Biodivers Conserv (2009) 18:3295–3307
DOI 10.1007/s10531-009-9642-2

ORIGINAL PAPER

An assessment of the use of volunteers for terrestrial invertebrate biodiversity surveys

Saskie Lovell · Michelle Hamer · Rob Slotow · Dai Herbert

Received: 8 March 2007 / Accepted: 3 April 2009 / Published online: 22 April 2009
© Springer Science+Business Media B.V. 2009

Abstract Species' distributions, assemblage patterns and the processes influencing these are poorly understood, and urgently require study. Use of volunteers to collect data is becoming increasingly common in biodiversity research. We assess the effectiveness of volunteers sampling terrestrial savanna invertebrates in comparison to experienced researchers, and examine the potential contribution of volunteers to terrestrial invertebrate surveys. There were relatively few differences in the diversity sampled by 54 Earthwatch Institute volunteers when compared to expert researchers. The major difference was in the results from the less spatially constrained method, where experience (microhabitat selection) most affected results, and experienced researchers performed better both quantitatively (more species sampled) and qualitatively (more unique and rare species). For the more constrained and less subjective methods, our training enabled the volunteers to quickly equal the experienced experts. Volunteers' experience in invertebrate research influenced both the researchers' perceptions of volunteers' capacity and the actual performance of the volunteers. This suggests that appropriate training for the methods used can help to improve volunteers' success with the sampling. We demonstrated that volunteers collect valid data; for the most part they sample invertebrates as effectively as a trained researcher, and that using volunteers has enormous direct benefits in terms of volume of work accomplished. For invertebrate studies using volunteers, we recommend that the subjectivity of the method be minimised, that experience is compensated for by increasing volunteer effort (two volunteers = one researcher), and that there is close management of volunteers in the field to ensure ongoing data quality. Volunteers provide a valuable resource to researchers carrying out biodiversity surveys, but using volunteers to carry out a scientifically sound project is not an easy option, and should only be implemented when volunteers would make a meaningful contribution and enable an otherwise impossible project.

S. Lovell · M. Hamer · R. Slotow (✉) · D. Herbert
School of Biological and Conservation Sciences, University of KwaZulu-Natal, Westville Campus, Private Bag X54001, Durban 4000, South Africa
e-mail: slotow@ukzn.ac.za

D. Herbert
Natal Museum, Pietermaritzburg, South Africa

Keywords Unskilled workers · Conservation · Environmental education · Sampling effectiveness · Active searching · Savanna · Survey design

Introduction

It is widely accepted that more biodiversity research is required if conservation efforts are to effectively conserve biodiversity (Brooks et al. 2004). Invertebrates comprise the majority of species (Ponder and Lunney 1999; Myers et al. 2000), and are critical for ecosystem functioning (Pimentel et al. 1997), but knowledge of species distributions, assemblage patterns and their drivers is lacking (Ward and Larivière 2004). A major constraint is logistics, with surveys of invertebrates being time-consuming and labour intensive (Slotow and Hamer 2000). Furthermore, specialist taxonomic knowledge and expertise are limited (Slotow and Hamer 2000). An additional challenge presented by invertebrate conservation is the negative perceptions and attitudes of most members of the public (Kellert 1993).

In general, conservation research is underfunded and there is also a lack of manpower in this field (Slotow and Hamer 2000; Foster-Smith and Evans 2003). The use of volunteers is becoming increasingly common in biodiversity and conservation research globally (see Cousins 2007) and there are several volunteer based projects which have made a significant contribution to conservation biology (e.g. Karr 1990; Burgess et al. 1992). While volunteers can contribute where resources are limited, being unskilled, there are concerns over their effectiveness and thus the reliability of the data that they collect (Darwall and Dulvy 1996; Foster-Smith and Evans 2003). The use of volunteers is rarely documented in journals (Cousins 2007), and the validation of volunteers' work is even rarer (but see Darwall and Dulvy 1996; Foster-Smith and Evans 2003; Newman et al. 2003; Goffredo et al. 2004).

United Kingdom-based volunteers provided funding of over £5 million in 2005 for conservation projects, but most were directed towards charismatic fauna, with only 3% of research on insects (Cousins 2007). This does not consider the direct contribution that the extra hands of volunteers make to data collection. No studies have been undertaken to assess effectiveness of volunteers in surveys of terrestrial invertebrates (but see Foster-Smith and Evans (2003) and Puky (2006) for studies on aquatic invertebrates). Techniques to survey terrestrial invertebrates are generally simple, especially if only passive sampling methods are used, such as pitfall trapping and colour pan traps. However, active collecting techniques present difficulties with recognition and capture of target taxa, especially for non-specialists. Many of the target species are cryptic, small or inconspicuous making them difficult to find, and other species are fast moving and difficult to catch. Validation of data collected by volunteers is required, especially if there is an assumption that data are quantified or effort-based and comparisons are to be made, for example, across habitats, sites, or years.

This study aimed to validate the potential contribution of volunteers for surveys of terrestrial invertebrates by addressing the following objectives: (1) to assess the effectiveness of volunteers in sampling invertebrates relative to experienced researchers by contrasting quantitative sampling (the number of species) and qualitative sampling (unique species, rare species and species assemblages), (2) to identify which qualities make volunteers valuable to field researchers, (3) to investigate changes in perceptions among volunteers as a result of their participation in the expedition by pre-and post sampling questionnaires, (4) to examine time benefits associated with the use of volunteer teams to carry out comprehensive invertebrate surveys, and (5) to provide guidelines for the use of volunteers for invertebrate surveys.

Methods

Fieldwork was carried out in the Mkhuze Game Reserve (370 km^2; 27.67°S 32.27°E), Phinda Private Game Reserve (140 km^2; 27.78°S 32.35°E) and False Bay Park (25 km^2; 27.94°S 32.38°E) in north-eastern KwaZulu-Natal, South Africa. These reserves are situated in the diverse region known as the Maputaland Centre, which consists of a mosaic of mainly extensive savanna communities arranged in complex patterns.

We sampled invertebrate diversity at 36 sites, each of 1 ha of uniform vegetation type between November 2002 and March 2005 (summer months). There were 15 sites at Mkhuze, 16 sites at Phinda, and five sites at False Bay. Six of the sites at Mkhuze were resampled twice, and two sites were resampled three times (to assess temporal turnover), but each resampling event was done by different teams, and so for the purposes of this study we treat the data from resampled sites as independent events. Site location was stratified across vegetation types, and spread as much as possible across the reserves.

Earthwatch Institute recruited all 54 volunteers spread across seven expeditions. There was an uneven gender split of 39 men and 24 women; most males in the 30- to 39-year-old age class ($N = 11$), and most females in the 20- to 29-years-old class ($N = 8$). There were two men and two women over 60. Sixteen volunteers were African Fellows, who work in conservation and/or have a tertiary education in a field directly related to the project, and five of these volunteers were experienced field researchers of invertebrates. Seven volunteers were community bird guides from the study region. Twenty-one volunteers were funded by corporate businesses as part of employee development schemes, and were placed by Earthwatch Institute. Nine volunteers were private individuals who personally chose to participate in this expedition. One volunteer was an Earthwatch representative. Each volunteer contributed ~US $200 per day towards Earthwatch administration, research costs, food and accommodation. Volunteers spent 10 nights on the project, enabling 1 day of training, eight sampling days and one rest day.

To gauge their understanding of biodiversity, environmental awareness and attitude towards invertebrates, and to assess the effect of the expedition on these, volunteers independently completed simple questionnaires, both prior to fieldwork and again at the end of the expedition (Table 1). The volunteers were then given a presentation on the aims and objectives of the project and its relevance to ecology, conservation and reserve management. Volunteers were given opportunities to ask questions throughout the presentation. Prior to sampling, we trained volunteers in the field in the methods and collection techniques, and in basic identification of focal taxa. We provided simple field guides to invertebrates, and basic method/taxa ID cards were available at all times in the field. Additional identification/field guides and relevant scientific papers were available in camp. We made a qualitative assessment of the questionnaire answers to identify positive aspects of using volunteers in conservation biology work, and to measure changes in the perceptions of volunteers. Data were obtained from Earthwatch regarding the post-expedition projects in which the corporate-funded volunteers participated.

Volunteers participated in all sampling methods under the supervision of at least one experienced researcher. A range of replicated sampling methods were carried out to sample the following 17 taxa: Lepidoptera (butterflies), Hymenoptera (Apoidea), Diptera (Asilidae

Table 1 The questionnaire which volunteers were asked to complete before and after the expedition

Question (possible responses to questions in italics in parentheses after each question)	Total score	Mean pre-sampling score	Mean post-sampling score	% change in score
1. Please assess the extent to which you feel a responsibility towards protecting the environment *(Very strongly (4), strongly (3), to a limited extent (2), hardly at all (1), not at all (0))*	4	3.6 (90)	3.8 (95)	5
2. When you go into the countryside, do you/will you investigate the invertebrates living here? *(Always (3), sometimes (2), occasionally (1), never (0))*	3	1.9 (63)	2.8 (94)	31
3. Do you think you are likely to join another ecological research survey in the future*? (Certainly (3), probably (2), unlikely (1), certainly not (0))*	3	2.6 (87)	2.8 (92)	5
4. In your opinion which of the following best fits the statement that volunteers can make a significant contribution to ecological studies. *(Strongly agree (3), agree (2), disagree (1), strongly disagree (0))*	3	2.5 (83)	2.8 (92)	9
5. How well do you understand the term biodiversity? *(Completely (4), almost completely (3), partly (2), vaguely (1), not at all (0))*	4	2.7 (68)	3.3 (82)	14
6. List five scientific journals in which research on biodiversity might be published. *(score 1 for each journal named)*	5	1.9 (38)	2.4 (47)	9
7. Do you actively conserve invertebrates at home*? (Always (2), occasionally (1), never (0))*	2	1 (50)	1.6 (81)	31
8. What is your perception of invertebrates*? (Positive (2), tolerate (1), negative (0))*	2	1.5 (75)	1.9 (94)	19
9. On your return do you think you will share you experiences and knowledge with family and friends? *(Certainly (3), Probably (2), Unlikely (1), Certainly not (0))*	3	2.9 (97)	3 (99)	2
10. How would you rate the importance of invertebrates on a global scale? *(*0 being of no importance, 5 being of critical importance *(score corresponded to value stated))*	5	4.5 (90)	4.8 (95)	5

We present the mean volunteer score for each question, with the percentage of the maximum score in parentheses

and Bombyliidae), Neuroptera, Odonata, Hemiptera (Cicadellidae), Coleoptera (Cetoniinae and Scarabaeinae), Orthoptera, Blattodea, Isoptera, Araneae (Araneidae, Thomisidae and Oxyopidae), Scorpionida, Diplopoda, Chilopoda, Mollusca and Annelida.

One site was sampled per day, with active sampling completed by teams during the morning. Where possible, only representative invertebrate samples were kept for identification in order to minimise the effect of sampling on the invertebrate populations. The supervising scientist determined these representative samples. The retained invertebrates were frozen or placed in killing jars containing ethyl acetate before being preserved in 70% ethanol or pinned. Invertebrates were sorted and recorded according to broad groupings at the field station by the volunteers together with researchers. Samples were then further sorted in the laboratory into the relevant taxon. Expert taxonomists undertook the species identification, and reference collections were developed for future use.

At each site, we sampled epigaeic (ground-dwelling) invertebrates (Scarabaeinae, Blattodea, Isoptera, Scorpionida, Mollusca, Diplopoda, Chilopoda and Annelida) using two different active searching methods: two quadrat and two plot searches. Each 2×10 m quadrat comprised five 2 × 2 m blocks, and one individual (either a volunteer or researcher, but there was always at least one researcher simultaneously sampling in the quadrat) thoroughly searched each block with no time limit. Each 20 × 20 m plot, delimited by measuring tapes, was sampled by three people (two volunteers and one experienced researcher) searching for 20 min, giving a totals of 1 h of sampling/plot. Within the plots, collecting focussed on sheltering microhabitats likely to favour the target epigaeic taxa.

We sampled flying and plant-dwelling invertebrates (Lepidoptera, Apoidea, Diptera, Neuroptera, Odonata and Orthoptera) using two 50 m transect walks at each site. A 50 m tape was laid out in a straight line and one person walked along the tape, with one on either side of the tape at a distance of 5 m from the centre line, meaning that three people observed a 10 m width. The three people walked in parallel lines, keeping pace with each other. Specimens were captured with insect nets, and the distance along the transect was noted for each insect captured. One researcher and two volunteers sampled each transect.

The volunteers also assisted in the setting and collection of fruit baited traps, colour pan traps, sweep netting and collection of leaf litter to sample the remaining taxonomic groups. Such passive sampling however, was not assessed in this study, as, unlike active sampling, it is not influenced by the sampler.

Each of the three supervising researchers assessed each volunteer at the end of the sampling trip (following Newman et al. 2003). We used a subjective scale of 0–5 (an experienced, professional researcher = 5/5) to assess: (1) ability of the volunteer to understand principles of the task, (2) execution of the task correctly and efficiently, (3) ability to work reliably without supervision, (4) attention to information and directions given by the supervisor, (5) fitness (scored from 0 = lacking the physical stamina to carry out 5 days of light fieldwork, to 5 = comfortably able) and (6) enthusiasm to complete the task. We informed volunteers before of the general principles of this assessment, but they were not aware of the scoring criteria.

Analyses

To assess whether the survey as a whole successfully sampled the target taxa, an individual-based species accumulation curve was calculated in EstimateS Version 7.5.0 for all invertebrates using all data from the survey.

Researchers and volunteers were directly comparable as they were sampling for the same time, or within the same area, or over the same distance. The values that we present, and that reflect differences, could easily be converted to a sampling rate by factoring in the time/area for each technique. For brevity, we present here only the mean number of species sampled within each of the three techniques. For each method, the target taxa were considered separately, and also combined to give a total for that guild (epigaeic or flying/plant dwelling). Because more volunteers are available than expert researchers, we also combined the efforts of two volunteers and contrasted their results with those of the single researcher. In addition, the quality of the species sampled may differ between an experienced, qualified expert and a relative novice. To assess qualitative differences, we also contrasted the number of unique species (species which were sampled by only one person at any site), or rare species [species occurring in the first quartile of the frequency distribution of species abundances (Gaston 1994)]. We contrasted rare species only for plots and transects. We contrasted the number of species, of unique species, and of rare species across all sites for volunteers and researchers using the Mann–Whitney *U* analysis because data were non-parametric.

We contrasted species assemblages sampled by researchers versus volunteers in plots and transects, using Bray–Curtis similarity matrices based on presence–absence, and then running ANOSIM (Clarke and Warwick 2001). In order to emphasise any potential differences in species assemblages, we removed species sampled at a site by all three individuals.

We defined volunteers' sampling performance in sampling epigaeic invertebrates using plots and quadrats, and in sampling flying insects using transects, as the mean number of species sampled at a site using each method. We defined the researchers' perceived usefulness of the volunteers in the field as the mean score of the researchers' assessment of the volunteers. We determined factors influencing both the effectiveness of volunteers and also their perceived usefulness to researchers using Spearman Rank correlations (data were non-parametric). The factors correlated with these were: age (7 categories), experience (3 categories), physical fitness determined by a self assessment on the Earthwatch application form (5 categories), and enthusiasm (8 categories) determined by the cumulative score of pre-sampling questions numbers 2, 7 and 8 (Table 1). The experience profile was constructed using a rating system of 0–2, based on knowledge of scientific methods, ecological assessments and invertebrate sampling experience. A score of 0 identified an individual with no previous experience or knowledge, 1 identified an individual with either a sound or working knowledge of scientific method determined by current employment or education history, a score of 2 identified a trained researcher of invertebrates.

We used SPSS version 13.0, Primer version 5.2 and EstimateS version 7.5.0 for analyses. We tested all assumptions of the analyses and used Bonferroni adjustment to avoid Type 1 error where applicable.

Results

In its entirety, this project sampled 50,558 individual specimens from 797 invertebrate species. The cumulative time the survey covered was 11 weeks, and an extensive database consisting of 33,257 identified records now exists. Plots sampled 3,987 individuals from 88 species, quadrats sampled 11,695 individuals from 119 species and transects sampled 572 individuals from 92 species. The individual-based species accumulation curve generated from all data collected on the project shows the curve approaching an asymptote (Fig. 1).

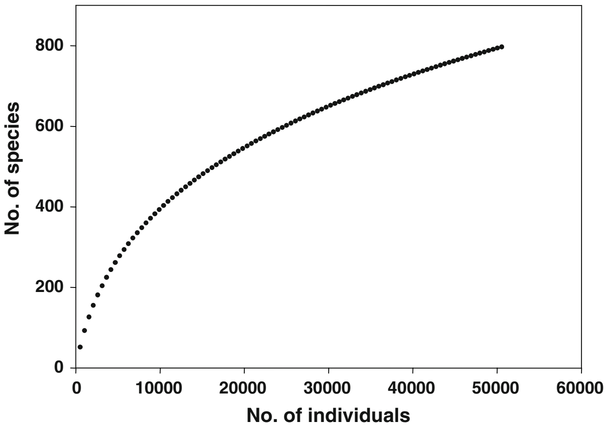

Fig. 1 Overall effectiveness of the sampling during the project indicated by an individual-based species accumulation curves computed from all data obtained from the project

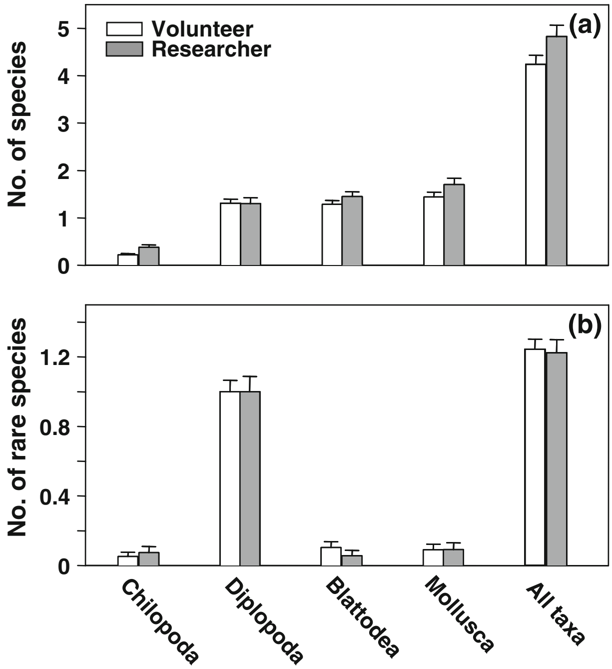

Fig. 2 Comparison of sampling effectiveness between volunteers and researchers using the quadrat method. **a** The mean number of species sampled and **b** and the mean number of rare species sampled. *Error bars* represent standard error

This demonstrates that using volunteers to sample invertebrates resulted in a high level of sampling completeness for the target taxa.

For the quadrat method, there were no significant differences in the mean number of species sampled by researchers and volunteers for all taxa sampled ($P > 0.05$) (Fig. 2a). For the plot method, researchers (n_{res}) sampled significantly more (mean number of species) than volunteers (n_{vol}) for Blattodea ($Z = -3.789$, $n_{res} = 49$, $n_{vol} = 74$, $P < 0.001$), Mollusca ($Z = -3.255$, $n_{res} = 49$, $n_{vol} = 74$, $P = 0.01$) and all epigaeic invertebrates combined ($Z = -4265$, $n_{res} = 49$, $n_{vol} = 74$, $P < 0.001$) (Fig. 3a). When the researcher was contrasted with the two volunteers combined (i.e. twice the effort), there was then no significant difference in the mean number of species sampled in plots ($P > 0.05$) (Fig. 3a). For the transect method, there were no significant differences in the mean number of species sampled by volunteers and researchers for any of the taxa, or combined (Fig. 4a). For the transects, when the efforts of two volunteers were combined ($n_{2\times vol}$), then they sampled significantly more than the researcher (n_{res}) for Diptera ($Z = -2.374$, $n_{res} = 16$, $n_{2\times vol} = 16$, $P = 0.018$), Lepidoptera ($Z = -3.620$, $n_{res} = 16$, $n_{2\times vol} = 16$, $P < 0.001$), Orthoptera ($Z = -4.963$, $n_{res} = 16$, $n_{2\times vol} = 16$, $P < 0.001$) and for all flying insects combined ($Z = -5.554$, $n_{res} = 16$, $n_{2\times vol} = 16$, $P < 0.001$) (Fig. 4a).

The quality of the species sampled may differ between researchers and volunteers, which we assessed by uniqueness (sampled only by a particular collector) or rarity (very few sampled). For the quadrats, there was no significant difference in the number of unique (not illustrated as there were too few) or rare (Fig. 2b) species sampled by the researchers versus the volunteers ($P > 0.05$). For the plots, the researchers (n_{res}) sampled significantly

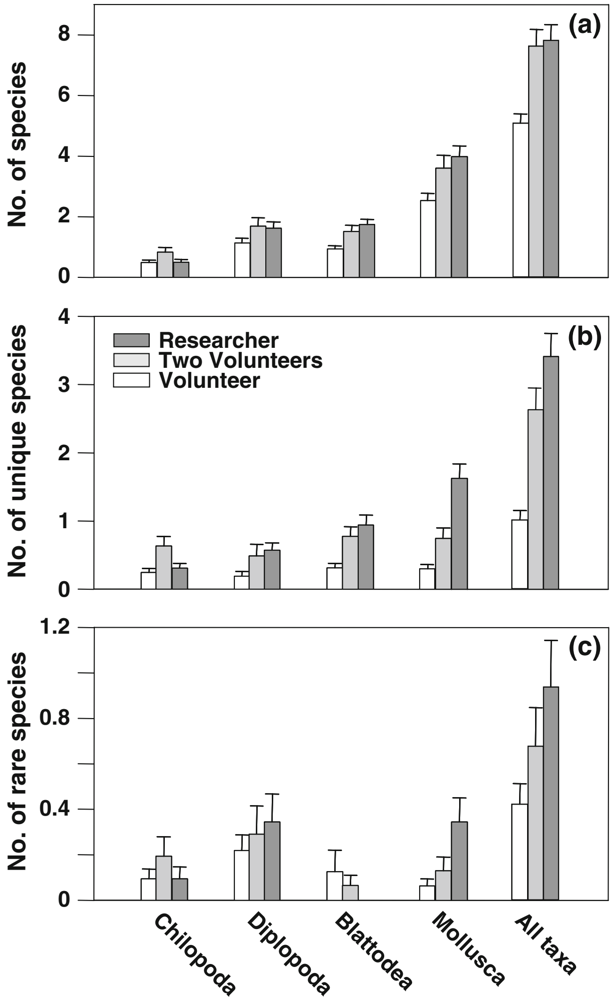

Fig. 3 Comparison of sampling effectiveness of volunteers and researchers using the plot method. **a** The mean number of species sampled; **b** the mean number of unique species; and **c** the mean number of rare species. *Error bars* represent standard error

more unique species than the volunteers (n_{vol}) for Diplopoda ($Z = -3.694$, $n_{res} = 49$, $n_{vol} = 74$, $P < 0.001$), Blattodea ($Z = -3.816$, $n_{res} = 49$, $n_{vol} = 74$, $P < 0.001$), Mollusca ($Z = -5.906$, $n_{res} = 49$, $n_{vol} = 74$, $P < 0.001$) and for all epigaeic invertebrates combined ($Z = -6.514$, $n_{res} = 49$, $n_{vol} = 74$, $P < 0.001$) (Fig. 3b). For plots, researchers sampled significantly more rare species than volunteers for Mollusca ($Z = -2.986$, $n_{res} = 32$, $n_{vol} = 64$, $P = 0.003$) and for all epigaeic invertebrates combined ($Z = -0.315$, $n_{res} = 32$, $n_{vol} = 64$, $P = 0.021$) (Fig. 3c). When two volunteers were contrasted with the researcher, there was no significant difference in either the number of unique or rare species sampled in the plots. For the transects, there were no significant differences between the researchers and volunteers in the number of unique (Fig. 4b) or rare (Fig. 4c) species for any of the taxa. For the transects, two volunteers combined sampled significantly more unique species than the researcher for Orthoptera ($Z = -2.368$, $n_{res} = 16$,

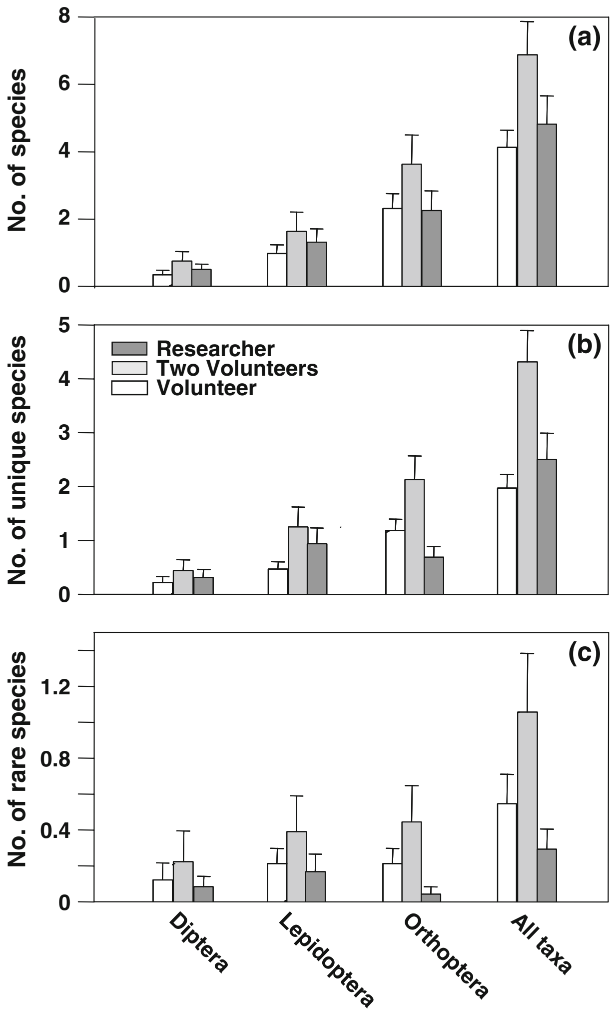

Fig. 4 Comparison of sampling effectiveness of volunteers and researchers using the transect method. **a** The mean number of species sampled; **b** the mean number of unique species; and **c** the mean number of rare species. *Error bars* represent standard error

$n_{2\times vol} = 16$, $P = 0.018$) and flying insects ($Z = -2.257$, $n_{res} = 16$, $n_{2\times vol} = 16$, $P = 0.024$) (Fig. 4b), but there were no differences in the number of rare species sampled (Fig 4c).

There were no significant differences for most of the contrasts of the species assemblages sampled by researchers versus volunteers (based on R values from ANOSIM). For three taxa, there were significant differences in the assemblages sampled by researchers versus volunteers, but the low R values indicate that these differences were relatively minor (following Clarke and Gorley 2001) (Diplopoda: $R = 0.1$, $P = 0.007$ and Blattodea: $R = 0.078$, $P = 0.008$ using plots; Diptera: $R = 0.095$, $P = 0.046$ using transects).

Eleven people working simultaneously in the field, required ~7 h to complete the sampling at a site. Over 3 years with 2 weeks each in November, January and March, our overall project sampled 77 sites (including some repeat sampling at different times) over 77 days. A research team of three people (minimum requirement for our sampling protocols) would have to spend 282 days in the field to complete an equivalent survey, and if conducted within the same seasonal constraints, the survey would take 11 years.

There was a significant positive correlation between the perceived usefulness score given by the researchers and experience of volunteers ($r_s = 0.332$, $n = 54$, $P = 0.014$), and between the effectiveness of volunteers using the transect method and their experience ($r_s = 0.617, n = 24, P = 0.004$). None of the other correlations were statistically significant.

All 54 volunteers were environmentally aware before the sampling, with a strong sense of responsibility towards protecting the environment (Table 1). Both pre- and post-sampling, all would like to participate in other ecological research surveys, although this was logistically constrained (Table 1). Volunteers made a significant contribution to ecological studies, and the strength of this sentiment increased post-sampling (Table 1). Understanding of the term 'biodiversity' increased and by the end of the expedition all volunteers had a complete, or almost complete, understanding of the term (Table 1). Volunteers gained knowledge as to where scientific research is published while on the expedition (Table 1). Volunteers developed an active interest in invertebrates, and indicated that they would in the future investigate and actively conserve invertebrates (Table 1: changes to questions two, seven and eight). Perceptions of invertebrates improved, with invertebrates rated as highly important at a global scale (Table 1). Most importantly in terms of conservation, all volunteers stated that they would share their experiences and knowledge with friends and family on their return home (Table 1).

Twenty-one volunteers were funded by corporate business. These volunteers were required by their funding companies to set up a small conservation project on their return. Examples of projects included: (1) Designing 'communication kits' for local threatened species to raise awareness of the general public about the research and conservation issues; (2) Assisting with the development of museum displays to educate the public about invertebrates living in local tree species; (3) Assisting with the development of a bird hide in a local nature reserve; (4) Developing a restoration project of a land patch invaded by alien plants.

Discussion

There were actually relatively few differences in the diversity sampled by volunteers versus experienced researchers. The major difference was in the results from the plot sampling, with experienced researchers doing better both quantitatively (more species sampled) and qualitatively (more unique and rare species). In this method the sampler has to cover a relatively large area in a short time, and microhabitat selection for searching may greatly effect the final return, and experience will influence this. The other two methods, the quadrats and transects, were much more constrained, and less subjective. In the quadrats, the entire 2×2 m area was searched comprehensively with no time limit, and in the transects, each sampler walked across a defined space. For both techniques the ability to actually capture the specimen is the limiting factor, and the training sessions we provide clearly enabled the volunteers to quickly equal the experienced experts. The influence of volunteers' prior experience on both the researchers' perceptions and actual success of the volunteers highlights the importance of training volunteers in the methods and especially in the capture and handling of invertebrate specimens before sampling is started.

Very few volunteer programmes involve work on insects (Cousins 2007), and we have demonstrated that volunteers can contribute meaningfully to terrestrial invertebrate survey work which has application in conservation biology, ecology, and systematics research. The effectiveness of volunteers is supported by a range of other studies (e.g. Mumby et al. 1995; Darwall and Dulvy 1996; Fore et al. 2001; Newman et al. 2003; Goffredo et al. 2004).

Data collection is only one reason for engaging volunteers in research (Foster-Smith and Evans 2003), and participation by volunteers in our survey was clearly beneficial to them in a broad sense. Volunteers broaden their perspectives, and participation contributes to solving environmental problems (Gilmour and Saunders 1995). Further, on return volunteers tend to participate in social movement activities (McGehee 2002), for example joining conservation groups (Newman et al. 2003). While the primary role of the researchers may be to use volunteers to collect data, the facilitating agencies in particular may see the indirect social benefits (e.g. Foster-Smith and Evans (2003) as an important aspect for longer-term sustainability of such programmes (see also McGehee 2002)). It may be particularly important for corporate funders of such programmes that these broader benefits accrue (personal observation), such as the projects initiated by our volunteers at their home-bases. Such broader societal benefits may thus be the foundation for sustainability of the volunteer phenomenon, i.e. its societal "acceptability", and our results support the credibility of Earthwatch's broader societal outputs (sensu McGehee 2002).

A clear recommendation to emerge from this study is that when volunteers are used for sampling, the subjectivity of the method needs to be minimised. A second recommendation is that it is possible to compensate for lack of experience by increasing effort, for example, two volunteers sampled the same diversity as a single expert researcher in the plots. However, one must be wary about extrapolation, as in the transects two volunteers sampled significantly more than one expert. In other words, each method needs to be quantified for effectiveness of volunteers versus experts, before decisions are made as to sampling effort allocated. There was also remarkably little qualitative difference in terms of sampling of unique species, rare species, or different assemblages. In other words, our results indicate that use of volunteers will not erode the quality of species collected. A third recommendation is for close management of volunteers in the field to ensure ongoing data quality, as well as the overall quality of the experience. Tasks must be realistic and achievable (Foster-Smith and Evans 2003), and sampling methods easily understood, and adequately supported by back-up information resources (e.g. field methods/identification cards). Experts should provide encouragement, reassurance and guidance, and should contextualise the activities as much as possible. Most importantly, we used continual field supervision at a relatively high ratio of one expert to two volunteers. To maintain larger group dynamics and prevent boredom, we rotated volunteers among tasks.

In conclusion, we have demonstrated that volunteers collect valid data, for the most part sample invertebrates as effectively as a trained researcher, and that using volunteers has enormous direct benefits (besides indirect financial contributions to fund the research) in terms of volume of work accomplished. Volunteers provide a valuable resource to researchers carrying out biodiversity surveys and raises environmental awareness and an appreciation of biodiversity, and may contribute to overcoming the logistical impediments (e.g. Slotow and Hamer 2000) to terrestrial invertebrate work. For high-quality data, a well structured, well supported, framework must be designed and implemented, considering training, appropriateness of techniques, researcher/volunteer ratio, as well as the overall experience of the volunteers. Unfortunately, each of these aspects would be project dependent, but we advise other researchers to err on the side of caution for quality maintenance. A sound scientific based project using volunteers is not an easy option, and should only be implemented when volunteers would make a meaningful contribution and enable an otherwise impossible project.

Acknowledgments Many thanks to all Earthwatch volunteers, field assistants and students for their time and effort in the field and in the laboratory. Funding was provided by the Earthwatch Institute and the National Research Foundation via a grant to MH. Conservation Corporation and particularly K. Pretorius, is thanked for accommodation and logistical support in Phinda. KwaZulu-Natal Wildlife and the Greater St. Lucia Wetland Park Authority are thanked for permission to work in Mkhuze and False Bay. We also thank KZN Wildlife staff for logistical support, and the Inland Invertebrate Initiative (UKZN) and Natal Museum for additional support.

References

Brooks T, da Fonseca G, Rodrigues A (2004) Species, data, and conservation planning. Conserv Biol 18:1682–1688. doi:10.1111/j.1523-1739.2004.00457.x

Burgess N, Mwasumbi L, Hawthorne W, Dickinson A, Doggett R (1992) Preliminary assessment of the distribution, status and biological importance of coastal forests in Tanzania. Biol Conserv 62:205–218. doi:10.1016/0006-3207(92)91048-W

Clarke K, Gorley R (2001) PRIMER v5: user manual/tutorial. PRIMER-E, Plymouth

Clarke K, Warwick R (2001) Change in marine communities: an approach to statistical analysis and interpretation. PRIMER-E, Plymouth

Cousins JA (2007) The role of UK-based conservation tourism operators. Tour Manage 28:1020–1030. doi:10.1016/j.tourman.2006.08.011

Darwall W, Dulvy N (1996) An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania—a case study. Biol Conserv 78:223–231. doi:10.1016/0006-3207(95)00147-6

Fore L, Paulsen K, O'Laughlin K (2001) Assessing the performance of volunteers in monitoring streams. Freshw Biol 46:109–123. doi:10.1046/j.1365-2427.2001.00640.x

Foster-Smith J, Evans S (2003) The value of marine ecological data collected by volunteers. Biol Conserv 113:199–213. doi:10.1016/S0006-3207(02)00373-7

Gaston K (1994) Rarity. Chapman and Hall, London

Gilmour J, Saunders D (1995) Earthwatch: an international network in support of research on nature conservation. In: Saunders D, Craig J, Mattiske E (eds) Nature conservation. Beatty, Surrey, pp 627–633

Goffredo S, Piccinetti C, Zaccanti F (2004) Volunteers in marine conservation monitoring: a study of the distribution of seahorses carried out in collaboration with recreational scuba divers. Conserv Biol 18:1492–1503. doi:10.1111/j.1523-1739.2004.00015.x

Karr J (1990) Avian survival rates and the extinction process on Barro Colorado Island, Panama. Conserv Biol 4:387–391. doi:10.1111/j.1523-1739.1990.tb00313.x

Kellert S (1993) Values and perceptions of invertebrates. Conserv Biol 7:845–855. doi:10.1046/j.1523-1739.1993.740845.x

McGehee NG (2002) Alternative tourism and social movements. Ann Tourism Res 29:124–143. doi:10.1016/S0160-7383(01)00027-5

Mumby P, Harborne A, Raines P, Ridley J (1995) A critical-assessment of data derived from coral cay conservation volunteers. Bull Mar Sci 56:737–751

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858. doi:10.1038/35002501

Newman C, Buesching C, Macdonald D (2003) Validating mammalian monitoring methods and assessing the performance of volunteers in wildlife conservation—"Sed quis custodiet ipsos custodies?". Biol Conserv 113:189–197. doi:10.1016/S0006-3207(02)00374-9

Pimentel D, Wilson C, McCullum C, Huang R, Dwen P, Flack J et al (1997) Economic and environmental benefits of biodiversity. Bioscience 47:747–757. doi:10.2307/1313097

Ponder W, Lunney D (eds) (1999) The other 99%. The conservation and biodiversity of invertebrates. Transactions of the Royal Society of New South Wales, Mosman, p 462

Puky M (2006) A new, volunteer-based, cost effective method for zoological mapping: the photo identification of freshwater crayfish (Crustacea: Decapoda) species and the importance of volunteers in crayfish research. Bull Fr Peche Piscicult 380–81:927–936. doi:10.1051/kmae:2006032

Slotow R, Hamer M (2000) Biodiversity research in South Africa: comments on current trends and methods. S Afr J Sci 96:222–224

Ward D, Larivière M (2004) Terrestrial invertebrate surveys and rapid biodiversity assessment in New Zealand: lessons from Australia. N Z J Ecol 28:151–159