	9/07/2018	3	3
Currawong Pred	30	2018	325	9750
Currawong Tunnels	20	2020		312
Flaxbourne Rd	6	31/01/2021	36	216
Forest Rd	2	31/01/2021	36	72
Harrison Tk north	6	15/03/2021	36	216
Denhams Salt Creek	2	1/06/2021	17	34
Painkalac Creek	10	12/07/2021	16	160
Tanners Rd	6	8/10/2021	13	78
Coalmine Creek	5	21/12/2021	23	115
Devils Elbow	1	21/12/2021	23	23
Distillery Creek	3	23/12/2021	27	81
Guvvos Beach	1	23/12/2021	27	27
Sunnymeade	3	20/12/2021	24	72
Urquharts headland	2	20/12/2021	24	48
Eastern View	8	16/12/2021	27	216
Sheoak Slope	2	16/12/2021	27	54
Moggs Creek	6	12/01/2022	19	114
Painkalac Creek	3	13/01/2022	19	57
Flaxbourne Road	9	19/01/2022	22	198
Hutt Dunes	4	19/01/2022	26	104
Hutt Gully	2	19/01/2022	26	52
Edwards Creek Tk	5	24/01/2022	33	165
Denhams Tk	6	08/02/2022	17	102
Harrison Tk nth NHM	6	20/01/2021	19	114
Harrison Tk nth swamp	3	20/01/2021	19	57
Urquharts beach	5	04/11/2021	18	90
Sheoak slope	2	16/12/2021	27	54
Moggs Creek Track	12	16/02/2022	22	264
Hutt's Dunes	2	25/02/2022	20	40
Aireys Lighthouse	7	27/02/2022	15	105
Painkalac Creek	5	30/03/2022	10	50
Hutt Gully	2	31/03/2022	9	18
Forest Road	7	20/04/2022	15	105
Bald Hills Tunnel	5	28/07/2022	27	135
Painkalac Creek	2	20/09/2022	25	50
Urquharts Beach	2	20/09/2022	25	50
Bald Hills Grid B	4	20/09/2022	25	100
Flax Forest Rd	7	26/06/2022	15	105
Flax Forest Rd	7	14/09/2022	14	98

Painkalac Creek	5	5/05/2022	8	40
Denhams Track	2	20/03/2023	24	48
Eastern View Burn	2	10/04/2023	21	42
Central Otways				
Carlisle	2	7/06/2019	4	8
Carlisle	9	18/05/2020	22	198
Forrest/Yaugher	12	12/04/2021	19	228
Devondale Road	5	18/12/2021	28	140
Egans Tk	3	01/12/2021	35	105
Old Carlisle, Cricket Pitch, Rapier Ridge	3	1/11/2021	24	72
Boggy Creek Tunnel	3	20/07/2022	35	105
Cricket Pitch Tunnel	3	20/07/2022	35	105
Carlisle	7	20/10/2022	14	98
Montys Tk	1	9/11/2022	10	10
Egans Tk	1	9/11/2022	10	10
Rapier Ridge	4	9/11/2022	10	40
Carlisle	13	24/01/2023	34	413
Porcupine	14	01/02/2023	15	210
Egans Tk	3	04/04/2023	20	60
Montys Tk	4	05/04/2023	19	76
Forrest/Yaugher	4	05/04/2023	19	76
Grey River	4	01/05/2023	25	100
Wye River	3	01/05/2023	25	75
Rapier Ridge	2	31/05/2023	23	46
Western Otways				
Blanket Bay	7	3/03/2022	31	217
Parker Hill	6	3/03/2022	31	186
Crayfish Bay	4	3/03/2022	31	124
Aire River	14	02/08/2022	24	264
Johanna River	10	02/08/2022	24	240
Skeenes Creek	7	04/26/2022	16	112
Blanket Bay	1	04/26/2022	16	16
Parker Hill	3	04/26/2022	16	48
				Total
				17454

Table S2. Summary of Otways live trapping January 2018 – December 2023

Region Site	Number traps	Start date	Number survey nights	Total trap nights
Eastern Otways				
Flax Grid A	30	20/04/2018	3	90
Forest Rd east	30	20/04/2018	3	90
Bald Hills Rd Grid B	30	11/05/2018	4	120
Pipeline Tk Grid 9	30	11/05/2018	4	120
Urquarts Bluff	30	12/05/2018	3	90
Hut Gully	30	12/05/2018	3	90
Edwards Ck Tk BH_RD	15	18/05/2018	3	45
Edwards Ck Tk KA_Gd	30	18/05/2018	3	90
Edwards Ck Tk, Haggarts	15	18/05/2018	3	45
Gilberts St, Hutt upper	6	29/06/2018	1	6
Hut Gully	6	9/07/2018	1	6
Hut Gully	7	10/07/2018	2	14
Currawong_HS_12	20	11/06/2019	3	60
Currawong_HS	20	6/07/2019	3	60
Currawong_HS	20	30/07/2019	4	80
Currawong_HS	20	30/08/2019	3	60
A1 Painkalac	17	20/12/2021	3	51
Coalmine Creek	8	06/07/2022	3	24
Eumeralla	18	18/07/2022	3	54
Hutt Gully	8	06/07/2022	2	16
Painkalac Creek	18	30/06/2022	7	126
Point Roadknight	15	18/07/2022	3	45
Urquharrrts Beach	20	28/06/2022	3	60
Urquharrrts Bluff headland	25	28/06/2022	3	75
Painkalac	10	21/03/2023	3	30
Painkalac	20	30/05/2023	4	80
Painkalac	20	09/06/2023	1	20
Painkalac	20	26/11/2023	1	20
Painkalac	40	08/12/2023	3	120
Central Otways				
Old Carlisle Tk Upsl	5	12/06/2019	2	10
Old Carlisle Tk gully	5	12/06/2019	2	10
Cricket Pitch Upsl	5	12/06/2019	2	10
Cricket Pitch gully	5	12/06/2019	2	10
Cricket Pitch swamp gully	5	12/06/2019	2	10
Peppermint Parade upsl	5	12/06/2019	2	10
Carlisle-Gellibrand Rd gully	5	23/05/2020	5	25
Carlisle-Gellibrand Rd Upsl	5	23/05/2020	4	20
Cricket Pitch gully Swamp 2	5	23/05/2020	4	20
Boggy Creek gully 3	5	23/05/2020	4	20
Boggy Creek upslope 3	5	23/05/2020	4	20
Boggy Creek upslope 4	5	23/05/2020	4	20
Rapier Ridge gully 5	10	23/05/2020	8	80
Old Carlisle Track gully 6	5	23/05/2020	5	25
Old Carlisle Track upslope 7	5	23/05/2020	4	20
Old Carlisle Track upslope 8	5	23/05/2020	4	20
Cricket Pitch upslope 9	5	23/05/2020	4	30

Cricket Pitch upslope 10	5	23/05/2020	3	15
Cricket Pitch gully 11	5	23/05/2020	3	15
Reedy ck 7 sites	210	2021	4	840
Sharps/Cora Lynn 6 sites	180	2021	4	720
Track off Old Carlisle gully 2	24	27/04/2021	4	96
Track off Old Carlisle gully 3	24	27/04/2021	4	96
Old Carlisle Track upslope 1	24	27/04/2021	4	96
Old Carlisle Track gully 1	24	29/04/2021	4	96
Old Carlisle Track upslope 2	24	29/04/2021	4	96
Old Carlisle Track gully 2	24	29/04/2021	4	96
Old Carlisle Track upslope 3	24	29/04/2021	4	96
Gellibrand-Carlisle Road gully 1	24	1/05/2021	4	96
Gellibrand-Carlisle Rd upslope 1	24	1/05/2021	4	96
Gellibrand-Carlisle Road gully 2	24	1/05/2021	4	96
Gellibrand-Carlisle Rd upslope 2	24	1/05/2021	4	96
Rapier Ridge Track gully 1	24	3/05/2021	4	96
Rapier Ridge Track gully 2	24	3/05/2021	4	96
Rapier Ridge Track gully 3	24	3/05/2021	4	96
Rapier Ridge Track midslope 1	24	3/05/2021	4	96
Rapier Ridge Track midslope 2	24	28/05/2021	4	96
Rapier Ridge Track midslope 3	24	28/05/2021	4	96
Rapier Ridge Track upslope 1	24	28/05/2021	4	96
Rapier Ridge Track upslope 2	24	28/05/2021	4	96
Rapier Ridge Track upslope 3	24	29/05/2021	4	96
Old Carlisle Track midslope 1	24	29/05/2021	3	72
Old Carlisle Track gully 3	24	29/05/2021	3	72
Old Carlisle Track gully 4	24	29/05/2021	3	72
Cricket Pitch Road midslope 1	24	1/06/2021	4	96
Cricket Pitch Road gully 1	24	1/06/2021	4	96
Gellibrand-Carlisle Road gully 3	24	1/06/2021	4	96
Gellibrand-Carlisle Rd upslope 3	24	1/06/2021	4	96
Cricket Pitch Road upslope 1	24	3/06/2021	4	96
Cricket Pitch Road midslope 2	24	3/06/2021	4	96
Boggy Creek Track gully 1	24	3/06/2021	4	96
Boggy Creek Track upslope 1	24	3/06/2021	4	96
Cricket Pitch Road midslope 3	24	5/06/2021	4	96
Cricket Pitch Road gully 2	24	5/06/2021	4	96
Old Carlisle Track gully 5	24	7/06/2021	3	72
Old Carlisle Track midslope 2	24	7/06/2021	4	96
Old Carlisle Track upslope 4	24	7/06/2021	4	96
Old Carlisle Track upslope 5	24	7/06/2021	4	96
Old Carlisle Track upslope 6	24	7/06/2021	4	96
Old Carlisle Track upslope 7	24	7/06/2021	4	96
Egans Track	24	24/08/2022	3	72
Montys Track	24	23/08/2022	3	72
Grey River	18	05/07/2022	3	54
Skenes Creek	30	05/07/2022	3	90
KA site 17	18	22/11/2022	2	36
KA site 18	17	22/11/2022	2	34
KA site 19	17	22/11/2022	2	34
KA site 20	17	22/11/2022	2	34
KA site 41	22	28/11/2022	3	66

KA site 42	22	28/11/2022	3	66
KA site 32	22	28/11/2022	3	66
KA site 43	23	28/11/2022	3	69
Wildlife Wonders	60	30/01/2023	4	240
KA site 18	24	8/05/2023	4	96
KA site 20	24	8/05/2023	4	96
KA site 1	24	9/05/2023	3	72
KA site 5	10	10/05/2023	2	20
Western Otways				
Bimbi Park	26	17/08/2022	3	78
Crayfish Bay	20	11/07/2022	9	180
Parker Inlet	22	11/07/2022	4	88
Blanket Bay	21	16/08/2022	1	21
Shelley Beach	20	25/07/2022	4	80
Gibson Steps	16	26/07/2022	3	48
Princetown 1	20	08/08/2022	3	60
Princetown 2	15	08/08/2022	3	45
Princetown 3	15	08/08/2022	3	45
Two Mile Track	20	25/07/2022	4	80
Crayfish Bay	25	05/07/2022	3	75
Crayfish Bay	20	15/08/2022	4	80
Gibson Steps	14	09/08/2022	3	42
Sparks Gully	24	22/05/2023	4	96
Shelley Beach	24	22/05/2023	4	96
The Arch	15	23/05/2023	3	45
				Total
				9771

Location/Site	Year last recorded 1975 - 2007	Maximum trap success	Year last recorded 2013-16	Maximum trap success	Year last recorded 2018-23	Maximum trap success
Eastern Otways						
Harvey	1981	7.0	0	0	0	0
Bald Hills B	2005	7.67	2013	1.33	0	0
Bald Hills C	2005	3.89	2015	0.33	-	-
Urquhart	2007	20.67	0	0	0	0
Coast dune 36	2001	3.33	2015	2.22	0	0
Coast dune 37	2001	4.44	0	0	-	-
Hutt	1997	1.11	2015	na	0	0
Coast dune 35	1983	2.22	0	0	-	-
Coast dune 39	2001	3.33	0	0	-	-
Eumeralla	2007	2.78	2015	1.24	0	0
Salt Creek 122	2001	2.22	0	0	-	-
Painkalac	2001	13.33	0	0	2022 - 23	1.5 – 35.0
Batson Tk	1981	1.6	0	0	-	-
Pipeline Pnov 9	1986-88	0.0	2015	1.11	-	-
Aireys Inlet LHW	2002	16.7	0	0	-	-
Aireys Inlet LHE	2002	20.0	0	0	-	-
Aireys Inlet Gully	2003	10.0	0	0	-	-
Aireys Inlet HBB	1999	16.7	0	0	-	-
Edwards Creek	2004	5.00	0	0	0	0
Distillery Creek	2002	5.3	0	0	-	-
No 2 Road_Gully	-	-	-	-	2019	5.0
Central Otways						
Cricket Pitch	-	-	-	-	2019	3.3
gully 3						
Rapier Ridge	-	-	-	-	2020	2.4
gully 5						
Carlisle					2021	21.5
Carlisle					2022 -23	0

Table S3. Comparison of live trap success (total captures/total number of nights *100) of swamp antechinus in the Otways over time (– not live trapped, na data not available)

Crayfish Bay	-	-	-	-	2022	1.7
Parker Inlet	1976	17.00			2022	12.5
Western Otways						
Shelley Beach	1992	10.0			2023	5.2
Gibson Steps	-	-	-	-	2022	18.8
Gibson Steps 2	-	-	-	-	2022	9.5
Princetown 2	-	-	-	-	2022	4.4
Sparks Gully	-	-	-	-	2023	4.2
The Arch	-	-	-	-	2023	2.2

Table S4. Identified refuges for swamp antechinus across the Otways and their characteristics

EVCs: HW, heathy woodland; SH, sandy heathland; HLF, heathy lowland forest; EW, estuarine woodland; CHS, coastal headland scrub; CS, coastal scrub; LF lowland forest, SWF, shrubby wet forest; SFF shrubby foothills forest; DHS, damp heath scrub, WH wet heathland. Ecological vegetation class (EVC) is the standard unit for classifying vegetation types in Victoria, based on floristics, lifeforms, and ecological characteristics. Links; linkages to habitat, *Phytophthora* dieback PPA (Priority Protection Area) (Walshe *et al.* 2021, 2022). Light grey shading represents mid-connected refuges and dark grey shading represents macro-refuges.

Refuge ID	Refuge category	Area (Ha)	Location	Topographic feature (creek, gully, dune)	EVCs	Notes
1	Micro-refuge	127.81	Eastern View	Coalmine Creek/Spout Creek/Moggs Creek	CS	Long Linear shape
2	Micro-refuge	255.59	Coastal Lorne-Wye River	Sheoak Creek, Cumberland River, Jamieson Creek		Long linear shape
3	Mid-connected refuge.	942.43	Creek headwater – Seaview to Moggs Creek	Reedy Creek, Grassy Creek, Spout Creek, Coalmine Creek, Moggs Creek.	SWF SFF	Inland refuge connected to source populations on coast
4	Micro-refuge	224.69	Painkalac, Aireys Clifftop, Sunnymead, Urquarts, Hutt Gully - Point Roadknight	Painkalac Creek, estuary, dune Aireys, Sunnymead, Urquharts Clifftop, Urquharts dunes Hutt- Point Roadnight dunes	EW CS CHS SH	Long liner shape.
5	Micro-refuges.	106.06	Hutt, Urquart Harvey Street Gullies Anglesea	Hutt Gully/Urquart Gully/Harvey Street Gully Anglesea	HW	Inland from coastal refuge habitat.
6	Micro-refuge.	339.31	Anglesea to Jan Juc	Anglesea River mouth, Point Addis gully systems, Jan Juc Coastal Headland	HW CHS EW	Linear feature.
7	Micro-refuge	59.82	Grey River	Grey River dunes	CS	Isolated from connectivity to the west.
8	Micro-refuge	39.14	Skenes Creek	Skenes Creek coastal scrub, unconnected	CS	Isolated.

Refuge ID	Refuge category	Area (Ha)	Location	Topographic feature (creek, gully, dune)	EVCs	Notes
9	Micro-refuge	59.47	Marengo	Some connectivity to Barham River		Isolated
10	Mid-connected refuge.	718.24	Cape Otway	Coastal connectivity east to Marengo.	CS	Connection eastwards
11	Micro-refuge.	245.83	Aire River Hordern Vale	Aire River	CS CHS	Surrounded by high impact agriculture.
12	Micro-refuge.	289.64	Johanna	Johanna River	CS	Border- high impact agriculture
13	Mid-connected refuge.	922.88	Porcupine Creek Ref. Area	Porcupine Creek, gullies	HW LF	Historic dieback, dense post-forestry regrowth. <i>Phytophthora</i> dieback PPA
14	Macro-refuge.	4395.07	Carlisle Heath	Creek, gully habitat	WH HW	<i>Phytophthora</i> dieback PPA
15	Macro-refuge.	4859.47	Egans Track – Mt McKenzie	Inland heathland, gully habitat	WH HW	<i>Phytophthora</i> dieback PPA
16	Macro-refuge.	1170.45	Port Campbell	Coastal Headland, gullies	CHS DHS	Linear habitat.
17	Micro-refuge	89.48	Denhams Track E. Otways	Salt Creek, inland heathland, wet gullies	HW HLF	Wet gullies <i>Phytophthora</i> dieback PPA

Table S5. Summary of fire history, specific disturbance and threats for refuges

Micro (micro-refuge), Mid- c (mid-connected refuge, light grey shading), Macro (Macro-refuge, dark grey shading),

Fragmentation threat based on habitat size, shape H high (< 340 ha, linear), M medium (60-300ha, not linear), L low (700- 4800 ha not linear)

WF Wildfire threat - H High for all based on Otway bushfire risk assessment (The State of Victoria Department of Environment, Land, Water and Planning 2020).

FRB fuel reduction burning as Low if in habitat not included in spatial and temporal fuel management and ecological fire regime burn plans e.g. coastal dunes, Medium if included in burn plans and High if included in burn plans to be implemented in next 3 years (The State of Victoria Department of Environment, Land, Water and Planning 2020, 2024)

Presence of weeds and the plant pathogen (*P. cinnamomi*), based on site observations, and scored as H high (> 30%), M medium (20-30%), L low < 20%) and for *P. cinnamomi* classed as NA not applicable where vegetation present was non susceptible, such as coastal scrub.

Recreation - Presence of DW dog walking, OLD, off leash dogs, MBR, motor and mountain bikes were based on camera results and site observations scored as H high, M medium, or N none

Introduced species R (rabbit), F (fox), C (cat), DR (deer), based on camera results and site observations scored as H high, M medium, or N none

Erosion vulnerability based on the Victorian Coastal Hazard Assessment (Very High, High, Medium) (CoastKit - marineandcoasts.vic.gov.au).

Refuge ID Category	Location	Fragmentation	WF threat, recent	FRB threat	Weeds	<i>Phytophthora</i>	Recreation	Introduced spp	Erosion vulnerability
1 Micro	Eastern View	H	H 1983	M	H	NA	DW H OLD H	F M C M	VH 40% H 10% M 50%
2 Micro	Coastal Lorne-Wye River	H	H 1983, 2015	M	H	NA	DW H OLD H	F M C M R H	M 100%
3 Mid connected	Creek headwater – Seaview to Moggs Creek	N	H 1983	M	M	L	N	F M C M	NA
4 Micro	Painkalac, Aireys Clifftop, Sunnymead, Urquarts, Hutt Gully - Point Roadknight	H	H 1983	L	H	NA	DW H OLD H MBR H	F M C M R H	VH 10% H 60% M 30%

Refuge ID Category	Location	Fragmentation	WF threat, recent	FRB threat	Weeds	Phytophthora	Recreation	Introduced spp	Erosion vulnerability
5 Micro	Hutt, Urquart Harvey Street Gullies Anglesea	H	H 1983	L	H	L	DW H OLD H MBR H	F M C M DR M	NA
6 Micro	Anglesea - Jan Juc	H	H 1983	L	H	H	DW H OLD H MBR H	F M C M DR M	VH 30% H 30% M 40%
7 Micro	Grey River	H	H UN	L	H	NA	N	N	M 100%
8 Micro	Skenes Creek	H	H UN	L	H	NA	N	F M C M	H 10% M 90%
9 Micro	Marengo	M	H UN	L	H	NA	DW H OLD H	F M C M DR M	VH 30% H 30% M 40%
10 Mid- c	Cape Otway	L	H UN	H	M	NA	DW H OLD H	F M C M	VH 5% H 5% M 90%
11 Micro	Aire River Hordern Vale	M	H UN	M	H	NA	DW H OLD H	F M C M DR M	NA
12 Micro	Johanna	M	H UN	M	H	NA	DW H OLD H	F M C M	NA
13 Mid- c	Porcupine Creek Ref	L	H UN	L		VH	N	F M C M DR M	NA
14 Macro	Carlisle Heath	L	H 2019	H	M	VH	DW M OLD M	F M C M DR M	NA
15 Macro	Egans Track – Mt McKenzie	L	H UN	H	M	VH	DW M OLD M	F M C M DR M	NA
16 Macro	Port Campbell	M	H UN	M	M	NA	DW M OLD M	F M C M	VH 40% H 20% M 40%

Refuge ID Category	Location	Fragmentation	WF threat, recent	FRB threat	Weeds	<i>Phytophthora</i>	Recreation	Introduced spp	Erosion vulnerability
17 Micro	Denhams Track	M	H 1983	H	M	H	DW H OLD H MBR H	F M C M DR M	NA