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CAPTURE EFFICIENCY AND PRESERVATION ATTRIBUTES OF DIFFERENT FLUIDS IN PITFALL TRAPS

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ABSTRACT. Pitfall traps are widely used to capture arthropods. The type of fluid employed in the traps can affect size and condition of the catch. Direct comparisons of different fluids allow entomologists to avoid suboptimal solutions, and facilitate comparisons between studies using different fluids. We compared capture efficiency and preservation attributes between five fluids in a field experiment with special respect to spiders (Araneae) and ground beetles (Coleoptera, Carabidae). Catches in pure water, ethanol-water and ethanol-glycerin were less well preserved than in brine or ethylene glycol-water. Brine and ethanol-glycerin showed low capture efficiencies, presumably because their high specific density made arthropods float and thereby facilitated escape. Only the mixture of ethylene glycol and water combined good preservation attributes with high capture efficiency, and therefore represented the best solution.

Keywords: Brine, ethanol, ethylene glycol, glycerin, pitfall traps

Originally described by Barber (1931), pitfall traps continue to be among the most widely employed sampling methods for ground-dwelling arthropods, particularly spiders (Araneae) and ground beetles (Coleoptera, Carabidae). Consisting of cups sunk into the ground flush with the surface, pitfall traps are inexpensive, easy to use and operate round-the-clock, resulting in large, species-rich samples (Clark & Blom 1992). A variety of liquids are employed to retain, kill and preserve the arthropods. Solutions of formalin and water were once common, but have been largely abandoned because of health hazards (van den Berghe 1992). Pure water is an alternative (Waage 1985), but mixtures with ethanol, glycerin, ethylene glycol or brine are often preferred because their conservation attributes are presumably better (Holopainen 1992; Teichmann 1994). The use of different preservatives also affects sampling efficiency and thereby complicates comparisons between studies. As only a few replicated field studies have been published that compare different preservatives, informed recommendations remain difficult (Weeks & McIntyre 1997; Lemieux & Lindgren 1999). Here, we compared sampling efficiencies and conservation attributes of five commonly used fluids in a field experiment.

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METHODS

The preservatives compared in this study were (tap) water, brine (saturated solution of NaCl in water), 2:1 mixture of ethanol and water, 3:1 mixture of ethanol and glycerin, and 1:3 mixture of ethylene glycol (automobile antifreeze) and water. An unscented detergent was added to all liquids to break the surface tension and accelerate wetting and killing of arthropods (Topping & Luff 1995). The traps consisted of 0.2 liter plastic cups with an opening of 7.0cm diameter. They were protected from rain with 25 × 25cm acrylic glass roofs. Two cm from the top of the cup, pieces of 2cm mesh hardware cloth were inserted to hold off vertebrates (Hall 1991). Forty of these traps were installed in a fallow on calcareous soil near Göttingen, Germany, in a grid with 5m distance between traps. Seventy ml of each of the five preservatives described above were added to the traps with eight replicates in a Latin square design. The traps were operated for seven days starting on 2 May 2003. Upon withdrawal, catches were transferred to polyethylene bottles and stored at 4°C for another week. Then, the volume of remaining liquid was recorded after pouring it

Table 1.—Differences between fluids in the percentage of damaged spiders (with detached legs, palps or opisthosomae), the amount of liquid retrieved, numbers of individuals (N), species (S) or genera (G) captured. Means ± SE. One-way ANOVA, or Kruskal-Wallis ANOVA when variance homogeneity was not met (Hymenoptera N and springtail N). Means preceded by different capitals are significantly different at $P < 0.05$.

Tested variable	Water	Brine	Ethanol-water	Ethanol-glycerin
Damaged spiders [%]	^{A}28.9 ± 3.7	^{B}9.0 ± 1.6	^{A}38.1 ± 6.0	^{A}33.3 ± 4.0
Liquid [ml]	^{B}46.8 ± 1.0	^{A}52.6 ± 1.4	^{D}8.8 ± 1.2	^{C}29.6 ± 0.9
Arthropod N	87.8 ± 9.7	63.9 ± 8.6	79.0 ± 7.2	68.5 ± 10.8
Spider N	^{A}45.8 ± 5.1	^{C}23.5 ± 3.2	^{AB}40.0 ± 4.8	^{BC}30.0 ± 4.8
Spider S	7.5 ± 0.6	5.9 ± 0.5	6.5 ± 0.7	6.0 ± 0.4
Ground beetle N	18.0 ± 2.8	11.6 ± 2.2	14.3 ± 1.4	14.0 ± 3.8
Ground beetle G	^{AB}4.4 ± 0.3	^{B}3.9 ± 0.3	^{A}5.1 ± 0.3	^{B}3.8 ± 0.4
Hymenoptera N	4.3 ± 1.0	17.3 ± 9.8	8.1 ± 4.4	3.5 ± 1.2
Springtail N	^{AB}2.6 ± 0.6	^{B}1.5 ± 0.5	^{AB}2.8 ± 0.8	^{A}8.3 ± 2.0
Diptera N	^{A}6.5 ± 1.1	^{B}1.6 ± 0.5	^{B}3.5 ± 0.7	^{B}2.6 ± 0.7

through gauze, and the arthropods were transferred to 80% ethanol. The condition of the catch was noted with particular attention to signs of decomposing processes, such as the percentage of spiders with detached body parts (legs, palps or opisthosomae). All arthropods were identified to order. Spiders were further identified to species, and ground beetles to genera. The number of genera was used as a surrogate of ground beetle species richness (Báldi 2003). The weather during the sampling period was dry and sunny, with an average temperature of 14.7 °C (2.9°–30.0°), mean wind velocity of 3.4 m/s (daily average 1.4–6.4), and 8.5 hours of sunshine per day (0.5–14.2). Rain (1.5mm) occurred only on the last of the seven sampling days (data supplied by Deutscher Wetterdienst, Offenbach, Germany).

RESULTS

The condition of the samples differed markedly between preservatives. The percentage of spiders that had lost body parts was nearly three times as high in water, ethanol-water and ethanol-glycerin as in brine and ethylene-glycol (Table 1). Additionally, all ethanol-water and two out of eight brine samples developed mold after one week in the refrigerator. Most liquid was retrieved from the traps filled with ethylene glycol and brine, representing 77% and 75% of the initial volume, respectively. Significantly less liquid was retrieved from traps filled with water (67%), ethanol-glycerin (42%) and ethanol-water (13%) at the end of the experiment (Table 1).

The overall catch was 1522 spiders (comprising 1232 Lycosidae, 248 Tetragnathidae, and 42 individuals from six other families), 607 ground beetles, 336 Hymenoptera (96% ants, Formicidae), 127 springtails (Collembola), 122 dipterans and 289 other arthropods. While the total number of arthropods was not significantly different between liquids, the number of spiders, springtails and dipterans, and the number of ground beetle genera showed significant treatment effects (Table 1). Thirty-five percent fewer spider individuals were captured in brine and ethanol-glycerin compared to the three remaining liquids. The number of ground beetle genera was 25% lower in brine and ethanol-glycerin than in ethanol-water and ethylene glycol. The number of dipterans was 6.5 times as high in water as in ethylene glycol, with intermediate values in the three remaining liquids, and 7.3 times as many springtails were captured in ethanol-glycerin than in brine and ethylene glycol.

DISCUSSION

Both preservation attributes and sampling efficiency differed between the fluids compared in this study. High losses of volume from ethanol-glycerin and ethanol-water suggest that the ethanol had largely evaporated during one week of exposure. The development of mold in ethanol-water catches gives additional indication that most of the ethanol, and thereby the conservation attributes of the solution, had disappeared. The mold presumably also kept back an additional part of the remaining liquid, explaining why markedly

Table 1.—Extended.

Glycol	$F_{4,35}$	P	χ^2	P
^{B}14.7 ± 3.7	9.5	<0.001		
^{A}53.6 ± 3.2	118	<0.001		
75.8 ± 7.8	1.1	0.38		
^{ABC}37.0 ± 6.1	3.2	0.026		
7.3 ± 0.6	1.6	0.18		
18.0 ± 2.4	1.1	0.38		
^{A}5.0 ± 0.4	3.6	0.015		
8.5 ± 5.8			2.0	0.73
^{B}0.8 ± 0.4			10.8	0.028
^{C}1.0 ± 0.4	9.3	<0.001		

less than the deployed amount of water could be retrieved, while losses from the pure water traps were minor. Water and brine catches smelled offensive, and water attracted high numbers of dipterans, which are further signs for the decay occurring in these catches. High percentages of spiders had lost body parts in the water, ethanol-water and ethanol-glycerin catches, indicating softening of the cuticle due to decomposition and/or chemical processes. Ground beetles appeared to be less vulnerable to decomposition than spiders (Holopainen 1992), and a certain degree of softening may even be desired because it facilitates mounting of specimens or preparation of genitalia. However, in other ground beetle studies, ethylene glycol was found to be preferable to brine because of its better conservation attributes (Lemieux & Lindgren 1999; Vennila & Rajagopal 2000). Therefore, a non-volatile preserving component like ethylene glycol is recommended to reliably prevent decomposition in pitfall traps exposed for one week or longer.

Numbers of spider individuals and beetle genera were lower in ethanol-glycerin and brine than in the three remaining liquids. Such differing sampling efficiencies can be ascribed to attraction or deterrence by the preservative (Teichmann 1994; Weeks & McIntyre 1997). However, the differences observed in our study suggest an additional mechanism. Arthropods usually float in liquids whose specific gravity (SG) is distinctly higher than that of water (SG = 1.0). Reduced capture efficiencies in ethanol-glycerin and brine may hence be due to arthropods floating at the surface, which facilitated escape of newly trapped individuals falling on top of them. Brine (SG = 1.18–1.20) and glycerin (SG = 1.26) were the liquids with the highest specific gravities employed in this study, and the specific gravity of the ethanol-glycerin mixture presumably rose to similar values as brine, once most of the ethanol (SG = 0.80) had evaporated. Arthropods may also float in pure ethylene glycol (SG = 1.11), but sink in 1:3 mixtures with water, as has been confirmed with wolf spiders in the laboratory (MHS personal observation). Hence, diluting ethylene glycol with water not only reduces expenses, but may also improve capture efficiency.

In conclusion, ethylene glycol had better conservation attributes and/or higher sampling efficiencies for spiders and ground beetles than brine, pure water, or any combination containing ethanol. If there are no specific purposes like DNA preservation (Gurdebeke & Maelfait 2002) or attraction of slugs and snails (to ethanol), mixtures of ethylene glycol and water remain the first choice preservative for pitfall traps. As ethylene glycol is potentially hazardous to wildlife, a bitter agent should be added, or physical obstacles employed to avoid access by vertebrates (Hall 1991; van den Berghe 1992). To date, only propylene glycol appears to be a comparably adequate, yet more expensive alternative (Weeks & McIntyre 1997).

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