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Scale-dependence of the correlation between human population and the species richness of stream macro-invertebrates

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Abstract

Recent biogeographical studies have shown positive correlations between plant/vertebrate species richness and human population presence. The same pattern has been reported for Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) amongst European countries. This is surprising as EPT are bio-indicators of stream pollution and most local studies report higher species richness of these macro-invertebrates where human influences on water quality are lower. Using a newly collated taxonomic dataset, we studied whether the species richness of EPT is related to human population size at finer resolutions (Italy's regions, provinces and $10 \times 10\,km^2$ UTM cells) controlling for sampling effort, variations in area and for spatial autocorrelation. At all study grains, observed EPT species richness was strongly correlated to the number of records available for the same taxon. At the regional level, the observed number of Ephemeroptera and Plecoptera species significantly increased with increasing human population size. At the provincial level, observed species richness decreased significantly with increasing human population size for Ephemeroptera and did not vary significantly for Plecoptera and Trichoptera. At the finest grain scale, there were significant negative correlations of observed Ephemeroptera and Trichoptera species richness with human population size, although the proportion of variance explained was very low. These results were broadly confirmed when analyzing the estimated number of species using the formula of Chao2. Our analysis confirms the scale-dependence of the human population–biodiversity correlation. Over broad scales more populated regions tend to have more species than less populated ones. Restricting the study grain, the positive EPT species–people relationship disappears and turns into a negative one. Our findings suggest a challenge also for the conservation of regional EPT diversity.

Zusammenfassung

Neuerliche biogeografische Untersuchungen haben positive Korrelationen zwischen dem Artenreichtum von Pflanzen bzw. Wirbeltieren und der Anwesenheit menschlicher Populationen gezeigt. Das gleiche Muster wurde für

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Ephemeroptera (Eintagsfliegen), Plecoptera (Steinfliegen) and Trichoptera (Köcherfliegen) (EPT) in europäischen Ländern gezeigt. Dies ist überraschend weil EPT als Bioindikatoren für Verschmutzungen gelten und die meisten lokalen Untersuchungen einen höheren Artenreichtum dieser Makroinvertebraten dokumentieren wenn der menschliche Einfluss auf die Wasserqualität geringer ist. Unter Nutzung eines neuerlich zusammengetragenen Datensets untersuchten wir, ob der Artenreichtum der EPT mit der menschlichen Populationsgröße bei feinerer Auflösung (Italiens Regionen, Provinzen und $10 \times 10\,km^2$ UTM Abschnitte) in Beziehung steht und kontrollierten Beprobungsaufwand, Variation der Fläche und räumliche Autokorrelationen. Bei allen Auflösungen der Untersuchung war der beobachtete Artenreichtum der EPT stark mit Anzahl der verfügbaren Erfassungen für jedes Taxon korreliert. Auf der regionalen Skala nahm die Artenzahl der Ephemeroptera und Plecoptera signifikant mit einer zunehmenden menschlichen Populationsgröße zu. Auf der Provinzebene nahm der beobachtete Artenreichtum bei den Ephemeroptera mit zunehmender menschlicher Populationsgröße signifikant ab und zeigte keine signifikante Variation bei den Plecoptera und Trichoptera. Auf der kleinsten Skala gab es signifikante negative Korrelationen zwischen dem beobachteten Artenreichtum der Ephemeroptera und Trichoptera und der menschlichen Populationsgröße, obwohl der Anteil der erklärten Variation sehr gering war. Diese Ergebnisse wurden weitgehend durch die Analyse der geschätzten Artenzahlen nach der Formel von Chao2 bestätigt. Unsere Ergebnisse bestätigen die Skalenabhängigkeit der Korrelation zwischen Biodiversität und menschlicher Population. Auf großen Skalen tendieren stärker besiedelte Regionen dazu mehr Arten zu haben als geringer besiedelte Gebiete. Bei einer Beschränkung des Untersuchungsrasters verschwindet die positive EPT-Menschen-Beziehung und verwandelt sich in eine negative. Unsere Ergebnisse stellen zudem eine Herausforderung für den Erhalt der EPT-Diversität dar.

Keywords: Animal biodiversity; Conservation biogeography; Ecosystem health; Fauna Europaea; Freshwater ecosystems; Geographical ecology; Landscape indicators; Macroecology; Taxa co-occurrence; Western Palaearctic

Introduction

A positive correlation between species richness and human population presence is now commonly reported (Luck, 2007). This correlation is at first sight counter-intuitive, as biodiversity could be thought to be higher in less densely populated and thus still semi-natural regions, but can be explained by the preferential settlement of human beings in regions with high environmental productivity and/or habitat heterogeneity, which in turn are species-rich regions. This broad-scale co-occurrence is relevant for conservation, because the many detrimental local impacts of human beings on biodiversity are magnified if species-rich regions are more densely populated.

Positive broad-scale species–people relationships are now known for most continents (Hunter & Yonzon, 1993; Fjeldså, 2007; Knapp, Kühn, Klotz & Schweiger, 2008). The range of taxa involved in these studies has been mainly limited to plants and vertebrates, but a positive large-scale species–people correlation can apply also to invertebrates such as butterflies, aphids and grasshoppers (Luck, Ricketts, Daily & Imhoff, 2004; Steck & Pautasso, 2008; Pautasso & Powell, 2009). Surprisingly, a positive species–people correlation has also been reported for bio-indicators of water quality (Ephemeroptera, Plecoptera and Trichoptera: EPT) amongst European countries (Pautasso & Fontaneto, 2008).

EPT are common bio-indicators of freshwater biotic integrity (Ode, Rehn & May 2005). Given their habitat requirements and sensitivity to disturbance, the species richness of EPT tends to be lower in streams with higher human impacts (Figueroa, Valdovinos, Araya & Parra, 2003; Dinakaran & Anbalagan, 2007). These impacts include watercourse and floodplain alteration, the related enhanced erosion, industrial and sewage waste (Fochetti & de Figueroa, 2006; Martel, Rodriguez & Berube, 2007). Therefore, it could be expected that EPT might be an exception to the positive large-scale species–people correlation. The report of a positive correlation between EPT species richness and people for European countries (Pautasso & Fontaneto, 2008) prompts the questions of (i) how general this pattern is for EPT, and whether it persists (ii) at a narrower scale of analysis and (iii) when controlling for sampling effort.

This study aims to answer these three questions. We investigate whether there is a species–people correlation for EPT in Italy's regions, provinces and $100\,km^2$ cells, thus at a much finer study grain and over a more restricted study extent than for European countries. Although Italy is a species-rich European country from the point of view of EPT, Italian investigations of stream macro-invertebrate diversity in relation to environmental parameters and human activities have only been patchy (DiGiovanni, Goretti & Tamanti, 1997; Ravera, 2001; Lucadamo, De Filippis, Mezzotero, Vizza & Gallo 2007). Moreover, the data available allow us to control for variations in sampling intensity and to study whether sampling intensity is correlated with human population presence.