

Anticipating the unexpected – managing pasture pest outbreaks after large-scale land conversion

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Abstract

Pasture pests are often held in check by natural enemies but we have observed that severe pest attack over a wide area can occur after large scale land use change. Data were reviewed from current projects and databases for pest density and damage records covering the past 30 years. The focus was on areas where large scale land change has been implemented, including new irrigation schemes, pasture development from tussock or scrub, and land moulding for drainage via “flipping” or “hump and hollow”. In these situations, pest outbreaks reached unprecedented levels, e.g. 2200 grass grub larvae/m² in the Amuri irrigation scheme, 770 porina larvae/m² on the East Otago Plateau and 3500 manuka beetle larvae/m² at Cape Foulwind on the West Coast. With major land use change, a new environment is created where pest species are provided abundant resources and the initial invaders multiply rapidly, free from the pressure of natural enemies. Monitoring systems, to provide early warning of pest attack, and remediation strategies can be used to overcome damage by these pests.

Keywords: Land development, pest outbreaks, grass grub, manuka beetle, porina

Introduction

New Zealand pastoral agriculture, based on grasses and clovers, is an introduced (exotic) system that has been both profitable and resilient, although it is susceptible to pest outbreaks and requires commitment to ongoing pest and weed management. European forages are attacked by a number of endemic pests, such as grass grub (*Costelytra zealandica*) and porina (*Wiseana* spp.), which have been able to adapt to the introduced pasture system and reach densities that can cause widespread damage. Grass grub, for example, rarely exceeds 50 larvae/m² in native, tussock-dominated habitats but can rise to 10 times that level in a new pasture. New Zealand pastures have also been attacked by invasive exotic pests, such as Argentine stem weevil (*Listronotus bonariensis*) and clover root weevil (*Sitona lepidus*), which often build up to very high levels in a post-invasion peak.

For endemic pests invading a new area or exotics entering the country, the balance between the particular pest or weed in its natural habitat and its natural enemies will have been broken. Pest upsurge in new habitats is described as “natural enemy release” and is often the cause of pest outbreaks in new crops and rotations (Keane & Crawley 2002; Torchin & Mitchell 2004). Enemy release occurs when individuals invading new or disrupted environments thrive with an abundance of food resources in the absence of natural enemies. This paradise (i.e. escape from natural enemies) comes to an abrupt end when the population collapses due to the ingress of species-specific, density-dependent biotic agents (Anderson & May 1981). The lack of natural enemies for exotic invasive species has underpinned the discipline and subsequent industry of classical biocontrol where natural enemies are introduced to control the pest. Alternatively inundative biological control can be used, where a naturally occurring organism is amplified outside the ecosystem and subsequently released in large numbers to control the pest (Jackson *et al.* 2000), such as the application of *Serratia entomophila*, the causative agent of amber disease in grass grub and active ingredient in the products Invade™ and Bioshield™ (Jackson 2007).

Pest outbreaks due to release from natural enemies in new pastures have serious implications for land use conversions but are seldom considered in development plans. In this paper, cases of serious insect pest outbreaks after land use conversion are reviewed and options for mitigation suggested.

Methods

In this study we have reviewed published data, scanned historical databases and taken results from current trials. Pest densities have been estimated by taking spade samples throughout the selected paddocks. Generally 10–20 samples were taken per paddock, which provides an estimate of population with an SEM of <10% of mean for populations in the medium range and above (Heffernan *et al.* 1992). Pests were identified according to characteristics provided in PestWebNZ™ (AgResearch 2011). The larval stages of pests in this

report were identified to species based on raster pattern of larvae for Scarabaeidae, or to genus level for porina (*Wiseana* spp.). The highest populations were selected from AgResearch databases and are reported as a series of case studies associated with large scale land developments.

Results

Highest insect populations associated with pasture are listed in Table 1.

Grass grub

Grass grub invasion into new areas is regulated by the limited flight of the female and a relatively low fecundity. These factors govern the predominant pattern of damage occurring in a new pasture. Firstly, there is an invasion phase, when a relatively small number of female beetles invade from nearby areas and establish foci in the pasture. This is followed by the growth phase when populations grow in a linear pattern for 4–5 generations (East & Kain 1982). Grass grubs become a problem to farmers when larval densities exceed the damage threshold, estimated at 150 larvae/m² for dryland pastures and 200 larvae/m² in irrigated pastures in Canterbury (Townsend & Jackson 1997), but which may vary in other regions due to local conditions. The invasion phase depends on the proximity of existing grass grub populations and will be omitted altogether if pasture is resown, particularly by direct drilling, into an existing, albeit low, population. After land conversion to pasture from a grass grub free habitat, it may take 4–6 years for the population to establish before entering the growth phase.

Case 1. Grass grub in the Amuri irrigation scheme, Canterbury.

The Amuri irrigation scheme in the Waiau valley, Canterbury, began delivering water through a border

dyke system in 1980 and by 1984, 13 606 ha were covered (Greer 1984). The valley had been home to dryland sheepfarms with regular summer drought and low pest numbers. Land was moulded for the border dyke system and new pastures were sown, fertilised and initially produced high forage yields. After some years, residents observed massive flights of brown beetles on warm November evenings and farmers reported damage to pastures. A visit to the region in autumn 1988 revealed massive damage to pastures from the root feeding grass grub larvae. The average population from selected damaged paddocks was 430 larvae/m² (range 230–580, n=4) with a maximum localised population of >2200 larvae/m² from one damaged patch. With such populations many pastures were destroyed by the larvae necessitating resowing.

Case 2. Grass grub after forestry conversion to pasture on the North Island volcanic plateau.

The changing prospects of forestry and dairy farming have led to large areas of pine forest in the Waikato/Taupo catchments undergoing conversion to dairy farms. After clearing the timber and debris, the land has been prepared, usually with a forage break crop, before sowing with pasture. A period of good pasture growth generally occurred before grass grub damage became evident, depending on distance from infested pastures. Damaging populations have been reported from new pastures, previously close to the forest perimeter, within 3–4 years from sowing. Some pastures have averaged more than 700 larvae/m² (with patches as high as 2000/m²) and suffered almost total loss. New pastures sown in areas that were previously deep in the forest block took longer to become infested and for damage to become evident. However, once established, grass grub populations grew to very high levels and were highly damaging as the larvae were large and healthy compared with equivalent populations from established pastures. Grass grub larvae from pastures after forestry

Table 1 High pasture pest densities following land use changes in various regions of New Zealand.

Species	Density/m ²	Situation
Grass grub (<i>Costelytra zealandica</i>)	430–2200	Amuri irrigation scheme, Canterbury 1988. Pastures 3–5 years from sowing within 5–8 years from start of scheme with border-dyke irrigation after conversion from dryland pastures.
Grass grub	705–2040.	Volcanic plateau, Taupo, 2011. Pine forest conversion to pasture in 2006. Break crop followed by ryegrass /clover.
Manuka beetle (<i>Pyronota</i> spp.)	700–3500	West Coast, Cape Foulwind, 2009. Pastures on flipped soil, 7 years from development.
Porina (<i>Wiseana</i> spp.)	377–778	East Otago Plateau. Pasture development from tussock grassland and old browntop pasture to ryegrass/white clover based swards, 2–4 years from development.
Porina	>90 (after control)	West Coast, Cape Foulwind, 2004. Pastures on flipped soil, 1.5 years from development

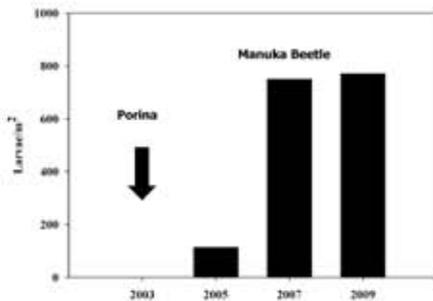


Figure 1 Pasture pests recorded from new pastures sown in 2002 after land flipping at Cape Foulwind

conversion sampled 3–5 years from sowing showed very low levels of amber disease (average <1%, n=6) compared with normal levels in this age of pasture (Jackson 2007).

Manuka beetle

Manuka beetles (*Pyronota* spp.) are a group of species of native scarab beetles whose larvae cause damage similar to grass grub by feeding on pasture plant roots. Outbreaks are frequently associated with development of pastures from scrub or bush (Thomson *et al.* 1978). Adult beetles are noticeable due to their bright metallic green colouring and swarming daytime flights that occur in early summer. Manuka beetle larvae are smaller than those of grass grub and damage will generally occur at population densities of more than 300/m².

Case 3. Manuka beetle infestations after large scale pasture developments on the South Island West Coast.

A large area of former pakihi swamp has been converted to pasture after “flipping” the soil. This process involves inverting and mixing the upper 1-2 m of the soil profile and preparing a new seed bed. Approximately 3000 ha of land has been converted to pasture on Cape Foulwind since 2001. Initial pasture growth was vigorous but was soon hindered by outbreaks of porina (see below) and the presence of manuka beetles was first noted in 2004 (Fig. 1). Populations rose rapidly and by 2009 all pastures were infested with average populations ranging from 100 to 1340 larvae/m². Interestingly, two species of manuka beetle were involved, *Pyronota festiva*, which is widely distributed through New Zealand, and a second species, *P. setosa* (det. Shaun Forgie, NZAC), which was previously considered rare but populations have developed to very high densities on Cape Foulwind. Without treatment, infested pastures will become covered with patches of larval damage in autumn, which then leads to a complete loss of sown species and replacement by weeds within 2–3 years from sowing. Despite an extensive and costly control programme, local farmers estimate that manuka beetles

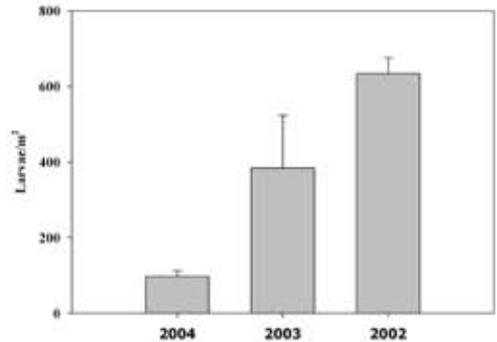


Figure 2 Porina densities (Number/m²) measured in pastures sown in 2002-2004. Error bars represent standard error of the means.

are causing a 30% loss in production on the Cape.

Porina

Porina moths are capable of long flights and are very fecund with a single female capable of producing up to 3000 eggs. As females fly, eggs are scattered over the pasture below. Survival of eggs and newly hatched, surface-dwelling larvae is enhanced by good pasture cover. When this is combined with the emergence of moths in close proximity to 2–4-year-old pastures that were sown after cultivation, high larval populations are often recorded. Densities of 20–40 porina larvae/m² in autumn/winter cause loss of pasture production, but plants generally survive. However, above 40 larvae/m² plants are killed by overgrazing and bare areas of pasture result (French 1973).

Case 4. Porina after large scale development of tussock and old browntop swards to ryegrass/white clover based pasture.

Porina densities on a property of 6300 ha on the East Otago plateau were monitored with the aim of early intervention to mitigate porina damage after a re-development programme commenced in 2002. Monitoring focused on 2–4-year-old pastures, as these are most often affected by porina in the region. Five pastures representative of those sown in each of spring 2002, 2003 and 2004 were sampled in the summer of 2006 in the early larval stages, prior to damage becoming evident. Porina numbers were massively higher than usually experienced, with densities increasing with pasture age (Fig. 2). Only 18 months from sowing (two flight seasons), porina numbers ranged from 19 to 97 porina/m², well within the damaging range. After 30 months, larval densities ranged from 81 to 778/m² and after 42 months from sowing, densities ranged from 512 to 756/m². Such massive populations required control actions and insecticide was applied. Despite control activities, the scale of the infestation,

the number of pastures affected (42 pastures between 18 and 40 months old) and the pressure from porina surviving insecticide application, there was a complete loss of pastures over a wide area resulting in large scale destocking, buying in compensatory feed and pasture renovation. When all expenses were taken into consideration the total cost of the porina infestation was estimated to be approximately \$600 000 (Simon Glennie, pers. comm.). In contrast, porina densities measured in 55 3-year-old ryegrass/white clover pastures on nearby properties between 2004 and 2007 showed a mean porina density of 55/m² with a range of 0–177 (n= 55, SEM 5.3). Within this more typical situation, 14 pastures were largely unaffected by porina, 15 were expected to suffer production losses without significant plant loss from porina densities of 20–40/m², 14 were expected to show production loss and some plant loss, while eight were predicted to show significant plant loss from populations of 100–110/m². One pasture, under pressure from 177 porina/m², was likely to be almost completely destroyed.

Case 5. Porina at Cape Foulwind on the West Coast of the South Island

Similar outbreaks of porina occurred in 2004 after land flipping on Cape Foulwind where larval populations reached very high levels, with >90 larvae/m² remaining after control actions, and caused extensive damage. This led to implementation of a monitoring and control plan as part of regular pasture management.

Discussion

These case studies demonstrate that land use conversions can have unintended consequences. In an economic evaluation carried out after commencement of the Amuri irrigation scheme (Greer 1984), there was no mention of grass grub as a potential threat, although the area was devastated by the pest just 4 years later. Pest outbreaks that are seen after large scale land conversions resemble outbreaks that occur after invasion of a new area by exotic insects and the driving principles may be the same, as described by the enemy release hypothesis (Keane & Crawley 2002; Torchin & Mitchell 2004). In cultivated, newly-sown pastures, diseases are uncommon among the low density insect pest populations, but as populations rise they often become host to a range of pathogens. Porina larvae are naturally infected by a number of viruses, e.g. nuclear polyhedrosis, granulosis and entomopox virus, that build-up and transmit readily among the high density larvae of outbreak populations causing subsequent population decline and regulation to low densities (Kalmakoff 1980). Similar effects are seen with grass grub and its range of natural diseases, e.g. amber

disease, milky disease and protozoan diseases (Jackson 1990). In cultivated, newly-sown pastures diseases are uncommon among the low density populations, but as populations rise they become host to what is often a range of pathogens causing population decline and regulation in older pastures. Manuka beetles on Cape Foulwind were initially very healthy, but after 10 years *Beauveria* fungi (Townsend *et al.* 2010), a microsporidean (S.D.G. Marshall, unpublished report) and a proteobacterial pathogen, *Rickettsiella pyronotae* (Kleespies *et al.* 2011), may be starting to have an impact on the beetle populations. In summary, the high outbreak populations that have been recorded after land conversions were all characterised by very healthy and vigorous larvae.

While this paper provides a warning for potential pasture land developers, the good news is that there are control methods that can be implemented. Prior knowledge of insects in the region will provide advance warning of potential invaders. Monitoring systems such as light traps for porina (Barlow 1989) and pheromone traps for grass grub (Unelius *et al.* 2008) can provide an early warning for farmers. Once populations are established, pest spread can be limited by judicious use of insecticides, although farmers should be aware that overuse of pesticides can lead to a constant rebound of healthy populations. The objective for new land developers should be to get to a “normal” situation where pasture pests are largely kept in check by their natural enemies. This “ecosystem service” can be aided by pasture management, minimising deep cultivation, using stock treading on damage patches and introducing natural diseases where possible, for example the bacterium *Serratia entomophila* for grass grub control (Jackson 2007). Pest management in pastures usually involves a combination of practices known as IPM (Integrated Pest Management) and details of recommendations for individual pests can be found on PestWebNZ™ (AgResearch 2011). In the unusual case of large scale land development it is especially important to consider the threat from pests and take remedial action early to avoid the widespread pasture destruction that can occur as an unintended consequence of this type of development.

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REFERENCES

- AgResearch. 2011. PestWebNZ™. Accessed: 1 June 2012. <http://www.pestweb.co.nz>.
- Anderson, R.M.; May, R.M. 1981. The population dynamics of microparasites and their invertebrate hosts. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 291: 451-524.
- Barlow, N.D. 1989. A simple trap for porina (*Wiseana* spp: Lepidoptera) (Lepidoptera: Hepialidae). *New Zealand Entomologist* 12: 87-89.
- East, R.; Kain, W.M. 1982. Prediction of grass grub, *Costelytra zealandica* (Coleoptera: Scarabaeidae) populations. *New Zealand Entomologist* 7: 222-227.
- French, R.A. 1973. Some aspects of the biology, population dynamics and economic status of *Wiseana cervinata* (Walker) (Hepialidae:Lepidoptera). PhD Thesis, Lincoln College, University of Canterbury.
- Greer, G. 1984. The economics of irrigation development of the Amuri Plains irrigation scheme. Research Report No. 159, Agricultural Economics Research Unit, Lincoln College, University of Canterbury, New Zealand.
- Heffernan, P.M.; Jackson, T.A.; Dyson, C.B.; Saville D.J. 1992. Sequential sampling of grass grub, *Costelytra zealandica*. *New Zealand Journal of Agricultural Research* 35: 299-305.
- Jackson, T.A. 1990. Biological control of grass grub in Canterbury. *Proceedings of the New Zealand Grassland Association* 52: 217-220.
- Jackson, T.A. 2007. A novel bacterium for control of grass grub. pp. 160-168. *In: Biological control: A global perspective*. Eds. Vincent, C.; Goettel, M.S.; Lazarovits, G. CABI Publishing, Wallingford, U.K.
- Jackson T.A., Alves, S.B., Pereira, R. 2000. Success in biological control of soil-dwelling insects with pathogens and nematodes. Pp 271-296. *In: Measures of Success in Biological Control*. Eds. Wratten, S. and Gurr, G. Kluwer, Academic Publishers, Dordrecht.
- Kalmakoff, J. 1980. The *Wiseana* story: enzootic control of a pasture pest. pp. 25-26. *In: Microbial control of insect pests*. Eds Kalmakoff, J.; Longworth, J.F. DSIR Science Information Division, Wellington, New Zealand.
- Keane, R.M.; Crawley, M.J. 2002. Exotic plant invasions and the enemy release hypothesis. *Trends in Ecology and Evolution* 17: 164-170.
- Kleespies R.G.; Marshall S.D.G.; Schuster C.; Townsend R.J.; Jackson T.A.; Leclerque A. 2011. Genetic and electron-microscopic characterization of *Rickettsiella* bacteria from the manuka beetle, *Pyronota setosa* (Coleoptera: Scarabaeidae). *Journal of Invertebrate Pathology* 107:206-211.
- Thomson, N.A.; Rys, G.; Carpenter, A. 1978. Control of manuka beetle. pp. 164-166. *In: Proceedings of the 31st New Zealand Weed and Pest Control Conference*.
- Townsend, R.J.; Jackson, T.A. 1997. Grass grub – a persistent problem in Canterbury pastures. pp 145-148. *In: Soil invertebrates in 1997*. Eds Allsop, P.G.; Rogers, D.J.; Robertson, L.N. Bureau of Sugar Experimental Research Stations, Brisbane, Australia.
- Townsend, R.J.; Nelson, T.L.; Jackson, T.A. 2010. *Beauveria brongniartii* - A potential biocontrol agent for use against manuka beetle larvae damaging dairy pastures on Cape Foulwind. *New Zealand Plant Protection* 63: 224-228.
- Torchin, M.E.; Mitchell, C.E. 2004. Parasites, pathogens, and invasions by plants and animals. *Frontiers in Ecology and the Environment* 2: 183-190.
- Unelius, C.R.; Townsend, R.J.; Mundy, D.C.; Manning, L.M.; Jackson, T.A.; Suckling, D.M. 2008. Comparisons of traps and lures for monitoring grass grub, *Costelytra zealandica*. *New Zealand Plant Protection* 61: 215-221.

