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Null models for study Rotifers and Crustaceans Zooplankton species richness in Chilean Patagonian lakes

Modelos nulos para o estudo de riqueza de espécies de Rotíferos e Crustáceos Zooplanctônicos na Patagônia Chilena

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Abstract: Aims: The Patagonian lakes are characterized by their oligotrophy that is the cause of low species number in their zooplankton assemblage. The aim of the present study is to analyze the crustacean and rotifers species number pattern in Patagonian lakes among a latitudinal gradient (40-51 °S). **Results:** The results revealed that there are direct significant correlations between total species with rotifer species, and chlorophyll concentration with crustacean species number, and an inverse association between latitude with total species. **Conclusion:** The results of co-occurrence species null model revealed presence of regulator factors in one of three simulations, that would be due to the presence of many species repeated in studied sites. Similar patterns were observed in Argentinean Patagonian lakes.

Keywords: crustacean; rotifers; zooplankton; species number.

Resumo: Objetivo: Os lagos da Patagônia são caracterizados pela sua oligotrofia que é a causa do baixo número de espécies em sua comunidade zooplanctônica. O objetivo do presente estudo é analisar o padrão de espécies de crustáceos e rotíferos em lagos da Patagônia em um gradiente latitudinal (40-51 °S). **Resultados:** Os resultados revelaram que existem correlações significativas diretas entre o total de espécies com espécies de rotíferos, e concentração de clorofila com o número de espécies de crustáceos, e uma associação inversa entre a latitude com total de espécies. **Conclusão:** Os resultados de modelo nulo de co-ocorrência de espécies revelaram a presença de fatores de regulação em uma das três simulações, que seria devido à presença de muitas espécies repetidas nos locais estudados. Padrões semelhantes foram observados nos lagos da Patagônia Argentina.

Palavras-chave: crustáceo; rotíferos; zooplâncton; número de espécies.

1. Introduction

The use of models for understand ecological patterns can involve the random presence in some determined cases for populations and community scales (Hilborn & Mangel 1997), that can be applied for statistical applications (Zar 1999; Gotelli & Ellison, 2013). At community ecology scale is proposed the null models that involve the absence of regulator factors in community structures (Harvey et al., 1983; Gotelli & Graves, 1996; Gotelli, 2000, 2001). The aim of the null models view point is based in randomization or absence of process and regulator factors on community ecology, and the null hypothesis is based that community is random or without defined structure (Harvey et al., 1983; Gotelli & Graves, 1996). On these null models one of the most applied in community ecology is the co-occurrence species that involves a presence-absence species matrix for a defined sites list with the aim of determine if the species associations are random or structured (Gotelli & Graves, 1996; Gotelli, 2000). These models are based mainly in terrestrial environments (Tondoh, 2006; Tiho & Josens, 2007) and in freshwater environments (De los Ríos, 2008; De los Ríos-Escalante et al., 2011). This kind of model has been applied mainly in field crustacean zooplankton studies on Chilean Patagonian lakes for understand the random or structuration in zooplankton species associations, unfortunately there are not other similar studies for other lakes (De los Ríos, 2008; De los Ríos-Escalante et al., 2011).

The Patagonian lakes are characterized by their oligotrophy and low species number in their zooplankton assemblages (Soto & Zúñiga, 1991; De los Ríos-Escalante, 2010). Similar pattern has been observed for Argentinean Patagonian lakes (Modenutti et al., 1998). The literature has been focused mainly in Crustacean species number (Soto & Zúñiga, 1991; Modenutti et al., 1998; De los Ríos-Escalante, 2010), but there are not detailed descriptive studies for rotifers assemblages, there are only basic descriptions about presence/absence rotifers species (Campos et al., 1989, 1992, 1988, 1990, 1994a, b; Villalobos, 1999). The aim of the present study is to analyze the crustacean and Rotifera zooplankton assemblages in Chilean Patagonian lakes with the aim of determine if the assemblages are random or structured.

2. Material and methods

Data of geographical location, surface, maximum depth, mean chlorophyll, rotifer, crustacean species number were obtained from literature, (Campos et al., 1989, 1992, 1988, 1990, 1994a, b; Villalobos, 1999) (Table 1, Figure 1), it was selected these variables, because: these are available for all studied sites; some trophic variables have wrong in some lakes due methodological procedures (Woelfl et al., 2003), and these variables are considered in many zooplankton studies in Chilean lakes (Soto & Zúñiga, 1991; De los Ríos & Soto, 2005, 2006; De los Ríos-Escalante, 2010, 2013).

Data was analyzed in three steps: a first step is determine if the rotifer, crustacean and total zooplankton species was associated with the mentioned parameters, for this purpose, it was previously verified the normality using a Shapiro test, and as this condition was not found, it was applied a Spearman non parametric correlation test using software "R" (R Development Core Team, 2009).

In the following steps a species absence/ presence matrix was constructed, with the species in rows and the sites in columns (Table 2). As second step consisted, it was applied a UPGMA cluster analysis using Neighbour-joining method for determine potential similarities between sites on the basis of species associations using the R package Phangorn (Schliep, 2011). Thirdly we calculated

Table 1. Geographical location, maximum depth (Zmax in m), surface (km^2), chlorophyll "a" concentration (µg/L), and rotifer and crustacean species number for sites considered in the present study.

	Lat. S, Long W.	Zmax	Surface	Chlorophyll "a"	Rotifer	Crustacean
Puyehue	40°40' 72°30'	123	165.4	2.1	6	7
Rupanco	40°50' 72°30'	272	235.0	1.2	9	4
Todos los Santos	41°08' 72°50'	335	178.5	0.4	9	4
Llanquihue	41°08' 72°50'	317	870.5	0.5	12	3
Los Palos	45°19' 72°42'	59	5.0	0.8	12	4
Riesco	45°39' 72°20'	130	14.7	0.9	9	4
Escondida	45°49' 72°40'	43	7.0	0.5	9	5
Del Toro	51°03' 72°38'	312	86.0	0.3	2	5
Sarmiento	51°12' 72°37'	300	196.0	0.4	5	4

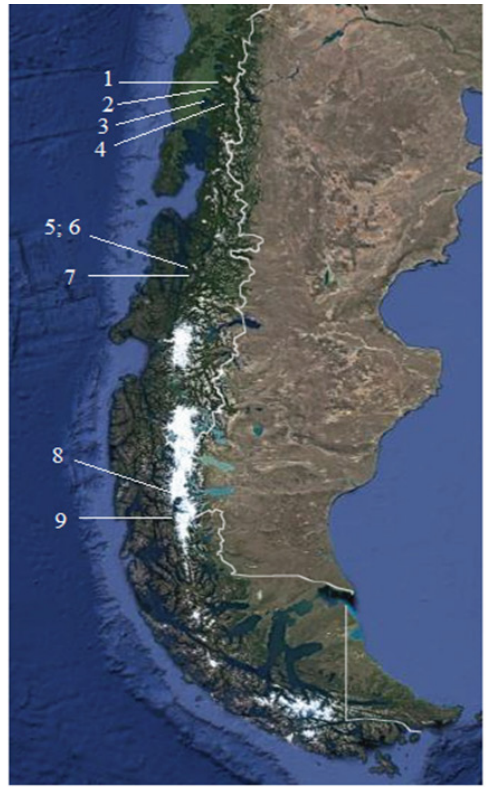

Figure 1. Map with sites included in the present study (1: Puyehue; 2: Rupanco; 3: Llanquihue; 4: Todos los Santos; 5: Los Palos; 6: Escondida; 7: Riesco; 8: Sarmiento; 9: Del Toro). Source: Google Earth (2016).

a Checkerboard score ("C-score"), which is a quantitative index of occurrence that measures the extent to which species co-occur less frequently than expected by chance (Gotelli, 2000). A community is structured by competition when the C-score is significantly larger than expected by chance (Gotelli, 2000; Tondoh, 2006; Gotelli & Entsminger, 2007; Tiho & Josens, 2007; Ehouman et al., 2009). Thirdly we compared co-occurrence patterns with null expectations via simulation. Gotelli & Ellison (2013) suggested the as statistical null models Fixed-Fixed: in this model the row and column sums of the matrix are preserved. Thus, each random community contains the same number of species as the original community (fixed column), and each species occurs with the same frequency as in the original community (fixed row). The null model analyses were performed using the package EcosimR version 7.0 (Gotelli & Ellison, 2013; Carvajal-Quintero et al., 2015).

Finally, it was applied a correspondence analysis with the presence-absence data with the aim of determine the potential groups of lakes and their respective zooplankton components. This analysis was perfomormed using the R-package CA (Nenadic & Greenacre, 2007).

3. Results

The correlation results revealed the absence of significant associations between studied parameters (Table 3). The results of cluster analysis revealed for total species and Rotifera the presence of three main groups, the first joined by Sarmiento and Del Toro lakes, the second joined by Los Palos, Escondida and Riesco lakes, and the third joined by Llanquihue, Todos los Santos, Rupanco and Puyehue lakes (Figure 2), whereas for crustacean the groups observed were first joined by Sarmiento, Del Toro, Llanquihue and Todos los Santos lakes, the second joined by Los Palos, Escondida and Riesco lakes, and the third group joined by Rupanco and Puyehue lakes (Figure 2).

The results of co-occurrence null model species revealed the presence of regulator factors for total, crustaceans and rotifer species (Table 4), that is confirmed by respective simulation graphs (Figure 3).

The results CA analysis agree with UPGMA about the presence of three main groups joined the first with Sarmiento and Del Toro lakes, the second joined by Riesco, Los Palos and Escondida lakes, and the third joined by Todos Los Santos, Rupanco, Puyehue and Llanquihue lakes (Table 5, Figure 4).

Table 2. Rotifera and crustacean species reported for sites considered in the present study.

	Del Toro	Sarmiento	Escondida	Riesco	Los Palos	Llanquihue	Todos Los Santos	Rupanco	Puyehue
Crustacea									
Daphnia pulex (Leydig 1860)	0	0	0	0	0	0	1	1	0
Ceriodaphnia dubia (Richard 1894)	0	0	1	1	1	0	0	1	1
Neobosmina chilensis (Daday 1902)	0	1	1	1	1	1	1	1	1
Diaphanosoma chilense (Daday 1902)	0	0	0	0	0	0	0	1	1
Tumeodiaptomus diabolicus (Brehm 1935)	0	0	0	0	0	0	0	1	1
Boeckella gracilipes (Daday 1901)	1	1	1	1	1	1	1	0	0
Boeckella michaelseni (Mrazek 1901)	1	1	0	0	0	0	0	0	0
Parabroteas sarsi (Ekman 1905)	0	0	1	1	1	0	0	0	0
Tropocyclops prasinus meridionalis (Kiefer 1927)	1	1	1	1	1	0	0	0	1
Mesocyclops araucanus (Löffler 1962)	1	1	1	1	1	1	1	0	1
Rotifera									
Ascomorpha sp. (Perty 1850)	0	0	0	0	0	1	1	0	0
Asplanchna (Gosse 1850)	0	0	1	1	1	0	0	0	0
Collotheca pellagica (Rousselet 1893)	0	0	1	1	1	1	1	1	1
Conochiloides coenobastis (Hudson 1885)	0	0	0	0	0	0	0	0	1
Conochilus unicornis (Rousselet 1892)	0	1	1	1	1	1	1	1	1
Euchalanis sp. (Ehrenberg 1832)	1	1	0	0	0	0	0	0	0
Filinia longiseta (Ehremberg 1834)	0	0	1	1	1	0	0	0	0
Gastropus sp. (Inhof 1898)	0	0	1	1	1	0	0	0	0
Keratella cochlearis cochlearis (Gosse 1851)	0	0	1	1	1	1	1	1	1
Keratella gracilienta Alstrom	0	0	0	0	0	0	0	1	0
Lecane luna (Müller 1776)	0	0	1	1	1	0	0	0	0
Monostyla lunaris (Ehrenberg 1832)	1	1	0	0	0	1	0	0	0
Notholca caudata (Carlin 1943)	0	1	0	0	0	0	0	0	0
Polyartha dolichoptera (Idelson 1925)	0	0	0	0	0	1	1	1	1
P. vulgaris (Carlin 1943)	0	1	1	1	1	1	0	0	0
Pompholyx sulcata (Hudson 1855)	0	0	0	0	0	1	1	0	0
Synchaeta sp. (Ehremberg 1832)	0	0	1	1	1	0	0	0	0
S. stylata (Wierzejski 1893)	0	0	0	0	0	1	1	1	0
Tricocerca (Lamarck 1801)	0	0	0	0	0	0	0	0	1
T. porcellus (Gosse 1851)	0	0	0	0	0	1	1	1	0
T. similis (Wierzejski 1893)	0	0	0	0	0	0	0	1	0
Phylodina indet	0	0	1	1	1	0	0	0	0
Rotatoria indet.	0	0	0	0	0	0	0	1	0
Bdelloida indet.	0	0	0	0	0	1	1	0	0

Table 3. Results of correlation between studied parameters with Rotifera, crustacean and total species number.

	Rho	P
Latitude – Rotifera	–0.386	0.304 n.s
Zmax – Rotifera	–0.131	0.736 n.s
Surface – Rotifera	0.043	0.911 n.s
Chlorophyll – Rotifera	0.321	0.398 n.s
Latitude – crustacea	–0.036	0.925 n.s
Zmax – crustacea	–0.477	0.194 n.s
Surface – crustacea	–0.477	0.194 n.s
Chlorophyll – crustacea	0.106	0.785 n.s
Latitude – total	0.362	0.337 n.s
Zmax – total	–0.391	0.297 n.s
Surface – total	–0.226	0.558 n.s
Chlorophyll – total	0.381	0.310 n.s

"P" values lower than 0.05 denotes significant association.

4. Discussion

The results revealed that the zooplankton species associations are not random, this mean the existence of regulator factors, this is supported first by marked significantly of co-occurrence species null models, that would avoid the presence of type I and type II errors (Gotelli, 2000; Veech, 2012). Although the correlation analysis does not denote significant associations, the literature mentioned an inverse relation between species richness latitude, and a direct association between species richness and chlorophyll a (De los Ríos-Escalante, 2010, 2013). This is because, there is an inverse association between chlorophyll and latitude in large and deep lakes due mixing depth increasing, that generate an strong physical stressor for phytoplankton activity (Soto, 2002; De los Ríos-Escalante, 2010).

The role of rotifers and crustacean zooplankton is important because they are main grazers in Patagonian lakes (Woelfl, 2007; Woelfl et al., 2010;

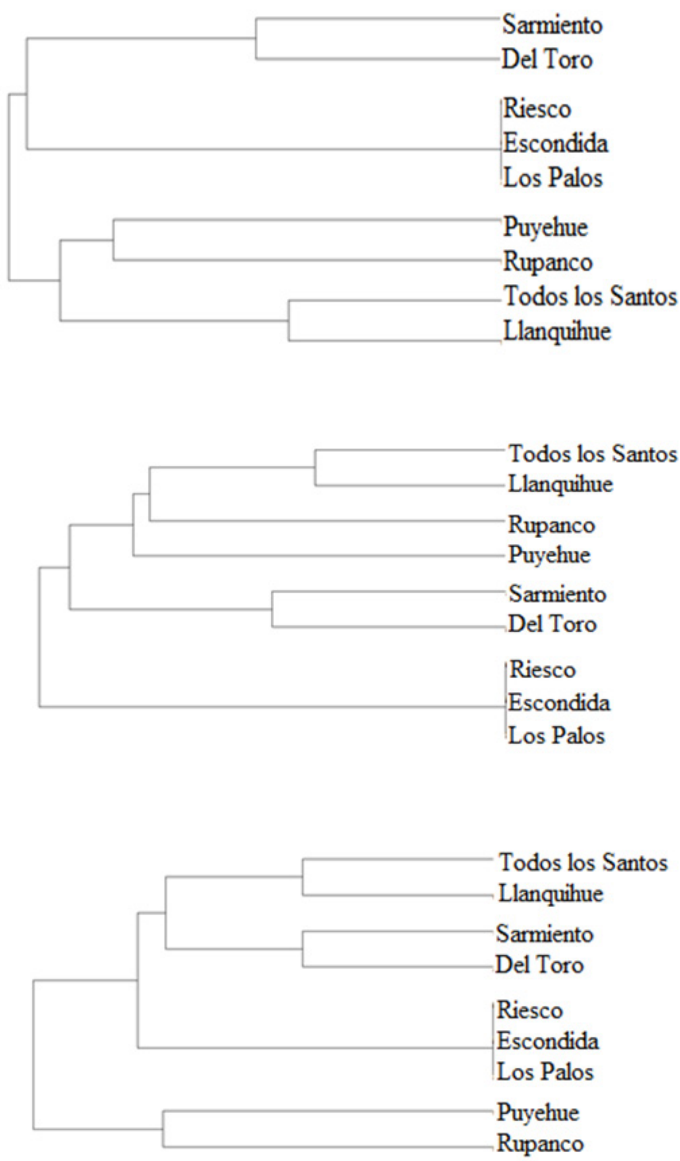

Figure 2. UPGMA based on neighbour-joining method for total species (up), rotifer species (center) and crustacean species (down).

Table 4. Results of null model co-occurrence species for total species number, rotifer and crustacean species for studied sites.

Total species					
Models	Observed index	Mean index	Standard effect size	Variance	P
Fixed-fixed Total species: 34	3.019	2.667	10.444	0.002	<0.001 *
Fixed-fixed Rotifer species: 24	3.511	3.064	3.663	0.014	0.004 *
Fixed-fixed Crustacean species: 10	2.858	2.526	7.586	0.001	<0.001 *

* “P” values lower than 0.05 denotes the presence of regulator factors.

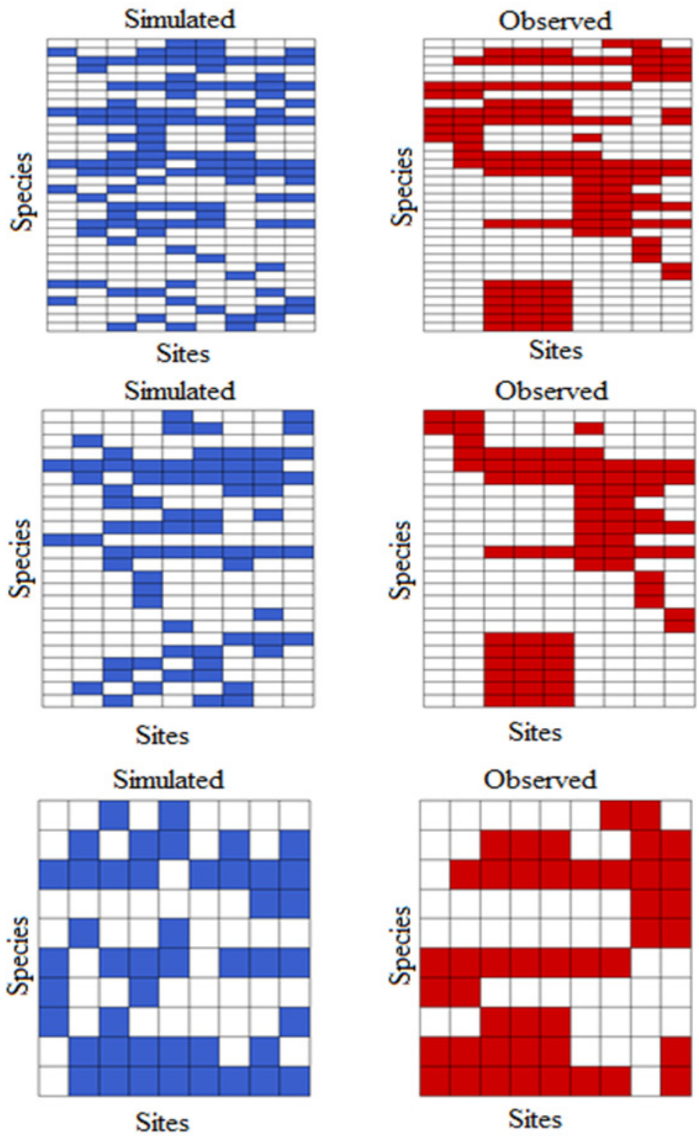

Figure 3. Graphs with simulated and observed species associations based on null model co-occurrence analysis for total species (up), rotifer species (center) and crustacean species (down).

Table 5. Results of correspondence analysis for presence-absence species matrix.

	Masses	Total quality	Inertia value
Crustacea			
D. pulex	17	575	34
C. dubia	43	630	15
N. chilensis	68	120	3
D. chilense	17	446	36
T. diabolicus	17	446	36
B. gracilipes	60	762	16
B. michaelseni	17	876	70
P. sarsi	26	961	22
T. prasinus meridionalis	51	638	23
M. araucanus	68	690	10
Rotifera			
Ascomorpha sp.	17	290	34

Table 5. Continued...

	Masses	Total quality	Inertia value
Asplanchna	26	961	22
C. pellagica	60	857	6
C. coenobastis	9	68	45
C. unicornis	68	120	3
Euchalanis sp.	17	876	70
F. longiseta	26	961	22
Gastropus sp.	26	961	22
K. cochlearis cochlearis	60	857	6
K. gracilienta	9	413	38
L. luna	26	961	22
M. lunaris	26	890	52
N. caudata	9	418	55
P. dolichoptera	34	894	25
P. vulgaris	43	439	17
P. sulcata			
Synchaeta sp.	26	733	29
S. stylata	26	961	22
Tricocerca	9	69	45
T. porcellus	26	733	29
T. similis	9	413	38
Phylodina indet	26	991	22
Rotatoria indet.	9	413	38
Bdelloida indet.	17	290	34
Sites			
Puyehue	103	131	153
Rupanco	120	612	193
Todos los Santos	111	413	105
Llanquihue	120	316	89
Los Palos	137	980	57
Riesco	137	980	57
Escondida	137	980	57
Del Toro	51	783	147
Sarmiento	85	787	142

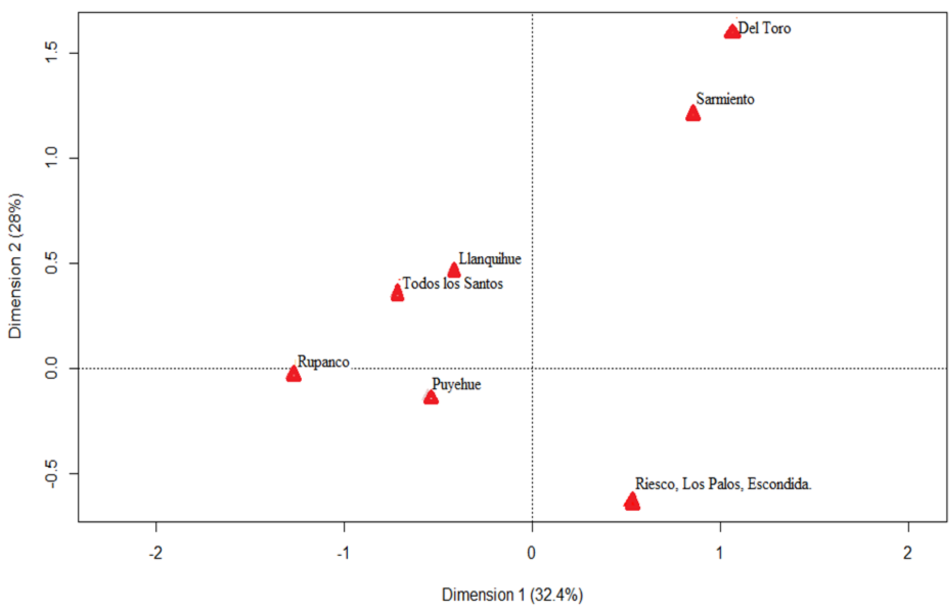

Figure 4. Results of correspondence analysis for sites in the presence-absence species matrix.

Montecino et al., 2011; Modenutti, 2014). In this scenario, the literature described a direct relation between chlorophyll concentration and crustacean species richness for Patagonian lakes (De los Ríos-Escalante, 2010, 2013), but the chlorophyll concentration is inversely related with latitude for these lakes (Soto, 2002, De los Ríos-Escalante, 2010). It was not found significant associations between crustacean zooplankton species richness with surface and depth (Soto & Zúñiga, 1991; De los Ríos-Escalante, 2010, 2013). These results would agree partially with observations for northern hemisphere lakes where it was found the direct association between crustaceans species number with chlorophyll concentration, nevertheless in northern hemisphere lakes it was found a direct association between crustacean species number with surface (Dodson, 1992; Karatayev et al., 2008; Dodson et al., 2009; Van Egeren et al., 2011).

In the present study, the lacks of coincidences between correlation test with null models would support the literature descriptions about null models because these are statistically robust (Tondoh, 2006; Tiho & Josens, 2007; Gotelli & Ulrich, 2012). The present study would suggest compare null model analysis with traditional statistical null hypothesis for improve the data analysis.

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