Monitoring and predicting populations of the tropical grass webworm *(Herpetogramma licarsisalis)* a pest of kikuyu pasture in Northland

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Abstract
A monitoring programme for the tropical grass webworm (TGW) (*Herpetogramma licarsisalis*) has been operating in the Far North since 1999, when high densities of the larva resulted in severe defoliation of large areas of kikuyu (*Pennisetum clandestinum*) pasture. Flight patterns of adult TGW were monitored using pheromone traps; larval populations were sampled using quadrat sampling of pasture. Rainfall and temperature measurements were recorded throughout summer and late autumn in each of the years sampled. The data collected have enabled an early warning system to operate which advises farmers of the risk of a tropical grass webworm outbreak. Warnings of potential outbreaks are distributed via local media and the Northland Regional Council website. When larvae numbers in pasture are greater than 50/m^2, and warm, moist conditions prevail, farmers can consider appropriate management decisions to secure feed for stock.
Keywords: tropical grass webworm, kikuyu, pheromone, monitoring program

Introduction
Tropical grass webworm (TGW), *Herpetogramma licarsisalis* (Lepidoptera: Pyralidae), is widely distributed throughout the tropics and subtropics. This species is also found in the Mediterranean and a single adult was recorded on the Isle of Wight in 1999 (Goater & Knill Jones 1999). In New Zealand, permanent breeding populations of TGW are confined to northern regions of Northland north of Kaitaia (Hardwick *et al*. 2000). However, sporadic reports of TGW adults have come from Nelson and from parts of the west coast of the North Island north of Waikanae, which are favourable to kikuyu (*Pennisetum clandestinum*) growth (Hardwick *et al*. 2000; B.E.Willoughby pers. comm.).

TGW is a major turf grass pest in Hawaii, Florida and north-eastern Australia (Champ 1955; Drane 1993; Tashiro 1977; Ward 1997). In New Zealand, severe and widespread damage to kikuyu pasture attributed to TGW feeding was first observed in the summer/autumn of 1999 throughout the Aupouri Peninsula in the Far North (northern Northland) and at Taupo Bay (20 km north of the Bay of Islands). Areas of high infestation resembled pasture that had been treated with herbicide – up to 1500 larvae/m^2 were recorded. Similar damage to kikuyu pasture on the Aupouri and neighbouring Karikari Peninsula had been recorded in the 1970s but were attributed to native species of webworm (also Pyralidae: Crambinae) (R. McDavitt pers. comm.). The identity of the insects responsible for these earlier outbreaks has never been confirmed (B. E. Willoughby pers. comm.).

Although it has never been confirmed how TGW arrived in New Zealand it is likely that the 1999 founding populations of this species on the Aupouri Peninsula were blown by wind to this country from Australia (Hardwick *et al*. 2000). The larvae feed on a wide range of grasses, but prefer kikuyu (Grant 1982).

The biology of TGW has been described in depth (Hammad *et al*. 1968; Tashiro 1976; Tashiro 1977; Jenson & Cameron 2004). In brief, adult TGW have light brown-grey wings spanning 25 mm. They fly at night, are readily attracted to light, and rest in sheltered areas during the day unless disturbed. Eggs are laid in batches on leaf surfaces of kikuyu and overlap, resembling fish scales. As eggs mature, they change from translucent to brown. After hatching larvae develop through five or six instars (stages). It is the final instar (about 20 mm long) that wreaks the greatest pasture damage, consuming 80% of what an individual TGW consumes during its entire lifetime. The colour of the larva varies from green (while feeding) to fawn (changing instars). In Northland during summer it takes TGW about 4 weeks to complete development from egg to adult. However, this period will be considerably longer during the cooler periods of the year. Immature stages cease development below 11^{o}C (Jensen & Cameron 2004). The mature larva makes a cocoon of webbing and dead grass material and forms a reddish-brown pupal case.

The term "webworm" comes from the webbing in grass made by larvae. Webbing provides shelter and maintains moisture and high humidity, key factors in survival of TGW larvae. Evidence of feeding can be seen when kikuyu is parted at the base. TGW larvae and/or their bright green frass (excreta) will be present. They prefer to feed on short (grazed) kikuyu in warm and sheltered north-facing paddocks and are not found in rank kikuyu. Substantial kikuyu damage is obvious, resulting in large brown patches of kikuyu. Large populations of early instar TGW can be present even when damage is not immediately apparent. As these larvae complete their development they can cause severe pasture damage.

An early warning system that predicts outbreaks of TGW larval damage to kikuyu pasture was developed using data collected on weather, moth flight patterns and numbers of immature stages over 10 years (2000-2009). Monitoring took place each year from January to May at a range of sites on the Aupouri Peninsula at various times and intervals. The most in-depth data were collected from one site (Motutangi) mid-way along the Aupouri peninsula. This site has shown to be representative of the area affected by TGW larval feeding damage and has been used successfully to predict TGW outbreaks.

Methods

Weather parameters

At the Motutangi site, kikuyu thatch temperatures 2 cm above ground were recorded hourly using an HOBO Pro 4.1 outdoor datalogger downloaded *in situ* to a laptop. Rainfall at the site was recorded weekly or fortnightly.

Monitoring immature stages

Grid searches for larvae and pupae in kikuyu pasture were undertaken at the Motutangi site. At each sampling date, 25 quadrat (0.2 x 0.2 m) positions were randomly selected and the number of larvae and pupae recorded to give an estimate of density.

Sampling frequency varied from year to year. In 2000 and 2001, sampling at the Motutangi site was weekly – to enable collection of detailed information on population trends in TGW numbers. There was no regular monitoring from 2002-2004; from 2005-2009, sampling of larvae and pupae occurred every 2-4 weeks. TGW populations were also sampled at other sites as far north as Te Paki on an irregular basis in 2000, 2001 and 2005-2008 to confirm that Motutangi was representative of TGW infestation on the Aupouri Peninsula.

Monitoring of adults

TGW pheromone, which attracts male moths, was available from 2006 (Gibb *et al*. 2007). The pheromone, dispensed in delta traps, was used to help determine seasonal changes in TGW moth abundance. Traps were placed at sites along the Aupouri Peninsula as far north as Te Paki and as far south as Waiharara, and included the site at Motutangi where other life stages were counted. The number of traps varied from year to year depending on resources. The traps were suspended from "pig-tail" stakes 0.7 m above the ground. Sticky bases were replaced every 2 weeks and new pheromone caps were placed in the traps every 4 weeks.

Results

TGW population trends

Fig. 1 shows the numbers of TGW larvae and pupae at the Motutangi site in 2000 and 2001. These patterns have been consistently observed at Motutangi and other Aupouri Peninsula sites from 2005-2009, albeit with less intensive monitoring during these latter years.

Fig. 2 shows the data collected using the TGW pheromone traps in summer 2006 at the Motutangi site, and the corresponding numbers of larvae and pupae recorded over the summer and autumn.

The two data sets show population trends of TGW throughout the potentially damaging period of February to May. The first peak of moths occurs in the last week of January, when moths from the spring generation of pupae emerge. This cohort of adults lays eggs and is followed by a small peak in larvae early/mid-February. The February larval generation does not reach the level (around 50 larvae/m^2) which causes a large loss of kikuyu pasture (Fig. 2).

In March, however, there is a large emergence of moths as TGW adults emerge from pupae of the February generation. Numbers remain high throughout March and April and sometimes into May. They give rise to the late summer/autumn larval populations. If conditions are suitable, it is the feeding of this generation that causes most damage to kikuyu at a time when it is the main pasture feed available. Temperate C_3 grasses and clover, which do not tolerate the high temperatures, are dominated by subtropical C_4 kikuyu grass in summer and autumn in the Far North.

Predicting damaging populations of TGW

Data collected hourly at the Motutangi site showed that kikuyu thatch temperature remained above the threshold of development for immature TGW of 11^{o}C until at least mid-April. From January to April a number of other factors determine whether the numbers of TGW larvae will reach damaging densities. Table 1 shows the important factors contributing to the build-up of TGW populations from 2000 to 2009, and the level of larval feeding damage recorded on the Aupouri Peninsula in these years. Rainfall is the most important factor affecting the risk of high infestation of TGW from January to April. Sufficient rainfall and the resulting high humidity improve survival of eggs and larvae and also provide fresh, lush kikuyu growth of high nutritional value for TGW larvae. A dry period at crucial times in the TGW life cycle reduces egg and larval survival.

Figure 1 Numbers of larvae and pupae of tropical grass webworm per square metre of pasture at Motutangi, Aupouri Peninsula, in 2000 and 2001.

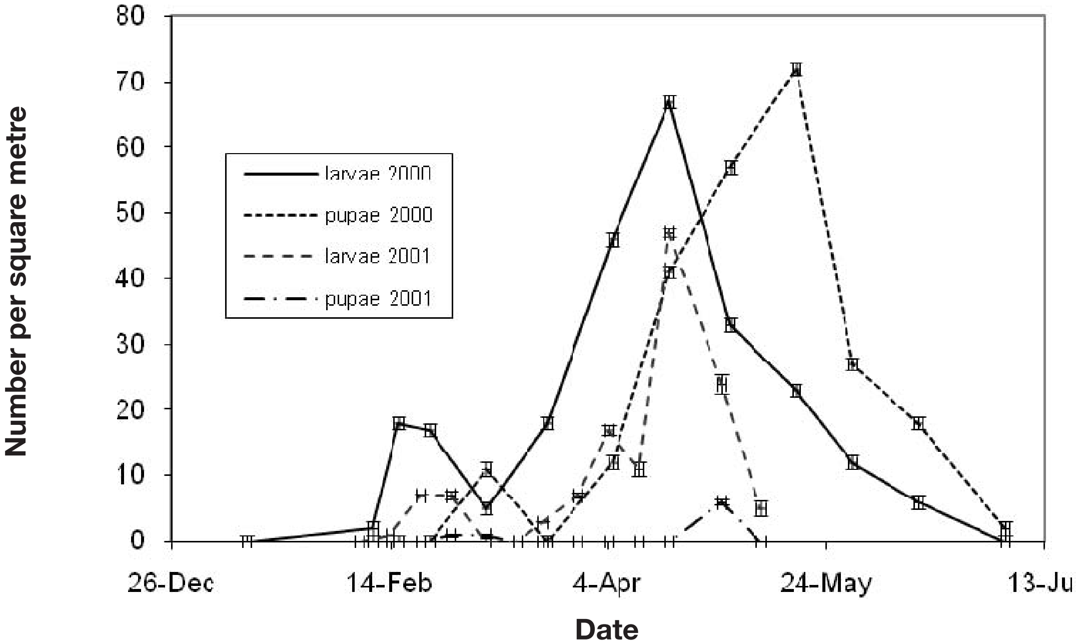
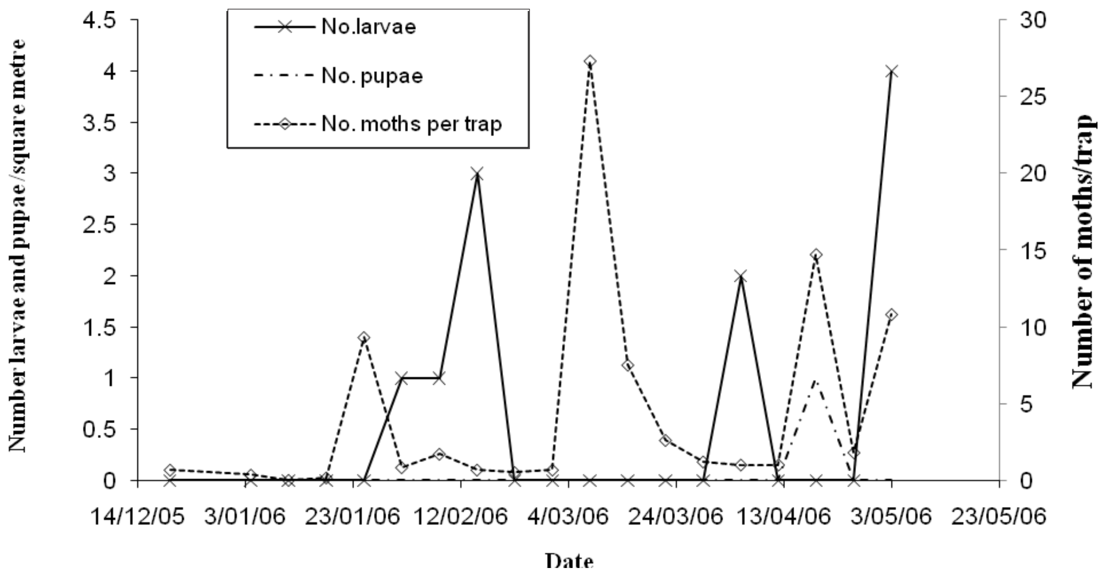


Figure 2 Number of tropical grass webworm moths per trap (N=6 traps), and larvae and pupae per square metre of pasture, in 2006.



Periods of low rainfall from January to April in 2005 resulted in low infestations. In 2006, low rainfall in January and February meant populations of TGW remained low, despite later rainfall in March and April. In 2009 there was no rain in January, and this resulted in fewer moths emerging in late January. Moist, humid conditions occurred briefly in February 2009 and kikuyu growth was renewed, but TGW were unable to take advantage of these favourable conditions that continued over March and April.

Table 1 Monthly rainfall, peak TGW adult and larval abundance, and feeding damage rating at Motutangi on the Aupouri Peninsula, January-April 1999-2009.

Month		1999[1]	2000[2]	2001[2]	2002-2004	2005	2006	2007	2008	2009
	Number of traps	-	-	-	-	-	6	3	4	4
January	Rainfall (mm)	124	80	82	-	40	38	128	76	0
	Peak moths/trap	-[4]	-	-	-	-	9	8	23	0.8
February	Rainfall (mm)	41	73	79	-	28	24	230	109	43
	Peak larvae/m^2	-	19	7	-	3	3	3	11	3
March	Rainfall (mm)	115	45	36	-	8	116	92	70	81
	Peak moths/trap	-	-	-	-	-	27	28	20	0.5
	Peak larvae/m^2	-	67	48	-	1	4	17	44	0
April	Rainfall (mm)	234	98	180	-	11	136	83	207	224[3]
	Damage rating	high	med.	med.	low	low	low	med./high	high	low

[1]Rainfall for this year from Kaitaia Observatory
[2]Rainfall for these years from Aupouri Forest records
[3]Rainfall data from Doubtless Bay, 20 km SE of Motutangi
[4] No data available; med. = medium

Years with regular and substantial January/February rainfall such as 2000, 2001, 2007 and 2008, resulted in moderate-to-high damage to pasture. Warnings of impending high populations of TGW larvae were able to be issued regularly on the Northland Regional Council website. In late February 2008, a warning of the high risk of TGW damage was published in the local newspaper well in advance of high larval populations the following March and April.

Unfortunately, there are no data on the key factors affecting build-up of TGW numbers available for 1999, the year that extremely high numbers of larvae occurred, and none for 2002-2004 when damage by TGW was low. However, although there is no meteorological data available for the Motutangi site, 1998/1999 data from Kaitaia and farmers on the Aupouri Peninsula suggest that warmer than average temperatures and greater than average summer rain in 1999 (Table 1), may have contributed to TGW populations observed in the region at the time. Records from Kaitaia show that the average daily temperature was 1.3°C warmer than average (NIWA, 15 year means) in winter of 1998. Furthermore, farmers report that the winter of 1998 was frost-free (E. Wagener pers. comm.). The summer of 1999 was also warmer than average with the mean daily temperature in the Far North 1.7°C higher than the NIWA 15 year mean.

Discussion

The monitoring system in place on the Aupouri Peninsula in the Far North from January to April can now accurately predict TGW outbreaks. The components of the monitoring system include female moth sex pheromone trapping, sampling of immature stages in kikuyu pasture and recording of local climate variables. This is the first time that an insect pheromone has been used in a pastoral system to monitor a pest. Pheromone trapping is widely performed in the horticultural sector in New Zealand, where it underpins decision support by growers (e.g. insecticide or other interventions). In the forestry sector, traps are used to detect the arrival of unwanted pests. In contrast, the pastoral sector had yet to adopt this approach, even where the pheromone has been known for decades, as in the case of the grass grub beetle, because of the lack of a practical cost-effective tool (Unelius *et al*. 2008). While there are probably many reasons for this sectoral difference, this project has demonstrated that pheromone trapping of pastoral pests can offer growers decision support in the same manner as for other sectors.

High-risk factors for the build-up of the TGW larval (feeding) stage are warm temperatures (above 11°C) and sufficient rainfall to generate high humidity. TGW do not have a protective over-wintering stage – development in winter depends solely on temperature. Frosts have detrimental effects on TGW survival. In the shelter of kikuyu on well-drained, north-facing and/or sheltered sites, TGW can overwinter (Hardwick *et al*. 2000). These sites should be identified on properties as areas at risk from subsequent defoliation by TGW larvae. When TGW numbers reach 50/m^2 and temperatures remain high and the pasture moist, there is a high risk of severe pasture damage occurring.

Populations of TGW have never reached the devastating proportions seen in 1999, and one reason may be that natural enemies of TGW are probably exerting some control on this pest. In Northland, TGW is killed by the generalist parasitic wasps *Meteorus puchricornis* (attacks larvae) and *Lissopimpla excelsa* (attacks pupae) (Jensen 2002). The parasitic Tachinid fly, *Pales* sp., attacks TGW larvae (Hackell & Hardwick 2005). The white-spotted ichneumonid wasp, *Echthromorpha intricatoria*, has also been observed hovering over pasture containing high numbers of TGW larvae and pupae, but has never been reared from them.

In Australia, the parasitic wasp, *Leptobatopsis indica*, is reared for release against TGW (R. Elder pers. comm.). In Hawaii, parasitoids of TGW include the egg parasitoid, *Trichogramma* sp.; larval parasitic wasps, *Casinaria infesta*, *Cremastus (= trathala) flavo-orbitalis*, *Meteorus laphygma*; Tachinid parasitic fly, *Eucelatoria armigera*; and the pupal parasitic wasp, *Brackymeria sp.* (Davis 1969). As generalist parasitoids of Lepidoptera, these insects are unlikely to be imported into New Zealand as biological control agents of TGW, because of their threat to native moths and butterflies. Given the large year-to-year fluctuations in TGW populations, classical biological control is unlikely to contain TGW populations, because when conditions are favourable TGW will build up quicker than a parasitoid.

TGW may continue to extend its range south as it becomes adapted to cooler conditions at the southern limit of its current distribution. During years of medium to high population numbers (1999, 2000, 2001, 2007 and 2008), feeding damage was seen as far south as Waipapakauri (10 km north of Kaitaia) and moths were observed in higher numbers in Ahipara (15 km west of Kaitaia) and Doubtless Bay (20 km north-east of Kaitaia).

If high populations of TGW are predicted, there are pasture management options available for farmers. Harrowing close-grazed kikuyu pasture infested with TGW larvae is now successfully used by farmers on the Aupouri Peninsula. This practice opens the thatch to expose the TGW larvae to desiccation; more than one pass using harrows may be necessary (Willoughby 2002). Mulching of pasture does not appear to offer an effective way to control TGW populations – the windrows of mulched grass probably offer good shelter for larvae, which emerge at night to feed on the kikuyu regrowth (Willoughby 2002).

While farmers are reluctant to apply insecticide for control of TGW, pesticides such as chlorpyrifos and diazinon have been shown to reduce damage in the field immediately after application (Hardwick & Davis 2000). Stock treading is unlikely to be effective in kikuyu pasture, because the thatch offers protection for TGW. Farmers can consider sowing a proportion of the farm in forage species less vulnerable to TGW. These include perennial ryegrass (preferably with AR37 endophyte to deter black beetle attack) and Italian ryegrass to improve winter/spring pasture production. Tall fescue (with Max P endophyte, again to reduce black beetle damage) could be tried provided management appropriate to the species is applied. Farmers can also take a hay/silage crops in spring when feed is surplus to requirements and/or secure off-farm grazing.

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REFERENCES

Champ, B.R. 1955. The grass caterpillar. *Queensland Agriculture Journal 80*: 22-24.

Davis, C.J. 1969. Notes on the grass webworm *Herpertogramma licarsisalis* (Walker) (Lepidoptera: Pyraustidae), a new pest of turfgrass in Hawaii and its enemies. Proceedings of the 20th Conference of the Entomological Society of Hawaii: 311-316.

Drane, D. 1993. Disease, insect and weed control in turf. 3rd Edition Australian Turf Grass Research Institute, Sydney.

Gibb, A.R.; Suckling, D.M.; El-Sayed, A.M. Bohman, B.; Unelius, C.R., Dymock, J.J.; Larsen, M.L.; Willoughby, B.E. 2007. (*Z,E*)-11,13-Hexadecadienyl acetate: sex pheromone of the grass webworm, *Herpetogramma licarsisalis* – identification, synthesis, and field bioassays. *Journal of Chemical Ecology 33 (4)*: 839-847.

Goater, B.; Knill Jones, S.A. 1999. *Herpertogramma licarsisalis* (Walker, 1859) (Lepidoptera: Pyralidae), the grass webworm, new to Britain. *Entomologist's Gazette 50*: 71-74.

Grant, M. D. 1982. Feeding preferences of larvae of *Herpertogramma licarsisalis* (Walker) (Lepidoptera: Pyralidae) and *Spodoptera mauritia* (Boisduval) (Lepidoptera: Noctuidae), two lawn pests common about Brisbane. *Journal of the Australian Entomological Society 21*: 201-205.

Hackell, D.L.; Hardwick, S. 2005. A record of parasitism of tropical grass webworm, *Herpetogramma licarsisalis* (Walker) (Lepidoptera;Pyralidae) by

Meteorus pulchricornis (Wesmael) (Hymenoptera: Braconidae: Euphorinae) and *Pales* spp. (Hutton) (Diptera: Tachinidae: Goniiae). Proceedings of the 58th New Zealand Plant Protection Society Conference: 312. (Abstract only)

Hammad, S. M.; El-Minshawy, A.; Saad, A.H. 1968. Studies on *Pachyzancla licarsisalis* Walk. (Lepidoptera: Pyralidae). *Bulletin of the Entomological Society of Egypt 52*: 312-317.

Hardwick, S.; Baltus, J.G.; Willoughby, B.E. 2000. Seasonal distribution of *Herpertogramma licarsisalis* (Walker) (Lepidoptera: Pyralidae) in northern Northland. *New Zealand Entomologist 23*: 77-83.

Hardwick, S; Davis, L.T. 2000. Field control of *Herpetogramma licarsisalis* (Walker) in northern Northland pastures. Proceedings of the 53rd New Zealand Plant Protection Society Conference: 360-364.

Jensen, J.G. 2002. A record of parasitism of tropical grass webworm *Herpetogramma licarsisalis* (Walker) (Lepidoptera: Pyralidae) by *Lissopimpla excelsa* (Costa) (Hymenoptera: Ichneumonidae) in New Zealand. *New Zealand Entomologist 25(1)*: 93-94.

Jensen, J.G.; Cameron, C.A. 2004. Development and kikuyu consumption of pre-imaginal *Herpertogramma licarsisalis* (Lepidoptera: Pyralidae) reared at temperatures between 15 and 25°C. *Environmental Entomology 33(5)*: 1178-1184.

Tashiro, H. 1976. Biology of the grass webworm, *Herpetogramma licarsisalis* (Lepidoptera: Pyraustidae) in Hawaii. *Annals of the Entomological Society of America 69*: 797-803.

Tashiro, H. 1977. Colonization of the grass webworm, *Herpertogramma licarsisalis*, and its adaptability for laboratory tests. Proceedings of the 22nd Conference of the Entomological Society of Hawaii: 533-539.

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. Proceedings of the 61st Conference of the NZ Plant* Protection Society: 215-221.

Ward, A.L. 1997. A non-destructive sampling technique for *Spodoptera mauritia* (Boisduval) (Lepidoptera: Pyralidae) in turf. *Australian Journal of Entomology 36*: 75-79.

Willoughby, B.E. 2002. A pilot study to evaluate the effect of harrowing on tropical grass webworm (TGW) populations in kikuyu. A report to the Tropical grass webworm Task Group No.2., 3 pp.