Biogeochemical isotopes and trace elements as geo-location markers for biosecurity: Can the technology determine the origin of pests?

Holder P.W.[1], *Armstrong K.*[1], *Clough T.*[1], *Frew R.*[2], *Van Hale, R.*[2], *Baker J.A.*[3], *Millet, M-A.*[3]

Peter Holder
peter.holder@lincolnuni.ac.nz

1. *Bio-Protection Research Centre Lincoln University New Zealand*
2. *Department of Chemistry Otago University New Zealand*
3. *School of Geography Environment and Earth Sciences Victoria University New Zealand*

Introduction

Stable isotope technology is being considered as a key geo-location biosecurity tool in New Zealand. Knowing whether an exotic pest specimen collected 'post border' is a new arrival, or part of a hitherto undetected established population, enables appropriate biosecurity response (i.e., enhanced surveillance vs an eradication campaign), potentially saving millions[1] (Fig. 1). Stable isotope and trace element signatures have been used to trace the origin of a wide range of non-biological and biological materials[2, 3, 4]. However, the value of this technology is unproven in biosecurity applications, where the sample sizes are small and from an unknown and unpredictable place, time and host. Fundamental research, on how geo-location signatures are reflected in such insects is needed[5].

Research aims

The internationally distributed *Helicoverpa armigera* (Noctuidae) is being used to discern processes fundamental to the location-to-plant-to-insect elemental profile imprinting in phytophagous insects. Aspects being examined include the turnover of elements in adult insects, as well as the influence of polyphagy and local variation in precipitation ^{2}H. This improved understanding is being applied to assess the validity of using stable isotope ratios and trace element profiles to differentiate insects of New Zealand natal origin from insects of exotic origin.

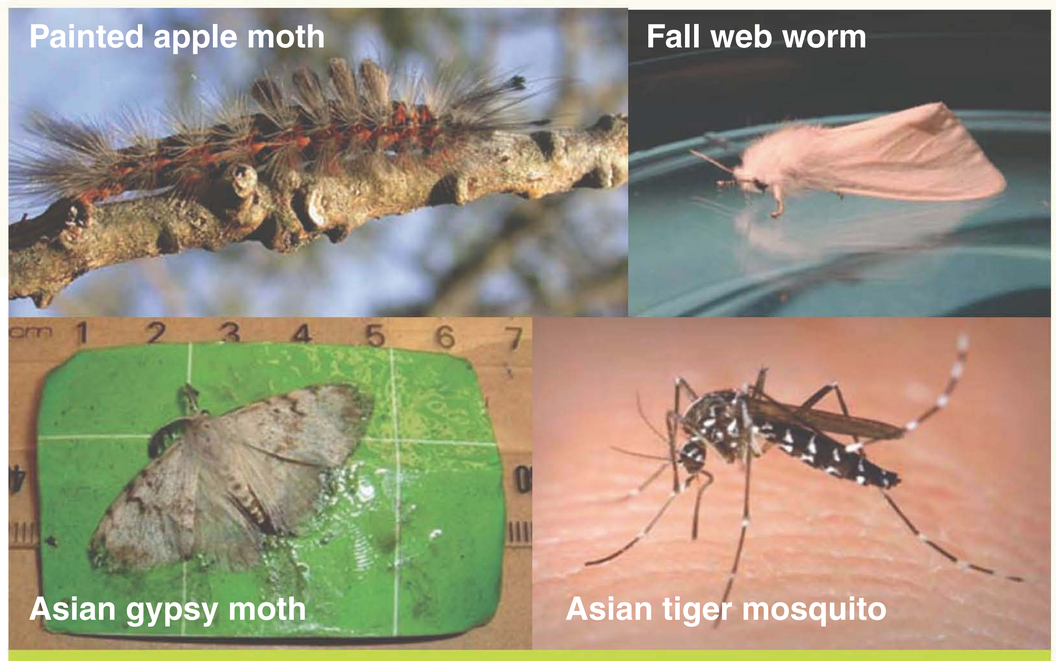

Figure 1. Stable isotope analysis ($\delta^{2}H$, $\delta^{13}C$) was engaged to determine whether the 'new' finds of painted apple moth and fall web-worm in Auckland in 2005 were new incursions, or indications of treatment failure in the 1999-2004 eradication campaigns. Only tentative conclusions were possible as the application of this technology in such cases has yet to be critically examined Other biosecurity responses where point of origin discrimination would have had high operational value have been detections of Asian gypsy moth in Hamilton, 2003, response cost $12.4M; and Asian tiger mosquito in Auckland, 2007, response cost approximately $500,000.

Results

The presence of readable stable isotope and trace element signatures in plants and individual insects has been confirmed. An integrated method of TC-IRMS, ICP-MS and MC-ICP-MS analyses of natural abundance ^{2}H, $^{87}Sr/^{86}Sr$, $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$ isotope ratios and trace element profiles from single insect specimens has been developed[6]. No single geo-location marker has been found in a preliminary comparison of international moths, although the latitudinal cline of $\delta^{2}H$ on a continental scale is confirmed (Fig. 2). In contrast, multi-element, multivariate analysis revealed successful preliminary geo-location discrimination for most of the study regions (Fig. 3).

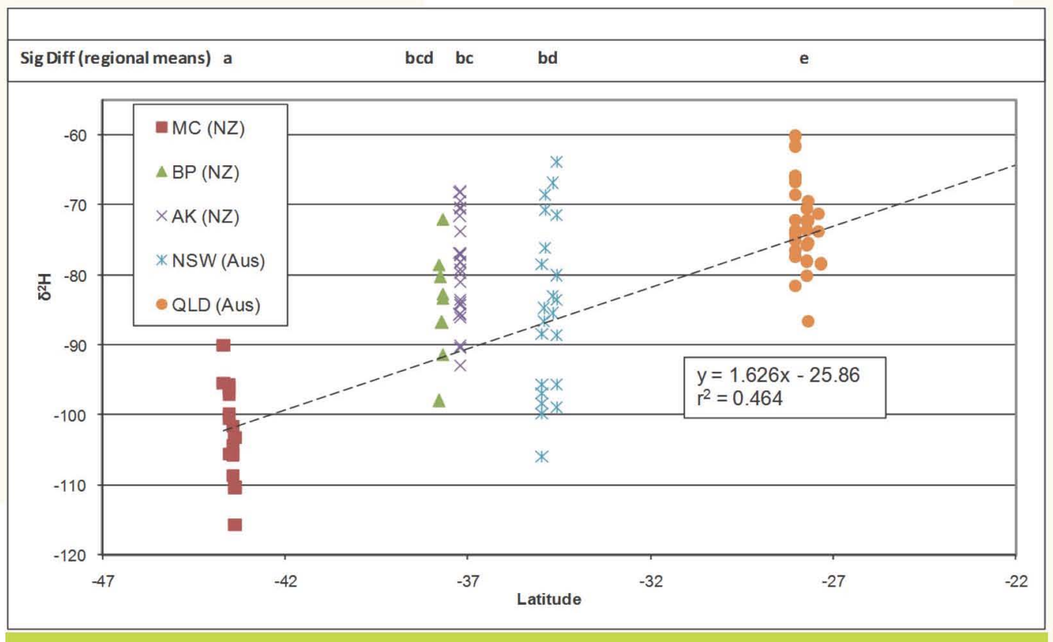

Figure 2. Adult Helicoverpa armigera $\delta^{2}H$ from 60 Australian and New Zealand sites, March 2008, showing country discrimination is not possible with $\delta^{2}H$. The $\delta^{2}H$ moth versus latitude regression reveals that 46% of the variation is due to latitude ($P<0.001$), and that biological and/or environmental variation within regions is just as influential as latitude. Significant differences between regional means indicated by letters in top box, calculated using Fisher's unrestricted LSD ($\alpha = 0.05$). MC = Mid Canterbury; BP, Bay of Plenty; AK, Auckland; NSW, Wagga Wagga; QLD, Toowoomba.

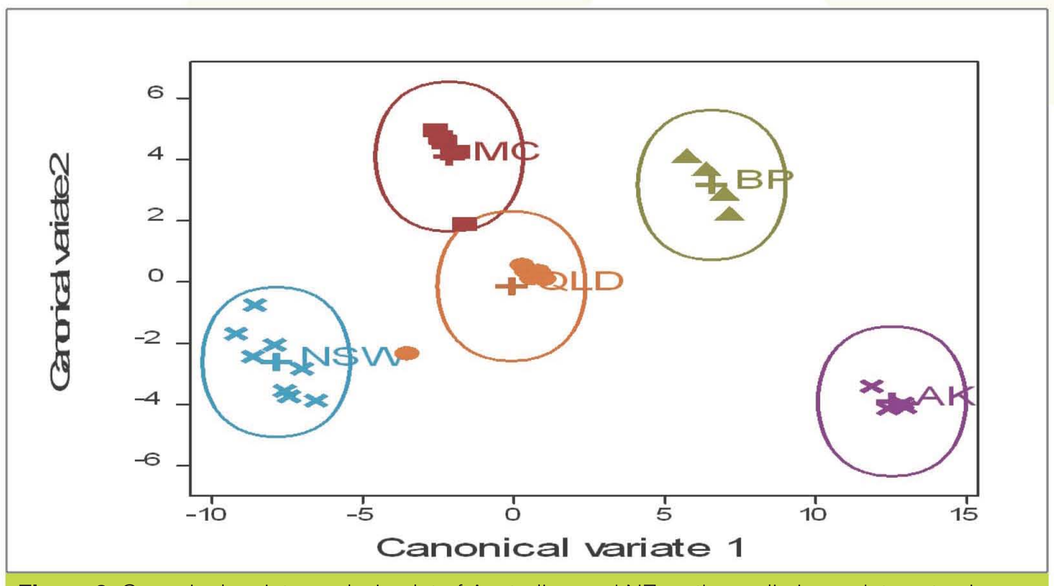

Figure 3. Canonical variate analysis plot of Australian and NZ moths preliminary data set using δ2H, $^{207}Pb/^{206}Pb$, $^{208}Pb/^{206}Pb$, and an optimised trace element concentrations and trace element ratio suite. Indicating that geo-location discrimination between the study regions is possible. Circles = 95% confidence limit of populations means. Canonical variates described in the table below. Regions as defined in Fig. 2

Canonical variate	% Variance explained	Most informative variates
CV1	80	Rb/Sr, Se, $^{207/206}Pb$, Cs, Rb/Ba
CV2	16	$\delta^{2}H$, Pb, W, $^{208/206}Pb$
CV3	3	$\delta^{2}H$, Sn, W, $^{208/206}Pb$, Rb/Sr, Cs, Rb/Ba, Cd

Conclusions

The promising preliminary geo-location demonstrated here provides solid leads for further investigation. Any geo-location system developed is likely to be applicable to other disciplines, including forensics, ecological studies and pest management.

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PO Box 84,
Lincoln University,
Canterbury,
New Zealand
Phone:
+64 3 325 3696
Fax:
+64 3 325 3864

Bio-Protection
Bio-Protection Science for New Zealand