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OPINION

Persistence and colonisation as measures of success in bog restoration for aquatic invertebrates: a question of detection

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SUMMARY

1. van Duinen *et al.* (*Freshwater Biol.*, 2006) raise an interesting point regarding Mazerolle *et al.*'s (*Freshwater Biol.*, 2006, **51**, p. 333) conclusion on the ability of invertebrates, especially sedentary species, to colonise newly created bogs pools. We wish to clarify that Mazerolle *et al.* (2006) targeted large arthropods and the absence of smaller sedentary species was purely a result of sampling design.
2. van Duinen *et al.* (2006) postulate that colonisation rates by bog specialists should be higher in Canada than in the Netherlands, given the extensive amount of intact peatlands in Canada. Here, we emphasise the importance of taking the regional context into account when assessing restoration success as our study site occurs in a landscape where most bog pools have been drained.
3. An evaluation of restoration efforts should focus on both sedentary and vagile invertebrates, to resolve the importance of persistence and colonisation. Such patterns are difficult to interpret, however, when sampling designs and analyses do not account for the probability of detection: an absence may be due to non-detection or true absence. We strongly urge investigators to directly estimate detection probability in addition to the parameters of interest (e.g. presence, abundance) to provide the best information possible regarding restoration success.

Keywords: arthropods, bog, detectability, restoration

In a recent Canadian study on the colonisation of man-made bog pools by animals and plants after peatland restoration, Mazerolle *et al.* (2006) concluded that some arthropods had readily colonised the pools. van Duinen, Verberk & Esselink (2006) have responded to the paper, casting doubt on the propensity of arthropods, especially those that have more limited mobility, to colonise pools, based on their own work in Dutch bog remnants (van Duinen *et al.*, 2003; Verberk *et al.*, 2006). They make a number of valuable points.

First, van Duinen *et al.* (2006) highlight that the conclusions of Mazerolle *et al.* (2006) probably hold for vagile species, but not for sedentary invertebrate species such as aquatic oligochaetes, and we agree with their argument. van Duinen *et al.* then suggest that the lack of sedentary species in Mazerolle *et al.* (2006) could indicate low colonisation rates of these species, sampling artefacts, or an incomplete restoration of site conditions. Here, we wish to clarify this 'lack' of sedentary species in Mazerolle *et al.*'s samples. Indeed, Mazerolle *et al.* (2006) focused primarily on several plants and one aquatic vertebrate taxon, amphibians. Amphibians were sampled with minnow

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traps (mesh size of 4.8 mm^2), and it was decided to collect and identify aquatic beetles (including bog specialists) captured in the same traps during the same sampling periods. Three years after the beginning of our study, we broadened our sampling to other large invertebrates captured in the traps, such as Hemiptera and Anisoptera. The lack of sedentary species in Mazerolle *et al.*'s (2006) data is simply because such species were not studied, and is neither a consequence of low colonisation rates nor incomplete restoration of site conditions: this is impossible to infer from our study.

Second, van Duinen *et al.* (2003) suggest that pool colonisation by bog specialists is more likely in Canada than in the Netherlands, because more undisturbed peatlands occur in Canada than in the Netherlands. They are only partly correct in that regard. Recent estimates of the surface area of peatlands in Canada stand between 117 and 170 million ha (Gorham, 1990; Poulin *et al.*, 2004), of which 90% are still more or less in a pristine state. However, the natural distribution of peatlands (and bog pools) is heterogeneous within the country, and the threats and disturbances are concentrated regionally. Some regions have suffered greatly from industrial development and our peatland restoration site is a case in point. It is located within a region in southern Québec where 74% of the peatlands have been either lost (12%) or greatly disturbed (62%) through peat mining, forestry or agricultural activities (Pellerin, 2003). The closest bog pools are 40 km from the study site, whereas the second closest are 70 km away. Our site is also isolated from northern bog pools by the St-Lawrence River which is 25 km-wide in this region and represents a barrier to insect movements. Finally, the entire portion of the province extending south of this major river covers 85 753 km^2, but encompasses only seven peatlands with pools. Thus, we believe that the return of the most vagile aquatic invertebrates in the restored pools did not simply result from the abundance of source sites in the region, but rather from the ability of these taxa to recolonise restored sites.

Third, we entirely agree with van Duinen *et al.* (2003) that the evaluation of restoration success must focus on both sedentary and vagile invertebrate species to disentangle the importance of persistence and colonisation rates. This brings us to an important point often ignored in field studies: it is difficult to draw robust conclusions from studies on patterns of species abundance or occurrence without accounting for the probability of detection. When sampling a given species in a plot, individuals are detected (seen or captured) with a given probability *P*. Thus, the expected count (C) of individuals sampled in the plot stems from the following relationship: $E(C) = pN$, where p is the probability of detection and N is the true unknown population size present at the site (Williams, Nichols & Conroy, 2002). To obtain an estimate of population size (N), one must know p. For example, if an investigator captures 15 individuals of a rare species during a survey at a site (i.e. $C = 15$), it is impossible to know how many individuals (N) are at the site: there is an infinite combination of products of p and N that yield 15 (e.g. 1×15, 0.5×30, 0.01×1500). One quickly realises that comparisons across sites or site types cannot be accomplished with classical analyses such as ANOVA, generalised linear models, or multivariate statistics, without making a number of often unrealistic assumptions.

Investigators typically assume that the probability of detection is the same across sites, sampling periods, species, observers, time of day and behaviour of the species. Though an impressive number of papers stemming from the mark-recapture literature indicates that assumptions of constant probability of detection are often invalid (Williams *et al.*, 2002), many routinely undertake studies without estimating and accounting for this parameter. These problems also extend to estimating species richness at a site (i.e. N is the number of species) or the number of sites occupied by a species of interest (i.e. N is the number of sites), and Mazerolle *et al.* (2006) have accounted for detectability in most of their analyses. We strongly urge investigators interested in sampling species that cannot be detected perfectly, such as rare plants, invertebrates and many other animals, to adopt techniques such as site occupancy analyses, distance sampling or mark-recapture analyses (see Williams *et al.*, 2002; Kéry, 2004; MacKenzie *et al.*, 2006). Such tools are essential to obtain accurate estimates in field experiments and monitoring studies and to assess restoration success efficiently.

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