Oregus inaequalis Castelnau, its distribution, and abundance at Swampy Summit, Otago

DOC SCIENCE INTERNAL SERIES 6

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Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff, or external contractors funded by DOC. It comprises progress reports and short communications that are generally peer-reviewed within DOC, but not always externally refereed. Fully refereed contract reports funded from the Conservation Services Levy are also included.

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ISSN 1175-6519

ISBN 0-478-22148-7

This is a client report commissioned by Otago Conservancy and funded from the Unprogrammed Science Advice fund. It was prepared for publication by DOC Science Publishing, Science & Research Unit; editing and layout by Geoff Gregory. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

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ABSTRACT

A comprehensive study was undertaken to determine the historical and current distributions of *Oregus inaequalis*, its abundance at Swampy Summit and the possibility of hedgehogs as potential predators. The report details six key characteristics that allow field distinction of *Oregus inaequalis* from coastal Otago *Oregus aereus* s.l. Extensive pitfall trapping indicated little range contraction based on the known historical distribution, but there was no recorded extension of the known range. *O. inaequalis* was recorded at Swampy Summit, Leith Saddle, Mt Cargill, Leith Valley (three sites) and Ross Creek Reservoir (both upper and lower portions of the reserve). No sound estimate was obtainable of the abundance of *O. inaequalis* at Swampy Summit. However, the population appears to be considerable and is unlikely to be declining. Trapping indicated that the period of greatest beetle activity was November–December, which represents the most suitable time for any future monitoring. Hedgehogs could not be excluded as predators of *O. inaequalis*, but further sampling is required before a conclusive statement can be made. No further monitoring is recommended at Swampy Summit, but a resurvey of Mihiwaka is recommended to confirm the absence of *O. inaequalis* from a location where it was previously recorded. Monitoring is recommended for all sites if they are subject to major disturbance (e.g. fire) to determine the resilience of known populations. Development on remaining native forest refugia in the Leith Valley should be discouraged, as it is likely that this represents the original habitat type for *O. inaequalis*.

Keywords: *Oregus inaequalis*, carabid beetles, identification, distribution, abundance, Swampy Summit, Otago, New Zealand, Waikouaiti Ecological District.

Pawson, S.M.; Emberson, R.M. 2001. *Oregus inaequalis* Castelnau, its distribution, and abundance at Swampy Summit, Otago. *DOC Science Internal Series 6*. Department of Conservation, Wellington. 20 p.

1. Introduction

The family Carabidae comprises a very diverse group of active ground-dwelling beetles. Worldwide there are more than 40 000 described species, making it one of the most species-rich Coleoptera families (Lovei & Sunderland 1996). The New Zealand carabid fauna consists of 424 species (92% endemic) currently assigned to 78 genera (Larochelle & Larivière 2001). However, the taxonomy, and phylogeny of the family Carabidae in New Zealand is still far from settled, and the exact number of genera and species is in a constant state of flux. Carabid beetles are easily distinguished by their streamlined bodies, prominent mandibles, and notopleural suture of the metasternum (Klimaszewski & Watt 1997; Lawrence & Britton 1991).

Most carabids complete their life cycle from egg to reproduction and death within a single year; however, longer life cycles are known in some cases (Lovei & Sunderland 1996). This is normally associated with relatively harsh environments, e.g. *Pterostichus madidus* and *Calathus fuscipes* from Europe have biennial life cycles above 300 m and annual development at lower altitudes (Butterfield 1996). The phenology and longevity of beetles in the genus *Oregus* remains unknown. Little is known about the larval stages of many New Zealand carabid species, including *Oregus*, the larvae of which are undescribed. However, typical larval carabids are campodeiform, actively mobile, and often soil-dependent for pupation (Lovei & Sunderland 1996). Carabid larvae have normally been associated with carnivory, but in some cases, e.g. some European *Harpalus* and *Ditomus*, are known to be granivorous (Jorgensen & Toft 1997; Sunderland et al. 1995). Furthermore, adults of *Metaglymma monilifer* (a broscine closely related to *Oregus*) have been found to have seeds in their gut (Ruth Guthrie, pers. comm. 2001). The majority of adult carabids are carnivorous, but some species are phytophagous or omnivorous (Jorgensen & Toft 1997; Lovei & Sunderland 1996). The feeding behaviour of the genus *Oregus* (both adult and larvae) is unknown.

Castlenau originally described *Oregus inaequalis* as *Mecodema inaequale* in 1867 (the syntypes are held at the Museo Civico Di Storia Naturale G. Doria Genova, Italy). Castlenau noted its similarity to *eneum,* a mis-spelling of *aereus*, as Castlenau refers in this instance to White's (1846) original description of *Broscus aereus* (later re-designated as *Oregus aereus*). Castlenau distinguished *M. inaequale* from *B. aereus* by its shorter, broader appearance and stronger elytral striation (Castelnau 1867). Putzeys transferred *Mecodema inaequale* and *Broscus aereus* into a newly erected genus *Oregus* in his review of the Australian Broscini in 1873 (Putzeys 1873). Britton (1949) retained this placement in his review of the New Zealand Broscini. No taxonomic work has been published since 1949 regarding the genus.

The conservation status of the New Zealand carabid fauna is a woeful tale. Four species are presumed extinct, and a further 47 species are considered threatened, based on existing information (Molloy & Davis 1994). Most of the threatened species belong to two genera of large flightless carabids, *Mecodema* and *Megadromus*. There have been few in-depth investigations, all since 1990, and all involve either the genus *Mecodema* or *Megadromus* (Anderson 2000; Barratt 1993, 1994; Tennyson 1998).

Large carabid beetles are particularly susceptible to predation, due to their ground-dwelling habits, nocturnal foraging, and the limited mobility of larval stages, which are also vulnerable to changes in environmental conditions (Lovei & Sunderland 1996). Molloy & Davis (1994) placed *Oregus inaequalis* as a Category B species in their prioritisation of New Zealand's threatened fauna. In response, DOC Otago Conservancy commissioned a report (Jamieson 1999) to collate existing records of *O. inaequalis* and provide recommendations for its conservation management. This study aims to extend the preliminary work of Jamieson (1999) and provide:

1. a guide to distinguishing *O. inaequalis* from coastal Otago *O. aereus* s.l.;
2. a re-inventory of the historical records of *O. inaequalis*, based on personal examination of all known and available specimens in New Zealand collections, and overseas collections where possible;
3. a comparison of historical records with the current distribution of *O. inaequalis* based on pitfall trapping and hand searching;
4. an estimate of the abundance of *O. inaequalis* at Swampy Summit;
5. a preliminary investigation of hedgehogs as potential predators of *O. inaequalis*.

2. Methods

Material was examined from collections, both institutional and private throughout New Zealand and overseas (Table 1). Using characters established by Britton (1949) and others developed by ourselves, we have revised the list of known specimens of *O. inaequalis*. This list (Appendix 1) formed the basis for the historical distribution of *O. inaequalis.*

TABLE 1. COLLECTIONS EXAMINED FOR *OREGUS* DURING THE COURSE OF THE STUDY.

INSTITUTIONAL COLLECTIONS	PRIVATE COLLECTIONS
Auckland Museum (AMNZ)	Barbara Barratt
New Zealand Arthropod Collection (NZAC)	Brian Patrick
Museum of New Zealand, Te Papa (MONZ)	Eric Edwards
Lincoln University (LUNZ)	
Canterbury Museum (CMNZ)	
Otago Museum (OMNZ)	
Natural History Museum, London (BMNH)	
Bishop Museum (Hawaii) (BMH)	
Genoa Museum (Italy)	

The current distribution of *O. inaequalis* was determined using unbaited pitfall traps installed at various locations in the greater Dunedin area. Pitfall traps were left active for approximately one month (the time between sampling periods at Swampy Summit). Locations were chosen based on the historical distribution of *O. inaequalis* and areas with similar habitat to Swampy Summit. Locations were recorded using a Trimble GeoExplorer. Initially sodium benzoate was used as a preservative, but 10% ethylene glycol proved to be more suitable and was used for the second and subsequent samples.

An attempt was made to estimate the abundance of *O. inaequalis* at Swampy Summit. A grid (8 × 10 m) of live pitfall traps (identical to those used to determine the current distribution of *O. inaequalis*) was installed on 23 August 2000. The four corners of the grid were located (using a Trimble GeoExplorer), in clockwise order from the bottom left:

45º 47′ 36.54″ S, 175º 28′ 58.98″ E;
45º 47′ 39.11″ S, 170º 28′ 51.51″ E;
45º 47′ 35.29″ S, 170° 28′ 48.46″ E;
45º 47′ 32.62″ S, 170º 28′ 55.80″ E.

Pitfall traps were spaced at 20 m intervals, the integrity of the grid was maintained by mapping it on the ground using tape measures and Pythagoras's theorem to obtain right angles. The traps were left for one month prior to their first use to prevent possible bias in trap captures due to disturbance during installation, a phenomena reported by Digweed et al. (1995). The traps were activated for periods of five nights (except for the last sampling period of four nights) between 23–27 September 2000, 29 October – 2 November 2000, 11–15 December 2000, 8–12 January 2001, and 17–20 February 2001. *O. inaequalis* caught during the trapping period were identified using a hand lens to observe their antennal segments, supraorbital setae and fore tibial spines. Individuals were marked with a fine-point silver marker (Pilot Super Colour Permanent Type Ink) and released in a random direction approximately 2 m from the trap. Anderson (2000) used a similar marking system with con-siderable success. The markings seemed to be impervious to the fossorial habits of *Mecodema howiti*, therefore it was assumed that the markings would be suitable for the closely related genus *Oregus*.

Minimum overnight temperatures were recorded using an electronic, max/min thermometer, with an accuracy of ± 0.1 ºC. Volumetric water content was recorded adjacent to each pitfall trapping during each sampling period using a Hydrosense soil water meter.

Hedgehog faecal pellets were collected from Swampy Summit to determine possible predation of *O. inaequalis*. Faecal pellets were separated in warm water and detergent, then sieved with a fine mesh to remove small particles. Coarser material was examined under a stereo-microscope using a Bogorov tray. Characteristic pieces such as tibia, elytral pieces, pronotum pieces, head capsules, antennal segments, and mouthparts were separated and preserved in 70 % alcohol. These remains were then compared with mounted specimens to determine the presence of *Oregus*.

Elytral remains were collected from the burrows of ground spiders. These were compared with mounted specimens to determine whether ground spiders predated *Oregus*.

3. Results

3.1 FIELD IDENTIFICATION

O. inaequalis can be separated from its sister species *O. aereus* with relative ease in the field using a simple 10× magnification hand lens. There are six key characters that in combination provide accurate field identification.

1. The initial assessment should look at the general shape and size of the beetle. *O. inaequalis* is shorter, and broader, with a significantly more prominent elytral shoulder (Fig. 1). This particular character is significant, and in combination with character (2) is often sufficient to identify *O. inaequalis*.
2. The striae on the elytra of *O. inaequalis* are more prominent and deeply impressed. Though difficult to illustrate in a photograph, e.g. Fig. 1, it is obvious on specimens.
3. The antennae of *O. inaequalis* are almost moniliform (bead-like), whereas in *O. aereus* they are more filiform (elongate). This gives *O. aereus* the appearance of much longer antennae. For a comparison between the two species, see Figs 2 and 3.
4. *O. inaequalis* has a row (6–8) of small spines that extend from the outer, anterior tip of the fore-tibia to the base of the antennal cleaning comb (Fig. 5). In coastal Otago *O. aereus* there are significantly fewer fore-tibial spines (Fig. 4). However, this character is quite variable and should not be used on its own to make a positive identification.
5. Both *O. inaequalis* and *O. aereus* have two pairs of setae above the eyes (supraorbital setae), but the number of pairs of setae located transversely across the vertex differs between the two species (*O. inaequalis* 3–4, whereas *O. aereus* normally has 1–2), see Figs 6 and 7 for a comparison.

Figure 1. *Oregus aereus* on the left and *O. inaequalis* on the right.

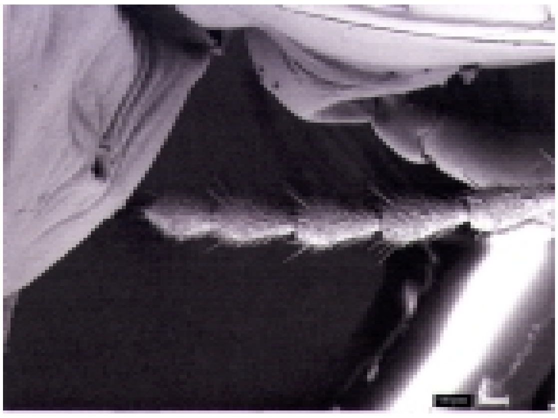

Figure 2. *O. aereus* antennae

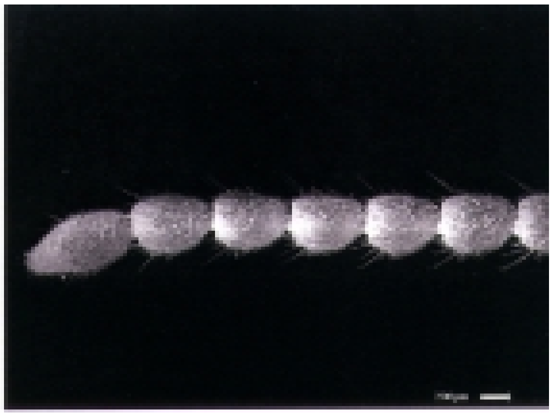

Figure 3. *O. inaequalis* antennae

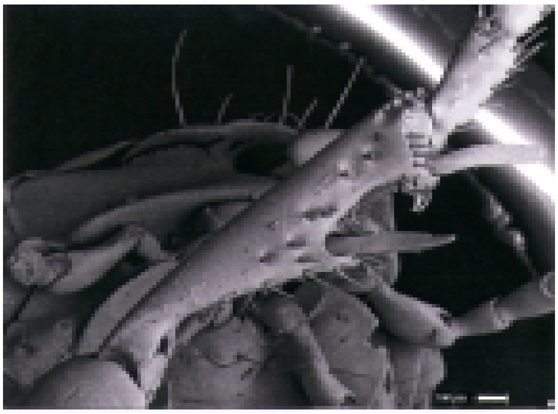

Figure 4. *O. aereus* fore-tibia

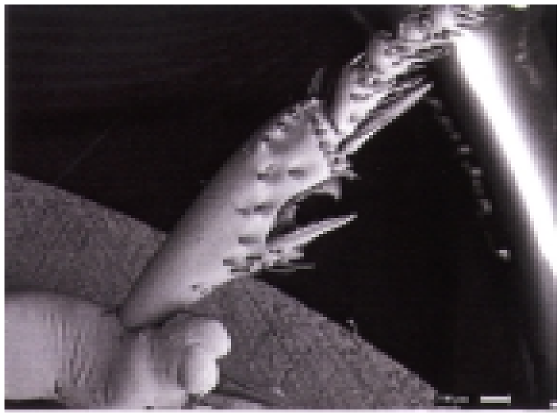

Figure 5. *O. inaequalis* fore-tibia

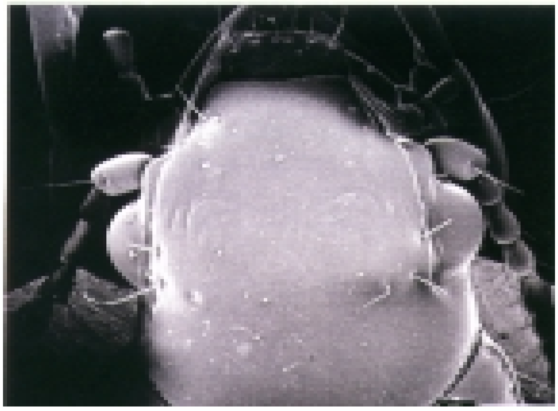

Figure 6. *O. aereus*, supraorbital setae

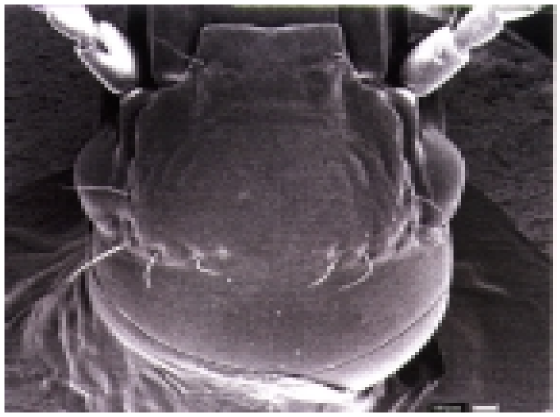

Figure 7. *O. inaequalis*, supraorbital setae

6. The tarsal segments of the fore-tibia in *O. inaequalis* are noticeably shorter than in *O. aereus* (see Figs 4 and 5 for a comparison). A similar difference is also present in the tarsal segments of the hind-tibia, see Fig. 1.

3.2 HISTORIC AND CURRENT DISTRIBUTION

The historical distribution of *O. inaequalis* (Appendix 2), is based on the personal examination of specimens known and available from national and international collections (a total of 56 individuals, Appendix 1). A similar inventory by Jamieson (1999) included a number of specimens that on reexamination proved to be *O. aereus* s.l. rather than *O. inaequalis*. Britton (1949) listed *O. inaequalis* from Invercargill, but examination of this specimen (held in NZAC) showed that it had been incorrectly identified and is in fact *O. aereus* s.l. A specimen from the C.E. Clarke Collection held in the Natural History Museum, London, records locality information indicating that Mihiwaka and Port Chalmers were probably used synonymously. A similar situation indicates that specimens labelled Waitati are in fact from the slopes of Swampy Summit on the Waitati side (Jamieson 1999).

Assuming that specimens labelled Port Chalmers really came from Mihiwaka, *O. inaequalis* was restricted in its historical distribution to flows from the third main eruptive phase of the Dunedin volcano (during the middle Miocene, 10–13 Ma) as mapped by Bishop & Turnbull (1996), which includes Swampy Summit, the Leith Valley, and scattered locations across the volcanic plugs between Leith Saddle and Mihiwaka.

The current known distribution of *O. inaequalis* was determined using pitfall traps and hand searching. Little range contraction appears to have occurred in the last 100 years. *O. inaequalis* was found at all sites where previously recorded, except Mihiwaka (Appendix 3). Although little range contraction was recorded during the study, there was a concurrent lack of extension to the known range. *O. inaequalis* was not recorded at any new sites, including Maungatua that has similar vegetation to Swampy Summit. However, most pitfall trapping was concentrated at sites with historical records of *O. inaequalis*.

3.3 ESTIMATE OF *O. inaequalis* ABUNDANCE AT SWAMPY SUMMIT

It should be noted that pitfall trap captures are in themselves not a measure of abundance, but a measure of the biological activity of the species captured. For example a very common species may not be caught in pitfall traps simply because it is not actively moving (and thus catchable) during the trapping period.

A total of 34 *O. inaequalis* were caught, marked and released in the pitfall trap grid on Swampy Summit during the five trapping periods. This amounts to a minimum population of 34 per 32 000 m^2. The distribution of trap captures throughout the grid is illustrated in Fig. 8. It was intended to use a removal method, e.g. Eberhardt's Removal Method (Krebs 1999), to estimate population size. However, insufficient beetles were caught to obtain a realistic estimate of the population using this or other removal methods. The lack of any recaptures suggests the population within the trapping grid is either much greater than 34, or alternatively captured individuals become trap-shy very quickly.

Trap captures followed a distinctive seasonal pattern, with increasing carabid activity from late October to December, and low activity in January that began increasing again in February (Fig. 9). This activity closely followed the trend of minimum overnight temperatures. Other studies have shown similar responses in carabid activity that are significantly correlated to temperature, e.g. Honek (1997).

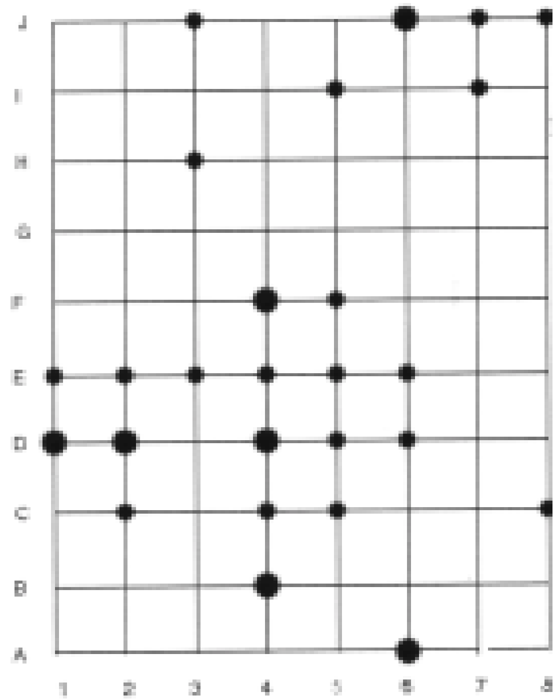

Figure 8. Distribution of pitfall trap captures of *O. inaequalis* at Swampy Summit.

Small circles, 1/trap; large circles, 2/trap.

Trap capture was not significantly affected by soil moisture (P < 0.128, Kruskal-Wallis, 4 d.f.). *O. inaequalis* was trapped at locations with soil moisture ranging from 54.8 to 96% (Fig. 10). However, due to the vegetation types, e.g. sphagnum, individual beetles were probably not experiencing the high soil moisture (in some cases 90–100%) measured by the probe. Trap captures of *O. inaequalis* were almost twice as frequent when surface boulders were present

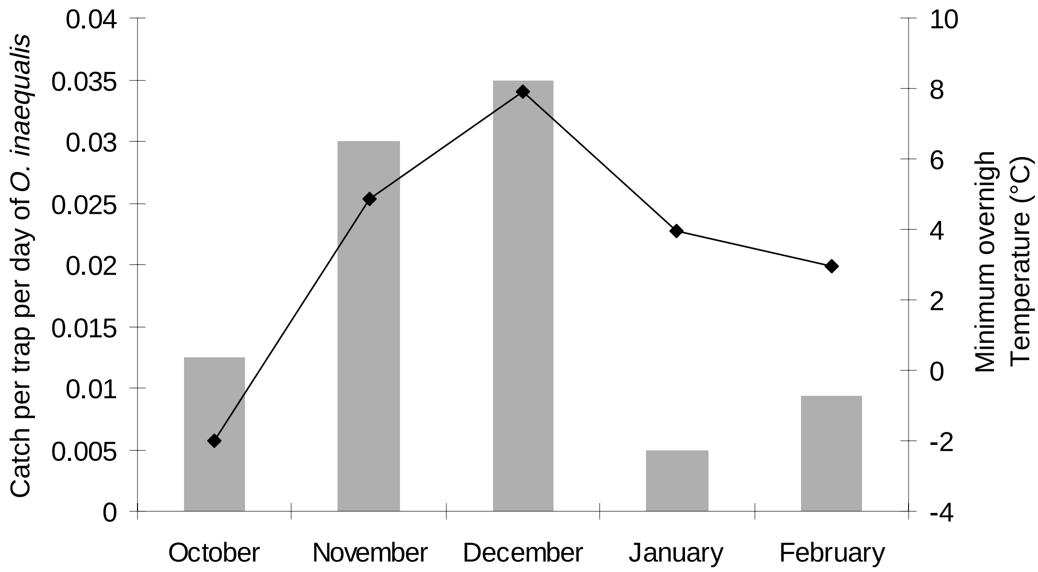

Figure 9. Monthly catch per trap of *O. inaequalis*, and minimum monthly overnight temperatures.

in the immediate vicinity (< 3 m) of the trap (Fig. 11), but this was not statistically significant, P < 0.465 Mann-Whitney U, 1 d.f.

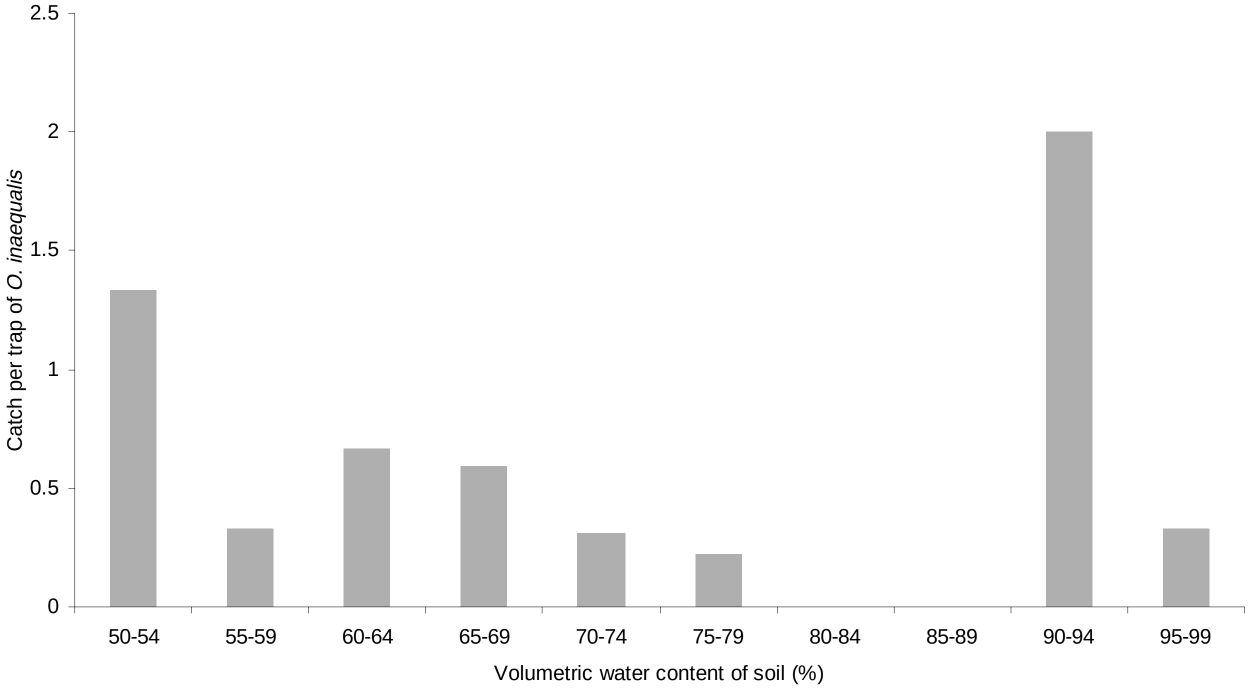

Figure 10. Influence of soil volumetric water content on rates of catch per trap of *O. inaequalis*.

Eight faecal samples from the European hedgehog were collected from Swampy Summit. Analysis of the remains did not conclusively identify *O. inaequalis* as a component of the diet. Remains of Coleoptera were common, including many Curculionidae, Scarabaeidae, Elateridae and Carabidae, including *Holcaspis* spp. and *Neoferonia* spp. Remains of both *O. inaequalis* and *O. aereus* were found in the nests of ground spiders; in

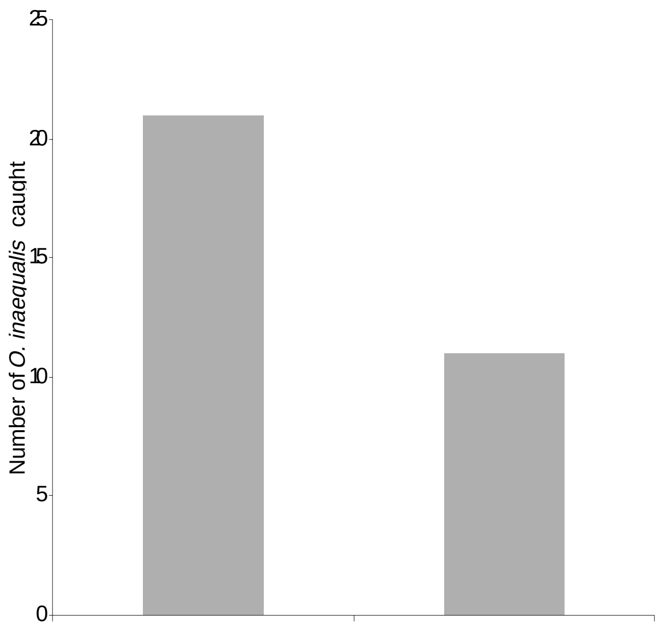

Figure 11. Influence of surface rocks on the catch per trap rates of *O. inaequalis*: (left) rocks present, (right) rocks absent.

some cases there were a dozen elytra in a single nest. This indicates that ground spiders are an important predator of *Oregus* as well as other Carabidae.

4. Discussion and recommendations

By following steps 1-6 in Section 3.1, it should be relatively straightforward for DOC staff to identify *O. inaequalis.* However, it is recommended that, prior to field identification, people should familiarise themselves with these characters from reference collections. Such collections are most easily accessed at Lincoln University, the Otago Museum, the New Zealand Arthropod Collection (Auckland), Auckland Museum, or the Museum of New Zealand (Te Papa).

The current distribution of *O. inaequalis* does not appear to have significantly contracted in comparison to historical records. It was not found at Mihiwaka in the present study, which was the most south-eastern known historical record. It is recommended that a detailed re-survey of Mihiwaka be completed (using pitfall traps and hand surveying techniques) during November and December to confirm its presence/absence in the area.

O. inaequalis was found in the mixed broadleaf podocarp forested gullies that adjoin Leith Valley, e.g. Ross Creek, Morrison's Burn, and an unnamed tributary accessed via a water access bridge at NZMS 260 I44 158 837, and in similar forest at Leith Saddle. This alters the perception that *O. inaequalis* is a tussock/ scrubland-adapted species. It is quite possible that *O. inaequalis* was originally a forest inhabitant and survives on Swampy Summit because of the wet environment. Swampy Summit, Mt Cargill and the sites in the Leith Valley are all on public land. Most is under the control of the Dunedin City Council and is used as water catchment land. As such it is afforded a degree of protection from urban development. Discouraging the removal of dead logs from the sites (particularly around Ross Creek Reservoir) would be beneficial to the continued survival of *O. inaequalis* at these sites.

Pitfall trapping indicates that *O. inaequalis* is relatively common at Swampy Summit. Other pitfall trap studies of carabids, e.g. Butcher & Emberson (1981) show highly variable catch rates per species. At Ahuriri Bush, on Banks Peninsula, the most common carabid (*Mecodema oregoides*) was caught at a rate of 0.19–1.44 per trap per month, whereas the least common species (*Oopterus laevicollis*) was trapped at a rate of 0.0027 per trap per month (these figures have been converted to represent an equivalent number of pitfall traps to Swampy Summit). Trap captures of *O. inaequalis* ranged from 0.005 to 0.0125 per trap per month. Though not as common as some comparable species (e.g. *M. oregoides*), *O. inaequalis* is probably more abundant on Swampy Summit than some carabids at other locations. This comparative approach gives an indication of the abundance of *O. inaequalis* at Swampy Summit. However, this should be understood in the context that pitfall trap captures are strongly influenced by the activity of the species involved and the habitat within which the trapping is conducted.

Further monitoring on a regular basis is not recommended at Swampy Summit or the adjoining broadleaf/podocarp forest gullies. However, it would be prudent to monitor following any major disturbance, e.g. fire or deforestation, to determine the resilience of the known populations. Development within the known distribution of *O. inaequalis*, especially the forested remnants of the Leith Valley, should be discouraged to prevent fragmentation of important forest refugia, especially as this forest type may be the original habitat for the species. Sampling/monitoring of *O. inaequalis* should be done during the months of November and December, as this corresponds to the known period of greatest surface activity.

The main threat to *O. inaequalis* on Swampy Summit is habitat modification by the invasion of introduced plant species. Gorse (*Ulex europaeus*) and broom (*Cytisus scoparius*) are widely, but sparsely, distributed across the area. Their effect on *O. inaequalis* is unknown, but it would be wise to take a proactive approach to prevent uncontrolled spread of these species.

Coleoptera remains were present in the faecal samples of hedgehogs, including two carabid species *Holcaspis* spp., *Neoferonia* spp., large numbers of Curculionidae, some Scarabaeidae and Elateridae. No recognisable remains of either *O. inaequalis* or *O. aereus* were observed. Unfortunately this does not preclude hedgehogs as a significant predator of *Oregus*. *Holcaspis* is more abundant than *Oregus* and therefore more likely to be present in the limited faecal samples examined. Given that they are known to feed on other carabids at Swampy Summit, it is highly likely that hedgehogs prey on *O. inaequalis*. Substantial further sampling would be required before hedgehogs could, with confidence, be eliminated as a predator of *O. inaequalis*.

Ground spiders are definitely predators of *O. inaequalis* and other carabids, e.g. *Holcaspis*, *Mecodema* and *Neoferonia*. Both ground spiders and Carabidae have probably co-existed for a substantial period of time and it is unlikely that predation by spiders has increased since human colonisation of New Zealand. As such, spiders are not thought to represent a potential threat to the survival of this species.

5. Acknowledgements

Many people must be thanked for their contributions, particularly Bruce McKinlay (DOC, Otago) for his assistance in setting up the field trial and monitoring some of the pitfall traps at various locations; Paul Pope (Dunedin City Council) for arranging access to many council reserves; Barbara Barrett (Agresearch) for discussions regarding *Oregus inaequalis*; Kathy Hill for help with fieldwork; Brian Patrick and Mark Walker (Otago Museum) for the loan of specimens and facilities at the Museum; Trevor Crosby (NZAC), Steven Thorpe and John Early (Auckland Museum), Ricardo Palma (Te Papa), Simon Pollard and

Peter Johns (Canterbury Museum), John Marris (Lincoln University), Stuart Hine (Natural History Museum, London), Roberto Poggi (Genoa Museum), Al Samuelson (Bishop Museum) for the loan of specimens; Work Bridge New Zealand for computing support; Neil Andrews (Canterbury University) for assistance with the scanning electron microscope; Mary Hennessy (Lincoln University) for assistance with GIS mapping. S.M.P. also thanks Brent Sinclair, Rebecca Eyles, Travis Cross and all their flatmates for accommodation while in Dunedin.

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Appendix 1. *Oregus inaequalis* in collections

Known specimens of *Oregus inaequalis* in collections

These are national, international and private collections that have been observed by S.M. Pawson.

LOCATION	SEX	DATE	COLLECTOR	COLLECTION
Dunedin	1M, 3?	? 1863	Castelnau	Museo Civico di Storia Naturale G. Doria Genova
Port Chalmers	1?	? Oct 1901	J.J. Walker	BMNH
Port Chalmers	2?	? Sep 1902	J.J.Walker	Hudson Collection, National Museum
Waitati	1?	11 Nov 1923	C.E.Clarke	AMNZ
Waitati	1M	14 Oct 1923	C.E.Clarke	AMNZ
Waitati	3F, 1M , 3?	7 Oct 1923	C.E.Clarke	AMNZ
Waitati	2?	7 Oct 1923	C.E.Clarke	National Museum
Waitati	1F	18 Oct 1925	C.E.Clarke	AMNZ
Waitati	4?	18 Sep 1926	C.E.Clarke	AMNZ
Waitati	2?	18 Sep 1926	C.E. Clarke Collection, BMNH	C.E. Clarke Collection, BMNH
Waitati Hills	1?	12 Sep 1926	C.E.Clarke	A.E.Brookes Collection, NZAC
?	1F	? Jan 1934	von Staudinger	F. van Emden Collection, BMNH
Mihiwaka, nr Port Chalmers	1?	21 Jan 1947	C.E. Clarke Collection, BMNH	C.E. Clarke Collection, BMNH
Leith Valley	2?	18 Apr 1960	I. Townsend	I.Townsend
Leith Saddle	1?	24 Sep 1966	R.R. Forster	Otago Museum (Wet)
Leith Saddle	1?	5 Nov 1967	R.R. Forster	Otago Museum (Wet)
Leith Saddle	1?	2 Dec 1967	R.R. Forster	Otago Museum (Wet)
Leith Saddle	1?	17 Jul 1967	R.R. Forster	Otago Museum (Wet)
Ross Ck Reservoir	1?	18 Oct 1981	J.C.Watt	NZAC
Mt Cargill	1?	21 Oct 1981	J.C.Watt	NZAC
Swampy Summit	1?	16 Dec 1984	B.I.P.Barratt	I. Townsend
Swampy Summit	1?	17 Nov 1984	B.I.P. Barratt	LUNZ
Swampy Summit	11?	17 Nov – 16 Dec 1984	B.I.P. Barratt	B.I.P. Barratt
Swampy Summit	10?	16 Dec 84 – 12 Jan 85	B.I.P. Barratt	B.I.P. Barratt
Swampy Summit	8?	12 Jan – 16 Feb 1985	B.I.P. Barratt	B.I.P. Barratt
Leith Saddle	1F	25 Dec 1989	A.C.Harris	Otago Museum
Bush track, Swampy Summit	1?	26 Nov 1993	I. Townsend	I.Townsend
Swampy Summit	1M, 1?	11 Feb 1995	B & H. Patrick	Otago Museum
Swampy Summit	1F	23 Nov 1997	E.Edwards, B & H. Patrick	E. Edwards
Flagstaff Hill	1M	?	?	A.E.Brookes Collection, NZAC
? Flagstaff Hill	1?	?	?	A.E.Brookes Collection, NZAC
Port Chalmers	1?	?	?	Hutton Collection, CMNZ
?	1?	?	?	CMNZ
?	1F	?	Wakefield	CMNZ
?	1?	?	?	Pasco Collection, BMNH

Appendix 2. Past distribution, *Oregus inaequalis*

Figure 12. Historical records of *O inaequalis*, based on personal examination of known and available specimens.

Black circles, known historical locations of *O. inaequalis*.

Appendix 3. Current distribution, *Oregus inaequalis*

Figure 13. Current distribution of *O inaequalis*, based on pitfall traps and hand collecting. Black circles, *O. inaequalis* present; grey circles *O. inaequalis* not found.