Arthropods, 2020, 9(3): 104-111

Article

Latitudinal gradient in *Gnomeskelus* species richness

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Received 23 February 2020; *Accepted 30 March 2020*; *Published 1 September 2020*

Abstract

The Tropical Conservativism Hypothesis suggests processes of speciation, extinction and dispersal resulted in higher species richness at the tropics and declined away from the equator. Biogeographical Conservativism Hypothesis suggests that the processes invoked are not intrinsic to the tropics but were dependent on historical biogeography to determine the distribution of species richness. 77 valid species were identified as belonging to the genus *Gnomeskelus* in order to test between the two hypotheses. There was a significant correlation between the number of species and latitudinal degrees away from the equator ($r=-0.7145$, $r^2=0.5105$, $n=77$, $p<0.00001$). Alternatively, there may be an evolutionary preference for temperate environments appearing to have led to climatic constraints on dispersal based primarily on temperature seasonality gradients.

Keywords diversity; gradient; latitude; richness; species.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Species richness is the number of different species represented in an ecological community, landscape or region (Colwell, 2009; Colwell and Hurtt, 1994; Colwell and Lees, 2000; Colwell et al., 2004). Species richness and biodiversity increase from the poles to the tropics for a wide variety of terrestrial and marine organisms and is referred to as a latitudinal diversity gradient (LDG) (Colwell, 2009). Inverse LDG include include aphids, Chinese litter-dwelling thrips, European bryophytes, freshwater zooplankton, Holarctic tree frogs, ichneumonids, New World snake tribe Lampropeltini, marine benthic algae, North American breeding birds, penguins, peracarid crustaceans, pitcher plant mosquito, pond turtles, Shallow-water molluscs, shorebirds, southeastern United States trees, subarctic forests and tropical leaf-litter ant communities (Kindlmann et al., 2007; Kwon et al., 2019; Marshall and Baltzer, 2015; Mateo et al., 2016; Pyron and Burbrink, 2009; Rivadeneira et al., 2011; Silva and Brandão, 2014; Sime and Brower, 1998; Wang et al., 2014).

Here the LDG is tested in the millipede genus *Gnomeskelus* (Hamer, 1998). This clade of millipedes belonging to the Order Polydesmida is distributed throughout southern Africa (Hamer, 1998; Theron, 2001).

The null hypothesis was the Tropical Conservativism Hypothesis which suggests processes of speciation, extinction and dispersal result in higher species richness at the tropics and decline away from the equator (Mittelbach et al., 2007). The alternative was the Biogeographical Conservativism Hypothesis which suggest that the processes invoked are not intrinsic to the tropics but are dependent on historical biogeography to determine the distribution of species richness (Pyron and Burbrink, 2009).

2 Materials and Methods

77 valid species were identified as belonging to the 77 valid species were identified as belonging to the genus *Gnomeskelus* (Hamer, 1998). These were tabulated and known localities also listed (Table 1). Localities were obtained from literature (Hamer, 1998). GPS coordinates were obtained from internet sources for known localities using the locality followed with the keyword "GPS" or http://gps-coordinates.org. Latitude and longitude coordinates were obtained. When co-ordinates were not in decimal degrees, they were subsequently converted to decimals by dividing the seconds by 60 and adding these to the minutes which were together divided through 60 to get the decimal behind or following the degree.

3 Results

19 *Gnomeskelus* species were found between -31 and -35 degrees latitude, 44 species between -27 and -31 degrees latitude, 10 species between -23 and -27 degrees latitude, 2 species between -19 and -23 degrees latitude, and 2 species between -11 and -15 degrees latitude (Fig. 1). There was a significant correlation between the number of species and latitudinal degrees away from the equator (Fig. 2: $R=-0.7145$, $R^2=0.5105$, $n=77$, $p<0.00001$).

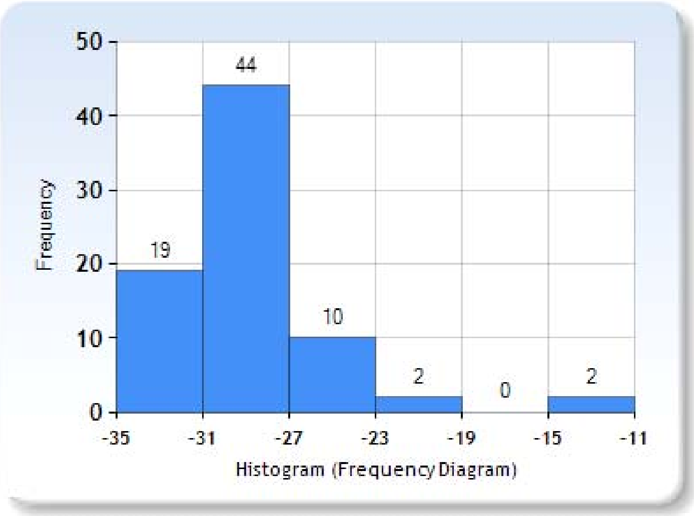

Fig. 1 Histogram showing the number of species (Frequency) across latitudes in *Gnomeskelus*.

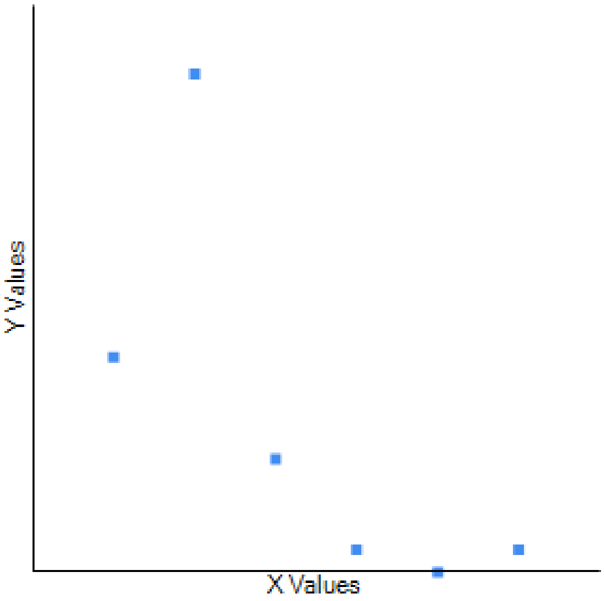

Fig. 2 Correlation between species number (Y Values) and latitude S (X Values) in *Gnomeskelus*.

4 Discussion

Gnomeskelus are more temperate and show a general decline in LDG (Colwell and Hurtt, 1994; Colwell and Lees, 2000; Colwell et al., 2004; Pielou, 1977; Willig and Lyons, 1998; Zapata et al., 2003). Other groups showing an inverse LDG include aphids, European bryophytes, freshwater zooplankton, Holarctic tree frogs, ichneumonids, New World snake tribe Lampropeltini, marine benthic algae, North American breeding birds, penguins, peracarid crustaceans, pitcher plant mosquito, pond turtles, Shallow-water molluscs and shorebirds (Kindlmann, 2007; Mateo, 2016; Pyron and Burbrink, 2009; Rivadeneira et al., 2011). Two general explanations for the inverse trends in LDG include precipitation and predation which may be pertinent to *Gnomeskelus.* Rapoport's rule, which states there is a decrease in the latitudinal extent of ranges at lower latitudes may exist independently of biodiversity gradients so it cannot be used as an explanation in *Gnomeskelus* (Yen et al., 2018).

There may be an evolutionary preference for temperate environments appearing to have led to climatic constraints on dispersal based primarily on temperature seasonality gradients (Schubart, 1966). LDG depends on proximate factors affecting processes of speciation, extinction, immigration, and emigration and in *Gnomeskelus* these factors are dependent on size which need investigating in *Gnomeskelus* based on temperature, precipitation and latitude. LDG may relate to body size in *Gnomeskelus* probably which does not agree with the trends in other taxa such as birds and fishes (Yen et al., 2018). The trend of small body size associated with the inverse LDG is expected to be similar to the weak tendency found in mammals (Zapata et al., 2003). Size-reductions makes sense for diplopods because the class has reduced in size over evolutionary time (Cooper, 2014, 2016-2020).

Appendix 1 Species in the genus *Gnomeskelus* with type or collected localities and GPS points.

Species	Locality	GPS latitude	GPS longitude
G. arator	Magoebaskloof	-23.8812	29.9833
G. arcuatus	Umgeni Poort	-29.8689	31.0617
G. armiger	Bainskloof	-23.4667	28.5667
G. attemsii	Champaigne Castle	-29.0030	29.4645
G. auriculatus	Rosetta	-29.3233	29.7153
G. bacillifer	Barkley East	-30.9694	27.5908
G. basuticus	Maseru	-29.3151	27.4871
G. bicornis	Van Stadens Pass	-33.9091	25.1970
G. bifurcates	Kranskop	-23.0500	29.5500
G. breviceps	Bulwer	-29.8034	29.7637
G. brincki	Gudu falls	-28.6773	28.9276
G. burius	Pietermaritzburg	-29.6180	25.6590
G. ceresinus	Swellendam	-34.0034	20.3333
G. circulipes	Karkloof	-29.3000	30.0670
G. clavatus	Mossel bay	-34.1811	22.1058
G. cyclocanthus	Kranskop	-23.0500	29.5500
G. cygniceps	Entabeni	-22.9833	30.2500
G. dentipes	Chai Chai	-11.8525	40.0250
G. edentulous	Giant's Castle	-29.2705	29.5203
G. elizabethae	Port Elizabeth	-33.9820	25.6590
G. fitsimonsi	George	-33.9680	22.4499
G. fluvialis	Bulwer	-29.8034	29.7637
G. forcipifer	New Hanover	-29.355	30.5264
G. furculatus	Port Shepstone	-30.667	30.5130
G. glaber	Kloof	- 29.7723	30.8302
G. globifer	Uitenhage	-33.7746	25.3788
G. globulatus	Makhanda	-33.3100	26.5270
G. gonoarthrodus	Cathedral Peak	-28.9441	29.2307
G. graemi	Makhanda	-33.3100	26.5270
G. hamuliger	Nkhandla forest	-28.7167	31.1333
G. harpagonifer	Nkhandla forest	-28.7167	31.1333
G. hewitti	Makhanda	-33.3100	26.5270
G. inermis	Redhouse	-33.8166	25.5500
G. jaculator	Pietermaritzburg	-29.6180	25.6590
G. kambianus	Kambi forest, Umtata	-31.4667	28.6000
G. krausi	Ngomi forest	-27.8667	31.4000
G. krugeri	Punda Maria	-22.6954	31.0161
G. laevigatus	Champaigne Castle	-29.0030	29.4645

G. larvatus	Pietermaritzburg	-29.6180	25.6590
G. latzeli	Van Reenen	-29.0002	29.4691
G. lawrencei	Nkhlandla forest	-28.7167	31.1333
G. maritimus	Umhlali	-29.4500	31.2667
G. medius	Bluff Durban	- 29.7723	30.8302
G. montifelis	Winterberg	-32.5167	26.4500
G. montivagus	Cathkin Peak	-29.0538	29.3955
G. multidentatus	Ingwavuma	-27.1343	31.9965
G. natalicus	Empangeni	-28.7549	31.9015
G. origensis	Drakensberg	-29.0030	29.4645
G. outeniqua	Nature's Valley	-33.9797	23.5567
G. pencillatus	Mossel bay	-34.1832	22.1536
G. petersii	Ingwavuma	-27.1343	31.9965
G. processiger	Kokstad	-30.5475	29.4244
G. pugnifer	Champaigne Castle	-29.0030	29.4645
G. puteinus	Matjesfontein	-33.2319	20.5803
G. retrusus	Pietermaritzburg	-29.6180	25.6590
G. rhodobates	Humansdorp	-34.0299	24.7707
G. rudebecki	Entabeni	-30.5485	28.2590
G. serratus	Karkloof	-29.4064	30.2805
G. setosus	Champaigne Castle	-29.0030	29.4645
G. silvaticus	Knysna	-34.0357	23.0485
G. skukuzae	Skukuza	-24.9613	31.5900
G. spectabilis	Umhlali	-29.4773	31.2181
G. spiculifer	Port St Johns	-31.6205	29.5453
G. spinifer	Chai Chai	-11.8525	40.0250
G. stuckenbergi	Pilgrim's Rest	-24.9044	30.7536
G. subterraneus	Elandskop	-29.7242	30.0700
G. swazianus	Mbabane	-26.3257	31.1447
G. swazius	Swaziland	-26.5625	31.3991
G. tembulicus	Qolora River Mouth	-32.6345	28.4273
G. tenuipes	Kosi Bay	-27.2593	32.7522
G. tereticornis	Ngome forest	-27.8667	31.4000
G. transvaalicus	Barberton	-25.7822	31.0475
G. trichardti	Makhado	-23.0383	29.9067
G. trifurcatus	Kranskop	-30.9892	23.7709
G. tristriatus	Albert falls	-30.9892	23.7709
G. tuberosus	Drakensberg	-29.0474	29.4178
G. tugelanus	Cathkin Peak	-29.0538	29.3955

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