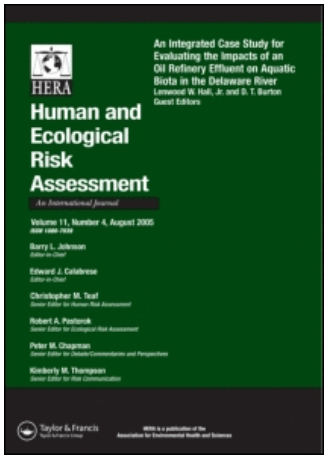
This article was downloaded by:[University of Technology, Sydney]
[University of Technology, Sydney]
On: 4 February 2007
Access Details: [subscription number 769326119]
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number: 1072954
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Human and Ecological Risk Assessment
An International Journal
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713400879

Comment on Assessing the Need for Groundwater Quality Guidelines for Pesticides Using the Species Sensitivity Distribution Approach by Hose (2005).

To link to this article: DOI: 10.1080/10807030601107551
URL: http://dx.doi.org/10.1080/10807030601107551

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf
This article maybe used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.
The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.
© Taylor and Francis 2007

Human and Ecological Risk Assessment, 13: 236–240, 2007
Copyright © Taylor & Francis Group, LLC
ISSN: 1080-7039 print / 1549-7680 online
DOI: 10.1080/10807030601107551

Downloaded By: [University of Technology, Sydney] At: 22:18 4 February 2007

LETTER TO THE EDITOR

Comment on *Assessing the Need for Groundwater Quality Guidelines for Pesticides Using the Species Sensitivity Distribution Approach* by Hose (2005).

People are increasingly reliant on aquifers for water but the nature, extent and distribution of hyporheic and groundwater ecosystems is widely overlooked (Boulton 2001; Humphreys 2006). Aquifers contain a significant component of total biodiversity (Gibert *et al.* 1994; Marmonier *et al.* 1994; Rouch and Danielopol 1997; Culver and Sket 1999; Danielopol *et al.* 2002) and play an important role in maintaining water quality (Danielopol *et al.* 2003). However, the ability of aquifers to sustain these functions is potentially threatened by the increasingly degraded quality of groundwater owing to their contamination with a wide range of industrial chemicals and from eutrophication. Thus, it is timely that Hose (2005) questions whether surface water quality guidelines are appropriately applied to groundwater ecosystems. In the absence of data on groundwater (hypogean) organisms he used, as surrogate groundwater taxa, the types of organisms found in both surface and groundwaters compared with taxa found only in surface waters (epigean) (Hose 2005, p. 954), while appropriately restricting his comparison to those groups of animals that are found within the truncated subterranean biodiversity found in subterranean waters (Gibert and Deharveng 2002). Within this subset of animals he then uses published acute (48 h and 72 h) toxicity data to apply species sensitivity distribution (SSD) analysis (Brix *et al.* 2001). Significantly, his analysis suggests that some hypogean fauna may be less sensitive than epigean fauna, for example to Atrazine, or that there was no indicated risk for groundwater animals at the concentrations of toxicants that have been reported from Australian groundwaters (two herbicides and five insecticides).

Here, I question whether it is appropriate to use data in this manner as a measure of acute toxicity on groundwater organisms and caution against its uncritical general acceptance. The first concern is the absence of close phylogenetic matching of the tested taxa whereby sister taxa with epigean and hypogean representatives should properly be compared. This has been a general issue in the analyses of hypogean adaptations (*e.g.*, Hervant *et al.* 1997 and papers therein) owing to the widespread lack of suitable paired taxa, and it will not be further discussed here.

The second factor is that subterranean organisms, as a class, have much lower metabolic rates than comparable surface lineages. This factor is generic to the SSD approach taken by Hose and could lead to severe systematic error in the estimates of the toxicity of test substances to subterranean organisms, although the direction of any bias is not always clear. Although metazoans of many higher taxa, including

insects and vertebrates, are represented in groundwaters, stygofauna overwhelmingly comprise crustaceans belonging to many different groups. Although insects and arachnids are better represented in hyporheic fauna, here I will focus on metabolic differences between epigean and hypogean crustaceans.

Obligate subterranean metazoans typically display a suite of characteristics presumed to adapt them to life underground in low energy and low PO_2 environments (Hervant *et al.* 1998c; Malard and Hervant 1999; Hüppop 2000), the latter being a common feature of groundwaters. Among these characteristics, and especially pertinent in this context, are the low metabolic rates in hypogean species (rates from 29–59%: Hervant *et al.* 1998b) compared with surface members of their broad lineage, and reductions up to an order of magnitude in anchialine animals (Bishop *et al.* 2004) that typically inhabit severely hypoxic water (Sket 1996; Humphreys 1999). Even in fish, cave-adapted forms had reduced standard (18–27%) and resting (19–53%) metabolic rates compared with epigean forms (Poulson 1985; Hüppop 1986). This reduced metabolism is not solely a result of reduced activity, because in excised gill tissue of *Procambarus* spp. (Decapoda) rates of oxygen consumption were 12–17% that of surface dwelling relatives and this may be coupled with concomitant changes in ventilation rates, ATP turnovers, resistance to starvation, fat mobilization, *etc.* (Dickson and Franz 1980).

Many stygobitic animals are highly resistant to low levels of dissolved oxygen, some only being known from such waters (<0.5 mg L^{-1} DO), and may sometimes rapidly switch between areas of low and high PO_2 (Hervant *et al.* 1998c; Malard and Hervant 1999) and many hypogean species survive anoxia for much longer than surface relatives (Hervant and Mathieu 1995; Hervant *et al.* 1995). The responses of crustaceans to PO_2 are complex and may have significant impact on energy balance in low-energy environments. The critical PO_2 level below which respiration rates could not be maintained, and post-hypoxic oxygen debt repayment, was lower in hypogean than in surface species (Hervant *et al.* 1998b). Some hypogean species, having no critical PO_2 (Caine 1978; Danielopol *et al.* 1994), are even considered to be oxyregulators (Hüppop 2000).

Resistance to hypoxia in hypogean animals is mainly due to lower energy expenditure by a reduction in ventilation and locomotion, and due to anaerobic metabolism based on the coupled fermentation of glycogen and amino acids. In some crustaceans this is aided by the large stores of glycogen and arginine phosphate that permit efficient and prolonged anaerobic metabolism and subsequent recovery by gluconeogenesis from the lactates synthesized during hypoxia (Hervant and Mathieu 1996). Similarly, hypogean crustaceans survive longer without food than any crustaceans previously studied and during which time locomotion, ventilation, and respiratory rates were markedly reduced in hypogean species, whereas epigean species responded by marked and transitory hyperactivity (Hervant 1998a; Hervant *et al.* 1997), factors of particular import in acute testing.

Hypogean vertebrates and invertebrates commonly have much greater fat stores than surface relatives (Hüppop 2000; Gibert and Mathieu 1980; Mathieu and Gibert 1980), and this is pertinent to measures of metabolic intensity and where fat solubility of toxicants may be an issue. Metabolic pathways may also differ between epigean and hypogean species, as shown by lactate excretion by the hypogean isopod *Stenasellus virei*, which is unusual for crustaceans (Hervant *et al.* 1998c).

Downloaded By: [University of Technology, Sydney] At: 22:18 4 February 2007

In the presence of a toxicant, the significance of metabolism may be detected only after exposure to hypoxic conditions (Spicer and Weber 1992; Meade and Watts 1995). The toxicant itself may require increased metabolism (Grieshaber and Völkel, 1998), or else result in elevated (Smith and Hargreaves 1984) or depressed (Smith and Hargreaves 1984; Meade and Watts 1995) metabolism of the test organism. Acute measures of toxicity occur in a time span that generally does not allow equilibrium conditions to be attained between the uptake of the toxicant and its elimination, and significant improvement in testing can be achieved, even over a 96-hour test by a mere 2.5-fold increase in test time (Canivet *et al.* 2001). Toxicants may accumulate and be eliminated passively but in many cases the degradation/elimination of toxicants is an active process and thus metabolically dependent. Under toxic stress an organism may exhibit an increase in respiration rate as a result of the increased rate of protein turnover, which is thought to play an important part in the general response of animals to toxicants (Barber *et al.* 1990). Because toxicants induce stress this results in a reduction of the net energy balance (Koehn and Bayne 1988) and thus may impact differentially on groundwater animals that typically inhabit low energy environments.

The varied nature, but seeming ubiquity, of large differential metabolic responses of hypogean as compared with epigean species, makes suspect the use of the epigean groundwater surrogates in toxicity testing of relevance to groundwaters as used by Hose (2005). Even if hypogean organisms are to be used, the effects of toxicants may be enhanced *in vivo* by the low PO_2 environment and manifest only slowly due to the increased metabolic rate required of the organism by the toxicant.

William F. Humphreys
Western Australian Museum
Locked Bag 49
Welshpool DC
WA 6106
Australia
E-mail: bill.humphreys@museum.wa.gov.au

Downloaded By: [University of Technology, Sydney] At: 22:18 4 February 2007

REFERENCES

Barber I, Baird DJ, and Calow P. 1990. Clonal variation in general responses of *Daphnia magna* Straus to toxic stress. II. Physiological effects. Functional Ecol 4:409–14

Bishop RE, Kaluk B, and Torres JJ. 2004. Life in the hypoxic and anoxic zones: Metabolism and proximate composition of Caribbean troglobitic crustaceans with observations on the water chemistry of two anchialine caves. J Crust Biol 24:379–92

Boulton AJ. 2001. 'Twixt two worlds: Taxonomic and function biodiversity at the surface water/groundwater interface. Rec Western Australian Mus Suppl No. 64:1–13

Brix KV, DeForest DK, and Adams WJ. 2001. Assessing acute and chronic copper risks to freshwater aquatic life using species sensitivity distributions for different taxonomic groups. Environ Toxicol Chem 20:1846–56

Caine EA. 1978. A comparative ecology of epigean and hypogean crayfish (Crustacea, Cambaridae) from Northwestern Florida. Am Midland Naturalist 99:315–29

Canivet V, Chambon P, and Gibert J. 2001 Toxicity and bioaccumulation of Arsenic and Chromium in epigean and hypogean freshwater macroinvertebrates. Arch Environ Contam Toxicol 40:345–54

Culver DC and Sket B. 1999. Hotspots of subterranean biodiversity in caves and wells. J Cave Karst Stud 62:11–17

Danielopol DL, Creuzé des Châtelliers M, Mösslacher F, *et al.* 1994. Adaptation of crustacea to interstitial habitats: A practical agenda for ecological studies. In: Gibert J, Danielopol DL, and Stanford JA (eds) Groundwater Ecology, pp 217–43. Academic Press, London, UK

Danielopol DL, Rouch R, and Baltanas A. 2002. Taxonomic diversity of groundwater Harpacticoida (Copepoda, Crustacea) in southern France. Vie Milieu 52:1–15

Danielopol DL, Griebler C, Gunatilaka A, *et al.* 2003. Present state and future prospects for groundwater ecosystems. Environ Cons 30:104–30

Dickson GW and Franz R. 1980. Respiration rates, ATP turnover and adenylate energy charge in excised gills of surface and cave crayfish. Comp Biochem Physl 65A:375–79

Gibert J and Deharveng L. 2002. Subterranean ecosystems: A truncated functional biodiversity. BioSci 52:473–81

Gibert J, Danielopol DL, and Stanford JA (eds). 1994. Groundwater Ecology. Academic Press, London, UK

Gibert J and Mathieu J. 1980. Relations entre les teneurs en protéines, glucides et lipides au cours du jeûne expérimental chez deux éspèces de *Niphargus* peuplant des biotopes différents. Crustaceana Suppl 6:137–47

Grieshaber MK and Völkel S. 1998. Animal adaptations for tolerance and exploitation of poisonous sulfide**.** Ann R Physl 60:33–53

Hervant F and Mathieu J. 1995. Ventilatory and locomotory activities in anoxia and subsequent recovery of epigean and hypogean crustaceans. C R Acad Sci Paris Ser 3. 318:585–92

Hervant F and Mathieu J. 1996. Adaptations à l'hypoxie chez des crustacès souterrains et superficiels. Mèm Biospèol 23:211–15

Hervant F, Mathieu J, Garin D, *et al.* 1995. Behavioral, ventilatory, metabolic responses to severe hypoxia and subsequent recovery of the hypogean *Niphargus rhenorhodanensis* and the epigean *Gammarus fossarum* (Crustacea: Amphipoda). Physiol Zool 68:223–44

Hervant F, Mathieu J, Barre H, *et al.* 1997. Comparative study on the behavioral, ventilatory, and respiratory responses of hypogean and epigean crustaceans to long-term starvation and subsequent feeding. Comp Biochem Physiol 118A:1277–83

Hervant F, Mathieu J, Barre H, *et al.* 1998a. Long-term starvation and re-feeding in hypogean and epigean crustaceans: Survival, locomotory and respiratory adaptations. Mèm Biospèol 25:15–23

Hervant F, Mathieu J, and Messana G. 1998b. Oxygen consumption and ventilation in declining oxygen tension and posthypoxic recovery in epigean and hypogean crustaceans. J Crust Biol 18:717–27

Hervant F, Mathieu J, Messana G, *et al.* 1998c. Severe hypoxia and subsequent recovery in the hypogean isopod *Stenasellus virei.* Mèm Biospèol 25:7–13

Hose GC. 2005. Assessing the need for groundwater quality guidelines for pesticides using the species sensitivity distribution approach. Hum Ecol Risk Assess 11:951–66

Humphreys WF. 1999. Physico-chemical profile and energy fixation in Bundera Sinkhole, an anchialine remiped habitat in north-western Australia. J Roy Soc W Aust 82:89–98

Humphreys WF. 2006. Aquifers: The ultimate groundwater dependent ecosystems. In Eamus D (ed.) Special edition on Groundwater Dependent Ecosystems. Aust J Bot 54: 115–32

Hüppop K. 1986. Oxygen consumption of *Astyanax fasciatus* (Characidae, Pisces): A comparison of epigean and hypogean populations. Environ Biol Fish 17: 299–308

Downloaded By: [University of Technology, Sydney] At: 22:18 4 February 2007

Hüppop K. 2000. How do cave animals cope with the food scarcity in caves? In: Wilkens H, Culver DC, and Humphreys WF (eds), Ecosystems of the World, vol. 30. Subterranean Ecosystems, pp 159–88. Elsevier, Amsterdam, The Netherlands

Koehn RK and Bayne BL. 1988. Towards a physiological and genetical understanding of the energetics of the stress response. In: Calow P and Berry RJ (eds), Evolution, Ecology and Environmental Stress, pp 157–71 Academic Press, London, UK

Malard F and Hervant F. 1999. Oxygen supply and the adaptations of animals in groundwater. Freshw Biol 41:1–30

Marmonier P, Ward JV, and Danielopol DL. 1994. Biodiversity and groundwater/surface ecotones. Biol Intern 28:14–17

Mathieu J and Gibert J. 1980. Evolution des teneurs en protéines, glucides et lipides de *Niphargus rhenorhodanensis* Schellenberg comparé entre l'évelage en milieu naturel reconstitué et le jeûne expérimental. Crustaceana, Supp 6:126–36

Meade ME and Watts, SA 1995. Toxicity of ammonia, nitrite, and nitrate to juvenile Australian crayfish, *Cherax quadricarinatus*. J Shellfish Res 14:341–6

Poulson TL. 1985. Evolutionary reduction by neutral mutations: Plausability arguments and data from amblyopsid fishes and linyphiid spiders. Natl Speleol Soc Bull 47:109–17

Rouch R and Danielopol DL. 1997. Species richness of microcrustacea in subterranean freshwater habitats. Comparative analysis and approximate evaluation. Int Rev Gesamten Hydrobiol 82:121–45

Sket B. 1996. The Ecology of anchihaline caves. Trends Ecol Evol 11:221–55

Smith RL and Hargreaves BR. 1984. Oxygen consumption in *Neomysis americana* (Crustacea: Mysidacea), and the effects of naphthalene exposure. Mar Biol 79:109–16

Spicer JI and Weber RE. 1992. Respiratory impairment by water-borne copper and zinc in the edible crab *Cancer pagurus* (L.) (Crustacea: Decapoda) during hypoxic exposure. Mar Biol 112:429–35

Downloaded By: [University of Technology, Sydney] At: 22:18 4 February 2007