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Supplemental material

Correlates of ecological-niche diversity and extinction risk of amphibians in China under climate change

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Table S1. Correlations of different niche diversity metrics and the significance of the correlations

Upper triangular matrix collects the correlation values, whereas the lower triangular matrix collects the *P*-values of the correlations. NC, niche connectivity; TNC, trend of NC; NB, niche breadth; TNB, trend of NB; NP, niche position; TNP, trend of NP; NA, niche amount; TNA, trend of NA; NCO, niche spatial correlation; TNCO, trend of NCO; NPA, niche packing; TNPA, trend of NPA; NFD, niche fractal dimension; TNFD, trend of NFD; NV, niche volume; and TNV, trend of NV

	NB	NP	NC	NA	NCO	NPA	NFD	TNB	TNP	TNC	TNA	TNCO	TNPA	TNFD
NB	1.000	0.515	0.263	0.088	0.335	–0.168	–0.071	–0.269	–0.056	–0.081	0.027	–0.086	0.095	–0.017
NP	0.000	1.000	0.003	–0.318	0.342	0.633	–0.423	–0.125	–0.134	–0.089	0.088	–0.151	–0.105	–0.041
NC	0.000	0.965	1.000	–0.242	0.002	0.035	–0.385	–0.391	0.161	–0.227	0.022	0.045	0.204	–0.225
NA	0.158	0.000	0.000	1.000	0.179	–0.623	0.561	0.068	–0.026	–0.041	–0.246	–0.103	0.007	0.123
NCO	0.000	0.000	0.977	0.004	1.000	0.169	–0.374	–0.128	–0.042	–0.030	–0.035	–0.034	0.004	–0.010
NPA	0.007	0.000	0.576	0.000	0.006	1.000	–0.675	0.026	–0.043	–0.040	0.167	–0.028	–0.169	–0.120
NFD	0.255	0.000	0.000	0.000	0.000	0.000	1.000	0.153	–0.093	0.060	–0.113	–0.025	–0.039	0.195
TNB	0.000	0.045	0.000	0.272	0.039	0.68	0.014	1.000	0.250	0.236	0.040	0.055	–0.094	0.197
TNP	0.365	0.030	0.009	0.672	0.500	0.493	0.136	0.000	1.000	0.143	–0.134	0.387	0.777	–0.263
TNC	0.193	0.154	0.000	0.508	0.627	0.525	0.336	0.000	0.021	1.000	–0.027	0.663	0.303	0.174
TNA	0.660	0.156	0.723	0.000	0.572	0.007	0.068	0.525	0.031	0.666	1.000	–0.102	–0.193	0.006
TNCO	0.164	0.015	0.470	0.099	0.582	0.656	0.685	0.374	0.000	0.000	0.102	1.000	0.488	–0.391
TNPA	0.127	0.091	0.001	0.911	0.948	0.006	0.533	0.130	0.000	0.000	0.002	0.000	1.000	–0.084
TNFD	0.787	0.510	0.000	0.048	0.870	0.054	0.002	0.001	0.000	0.005	0.921	0.000	0.176	1.000

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Table S2. Evolutionary distinctiveness-weighted extinction risk (EDGE) values calculated for the amphibian species of China used in the present study

The IUCN threatened status of each species was provided for comparison. DD, Data Deficient; LC, Least Concern; NT, Near Threatened; VN, Vulnerable; EN, Endangered; and CR, Critically Endangered

Species	EDGE	Status	Species	EDGE	Status
Glandirana minima	3.628201	CR	*Ingerana xizangensis*	0.825815	DD
Scutiger maculatus	3.530731	CR	*Ingerana medogensis*	0.825815	DD
Andrias davidianus	3.482265	CR	*Babina pleuraden*	0.819551	LC
Liuixalus ocellatus	3.007154	EN	*Babina lini*	0.819551	DD
Hynobius chinensis	2.933857	EN	*Babina daunchina*	0.819551	LC
Batrachuperus londongensis	2.912351	EN	*Babina adenopleura*	0.819551	LC
Tylototriton hainanensis	2.889313	EN	*Tylototriton verrucosus*	0.809871	LC
Quasipaa robertingeri	2.868084	EN	*Kurixalus odontotarsus*	0.801427	LC
Quasipaa boulengeri	2.868084	EN	*Kurixalus naso*	0.801427	DD
Pelophylax tenggerensis	2.861582	EN	*Kurixalus idiootocus*	0.801427	LC
Leptobrachium leishanense	2.852349	EN	*Kurixalus eiffingeri*	0.801427	LC
Leptobrachium boringii	2.852349	EN	*Kurixalus appendiculatus*	0.801427	LC
Scutiger pingwuensis	2.837584	EN	*Microhyla pulchra*	0.796883	LC
Scutiger ningshanensis	2.837584	EN	*Microhyla ornata*	0.796883	LC
Scutiger muliensis	2.837584	EN	*Microhyla mixtura*	0.796883	LC
Nanorana yunnanensis	2.837318	EN	*Microhyla heymonsi*	0.796883	LC
Nanorana unculuanus	2.837318	EN	*Microhyla fissipes*	0.796883	LC
Nanorana maculosa	2.837318	EN	*Microhyla butleri*	0.796883	LC
Oreolalax puxiongensis	2.828074	EN	*Microhyla berdmorei*	0.796883	LC
Rhacophorus yaoshanensis	2.813863	EN	*Pelophylax plancyi*	0.782141	LC
Parapelophryne scalpta	2.807471	EN	*Pelophylax lateralis*	0.782141	LC
Liua tsinpaensis	2.341806	VU	*Pelophylax hubeiensis*	0.782141	LC
Gracixalus jinxiuensis	2.314007	VU	*Pelophylax fukienensis*	0.782141	LC
Pseudorana weiningensis	2.310347	VU	*Bufo tibetanus*	0.780291	LC
Theloderma moloch	2.245825	VU	*Bufo stejnegeri*	0.780291	LC
Buergeria oxycephala	2.245825	VU	*Bufo minshanicus*	0.780291	LC
Hynobius yiwuensis	2.24071	VU	*Bufo gargarizans*	0.780291	LC
Hynobius arisanensis	2.24071	VU	*Bufo bankorensis*	0.780291	LC
Batrachuperus yenyuanensis	2.219203	VU	*Bufo aspinius*	0.780291	DD
Batrachuperus tibetanus	2.219203	VU	*Bufo andrewsi*	0.780291	LC
Batrachuperus pinchonii	2.219203	VU	*Bufo ailaoanus*	0.780291	DD
Batrachuperus karlschmidti	2.219203	VU	*Leptobrachium liui*	0.772907	LC
Limnonectes fragilis	2.212109	VU	*Leptobrachium huashen*	0.772907	LC
Ingerana liui	2.212109	VU	*Leptobrachium chapaense*	0.772907	LC
Ingerana borealis	2.212109	VU	*Hyla tsinlingensis*	0.764158	LC
Tylototriton wenxianensis	2.196166	VU	*Hyla simplex*	0.764158	LC
Tylototriton kweichowensis	2.196166	VU	*Hyla sanchiangensis*	0.764158	LC

Species	EDGE	Status	Species	EDGE	Status
Quasipaa spinosa	2.174937	VU	*Hyla japonica*	0.764158	LC
Quasipaa shini	2.174937	VU	*Hyla immaculata*	0.764158	LC
Quasipaa jiulongensis	2.174937	VU	*Hyla chinensis*	0.764158	LC
Quasipaa exilispinosa	2.174937	VU	*Hyla annectans*	0.764158	LC
Leptobrachium hainanense	2.159201	VU	*Scutiger nyingchiensis*	0.758142	LC
Scutiger tuberculatus	2.144437	VU	*Scutiger mammatus*	0.758142	LC
Hylarana spinulosa	2.142694	VU	*Scutiger glandulatus*	0.758142	LC
Oreolalax rhodostigmatus	2.134926	VU	*Scutiger boulengeri*	0.758142	LC
Oreolalax multipunctatus	2.134926	VU	*Nanorana ventripunctata*	0.757877	LC
Oreolalax major	2.134926	VU	*Nanorana parkeri*	0.757877	LC
Oreolalax jingdongensis	2.134926	VU	*Nanorana liebigii*	0.757877	LC
Pseudohynobius flavomaculatus	2.128232	VU	*Hylarana tytleri*	0.7564	LC
Pachyhynobius shangchengensis	2.128232	VU	*Hylarana taipehensis*	0.7564	LC
Amolops kangtingensis	2.123893	VU	*Hylarana nigrovittata*	0.7564	LC
Amolops jinjiangensis	2.123893	VU	*Hylarana macrodactyla*	0.7564	LC
Odorrana nasuta	2.121613	VU	*Hylarana latouchii*	0.7564	LC
Odorrana junlianensis	2.121613	VU	*Hylarana guentheri*	0.7564	LC
Odorrana jingdongensis	2.121613	VU	*Hylarana garoensis*	0.7564	LC
Odorrana hainanensis	2.121613	VU	*Hylarana cubitalis*	0.7564	LC
Rhacophorus yinggelingensis	2.120715	VU	*Rana zhenhaiensis*	0.751171	LC
Rhacophorus kio	2.120715	VU	*Rana shuchinae*	0.751171	LC
Xenophrys nankiangensis	2.116655	VU	*Rana omeimontis*	0.751171	LC
Xenophrys giganticus	2.116655	VU	*Rana multidenticulata*	0.751171	LC
Liua shihi	1.648659	NT	*Rana kukunoris*	0.751171	LC
Paramesotriton hongkongensis	1.584364	NT	*Rana johnsi*	0.751171	LC
Paramesotriton caudopunctatus	1.584364	NT	*Rana dybowskii*	0.751171	LC
Glandirana tientaiensis	1.548759	NT	*Rana chensinensis*	0.751171	LC
Tylototriton taliangensis	1.503019	NT	*Rana chaochiaoensis*	0.751171	LC
Tylototriton shanjing	1.503019	NT	*Rana amurensis*	0.751171	LC
Tylototriton asperrimus	1.503019	NT	*Oreolalax xiangchengensis*	0.748632	LC
Pelophylax nigromaculatus	1.475288	NT	*Oreolalax popei*	0.748632	LC
Bufo tuberculatus	1.473438	NT	*Oreolalax nanjiangensis*	0.748632	DD
Leptobrachium ailaonicum	1.466054	NT	*Salamandrella keyserlingii*	0.741937	LC
Nanorana quadranus	1.451024	NT	*Onychodactylus fischeri*	0.741937	LC
Nanorana pleskei	1.451024	NT	*Amolops wuyiensis*	0.737599	LC
Nanorana arnoldi	1.451024	NT	*Amolops ricketti*	0.737599	LC
Nanorana annandalii	1.451024	NT	*Amolops monticola*	0.737599	LC
Oreolalax schmidti	1.441779	NT	*Amolops mengyangensis*	0.737599	LC
Oreolalax rugosus	1.441779	NT	*Amolops marmoratus*	0.737599	LC
Oreolalax lichuanensis	1.441779	NT	*Amolops mantzorum*	0.737599	LC
Amolops viridimaculatus	1.430746	NT	*Amolops granulosus*	0.737599	LC
Amolops lifanensis	1.430746	NT	*Amolops gerbillus*	0.737599	LC
Odorrana lungshengensis	1.428466	NT	*Amolops formosus*	0.737599	LC
Odorrana grahami	1.428466	NT	*Amolops chunganensis*	0.737599	LC

Species	EDGE	Status	Species	EDGE	Status
Rhacophorus taipeianus	1.427568	NT	*Odorrana versabilis*	0.735319	LC
Rhacophorus gongshanensis	1.427568	NT	*Odorrana tiannanensis*	0.735319	LC
Xenophrys mangshanensis	1.423508	NT	*Odorrana swinhoana*	0.735319	LC
Xenophrys binchuanensis	1.423508	NT	*Odorrana schmackeri*	0.735319	LC
Pachytriton labiatus	0.957341	LC	*Odorrana margaretae*	0.735319	LC
Pachytriton brevipes	0.957341	LC	*Odorrana graminea*	0.735319	DD
Cynops orientalis	0.957341	LC	*Odorrana exiliversabilis*	0.735319	LC
Cynops cyanurus	0.957341	LC	*Odorrana chloronota*	0.735319	LC
Zakerana teraiensis	0.929697	LC	*Odorrana andersonii*	0.735319	LC
Zakerana nepalensis	0.929697	LC	*Rhacophorus tuberculatus*	0.734421	DD
Occidozyga martensii	0.929697	LC	*Rhacophorus translineatus*	0.734421	DD
Occidozyga lima	0.929697	LC	*Rhacophorus suffry*	0.734421	LC
Fejervarya limnocharis	0.929697	LC	*Rhacophorus rhodopus*	0.734421	LC
Fejervarya cancrivora	0.929697	LC	*Rhacophorus omeimontis*	0.734421	LC
Raorchestes longchuanensis	0.927713	LC	*Rhacophorus moltrechti*	0.734421	LC
Raorchestes annandalii	0.927713	LC	*Rhacophorus maximus*	0.734421	LC
Liuixalus hainanus	0.927713	DD	*Rhacophorus hungfuensis*	0.734421	DD
Gracixalus gracilipes	0.927713	LC	*Rhacophorus feae*	0.734421	LC
Chiromantis vittatus	0.927713	LC	*Rhacophorus dugritei*	0.734421	LC
Chiromantis doriae	0.927713	LC	*Rhacophorus dennysi*	0.734421	LC
Pseudorana sangzhiensis	0.924053	DD	*Rhacophorus chenfui*	0.734421	LC
Paramesotriton chinensis	0.891217	LC	*Rhacophorus bipunctatus*	0.734421	LC
Duttaphrynus stomaticus	0.877271	LC	*Xenophrys wushanensis*	0.73036	LC
Duttaphrynus melanostictus	0.877271	LC	*Xenophrys wuliangshanensis*	0.73036	DD
Duttaphrynus himalayanus	0.877271	LC	*Xenophrys spinata*	0.73036	LC
Hoplobatrachus tigerinus	0.861655	LC	*Xenophrys shuichengensis*	0.73036	DD
Hoplobatrachus rugulosus	0.861655	LC	*Xenophrys shapingensis*	0.73036	LC
Hoplobatrachus crassus	0.861655	LC	*Xenophrys robusta*	0.73036	DD
Theloderma andersoni	0.859531	LC	*Xenophrys parva*	0.73036	LC
Theloderma albopunctata	0.859531	DD	*Xenophrys pachyproctus*	0.73036	DD
Polypedates mutus	0.859531	LC	*Xenophrys minor*	0.73036	LC
Polypedates megacephalus	0.859531	LC	*Xenophrys medogensis*	0.73036	DD
Polypedates leucomystax	0.859531	LC	*Xenophrys major*	0.73036	LC
Buergeria robusta	0.859531	LC	*Xenophrys kuatunensis*	0.73036	LC
Buergeria japonica	0.859531	LC	*Xenophrys jingdongensis*	0.73036	LC
Leptolalax pelodytoides	0.85719	LC	*Xenophrys glandulosa*	0.73036	LC
Leptolalax oshanensis	0.85719	LC	*Xenophrys boettgeri*	0.73036	LC
Leptolalax liui	0.85719	LC	*Uperodon globulosus*	0.730326	LC
Brachytarsophrys platyparietus	0.85719	LC	*Kalophrynus interlineatus*	0.730326	LC
Brachytarsophrys feae	0.85719	LC	*Calluella yunnanensis*	0.730326	LC
Brachytarsophrys chuannanensis	0.85719	DD	*Pseudepidalea raddei*	0.728029	LC
Glandirana emeljanovi	0.855612	LC	*Ingerophrynus macrotis*	0.728029	LC
Hynobius leechii	0.854415	LC	*Euphlyctis cyanophlyctis*	0.709877	LC
Kaloula verrucosa	0.844046	LC	*Philautus microdiscus*	0.707405	DD

Species	EDGE	Status	Species	EDGE	Status
Kaloula rugifera	0.844046	LC	*Ophryophryne microstoma*	0.704679	LC
Kaloula pulchra	0.844046	LC	*Lithobates catesbeianus*	0.70284	LC
Kaloula borealis	0.844046	LC	*Humerana humeralis*	0.70284	LC
Limnonectes laticeps	0.825815	LC	*Clinotarsus alticola*	0.70284	LC
Limnonectes kuhlii	0.825815	LC	*Bombina orientalis*	0.695309	LC
Limnonectes fujianensis	0.825815	LC			

***R* script for calculating different climatic-niche properties in the paper**

```
#Calculation of different climatic niche indices
#Please cite the following paper:
#Youhua Chen, Tania Escalante (2017)
#Correlates of ecological niche diversity and extinction risk of amphibians of China under climate change
#Australian Systematic Botany
###############################################################################

library(ape)
###############################################################################
#calculation of Evolutionary Distinctiveness Index
ED<-function(tree)
{
tips<-get.tipnames(tree) #obtain tip species names
node<-node.speciesnumber(tree) #obtain species number for internal nodes
nsp<-node$number
nns<-node$nodes
br<-tree.branches(tree)
na<-tree.names(tree)
#
values<-vector()
for(i in 1:length(tips))
{
#obtain the path from a tip to the root
thisp<-tip2root(tree,tips[i])
#deleting the root
thisp<-thisp[-length(thisp)]
#calculating the index
thisv<-vector()
thisn<-vector()
for(j in 1:length(thisp))
{
dii<-which(na==thisp[j])
thisv<-c(thisv,br[dii])
#
```

```
if(length(which(nns==thisp[j]))!=0)
{
id<-which(nns==thisp[j])
thisn<-c(thisn,nsp[id])
}else
{
thisn<-c(thisn,1)
}
}#j
#
values[i]<-sum(thisv/thisn)
}#i
return(list(species=tips,ED=values))
}#end


###########################################################################
###########################################################################
###########################################################################
#niche breath
#mat is the site-species matrix, thus its row is equal to that of env
#env is site-climate matrix
#coords is the site geographic matrix (the first column is latitude,
#the second column is longitude)
NB<-function(mat,env,coords)
{
spnum=dim(mat)[2]
env=scale(env) #standardized!
nbv=vector()
for(i in 1:spnum)
{
occ=which(mat[,i]==1)
if(length(occ)==1)
{
nb=0 #single-point distribution
}else
{
this=env[occ,]
#
nb=sum(apply(this,2,var))
}#
nbv=c(nbv,nb)
}#i
return(nbv)
}
```

```
##########################
#niche position
#NP
NP<-function(mat,env,coords)
{
spnum=dim(mat)[2]
env=scale(env) #standardized!
nbv=vector()
for(i in 1:spnum)
{
occ=which(mat[,i]==1)
if(length(occ)==1)
{
#single-point distribution
this=env[occ,]
}else
{
this=colMeans(env[occ,])
#
}#
nb=sum(this^2)
#######
nbv=c(nbv,nb)
}#i
return(nbv)
}

##########################
#niche connectivity
#NC
NC<-function(mat,env,coords)
{
spnum=dim(mat)[2]
env=scale(env) #standardized!
nbv=vector()
for(i in 1:spnum)
{
occ=which(mat[,i]==1)
if(length(occ)==1)
{
#single-point distribution
nb=0
}else
{
```

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```
this=coords[occ,]
dis=dist(this)
tr=vegan::spantree(dis) #construct spanning tree
nb=mean(tr$dist)
#
}#
nbv=c(nbv,nb)
}#i
return(nbv)
}#
#

##########################
#niche amount
#NA
Na<-function(mat,env,coords)
{
return(colSums(mat))
}

##########################
#niche occupancy
#NO
#occmat is the observed occurrence of species (before SDMs)
NO<-function(occmat,mat,env,coords)
{
return(colSums(occmat)/colSums(mat))
}

##########################
#niche packing
#NPK
NPK<-function(mat,env,coords)
{
spnum=dim(mat)[2]
env=scale(env) #standardized!
nbv=vector()
for(i in 1:spnum)
{
occ=which(mat[,i]==1)
if(length(occ)==1)
{
nb=0 #single-point distribution
}else
{
```

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```
this=env[occ,]
dis=as.matrix(dist(this))
#
nb=mean(apply(this,2,min))
}#
nbv=c(nbv,nb)
}#i
return(nbv)
}


##########################
#niche volume
#NV
NV<-function(mat,env,coords)
{
spnum=dim(mat)[2]
env=scale(env) #standardized!
nbv=vector()
for(i in 1:spnum)
{
occ=which(mat[,i]==1)
if(length(occ)<=5)
{
nb=0 #single-point distribution
}else
{
this=env[occ,]
nb=geometry::convhulln(this,options="FA")$vol #volume of the multi-dimensional volume
}#
nbv=c(nbv,nb)
}#i
return(nbv)
}


###########################
#find the edge from a presence/absence information of species over square sites
#spatial coordinates (lat and long) of the sites must be provided and the distance to adjacent cell
Edge.length<-function(occ,coords,dxy=1)
{
ids=which(occ==1)
ec=0 #edge count
#
for(i in 1:length(ids))
```

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```
{
lxy=coords[ids[i],]
up=down=left=right=lxy
up[2]=up[2]+dxy
down[2]=down[2]-dxy
left[1]=left[1]-dxy
right[1]=right[1]+dxy
#
di=which(coords[,1]==up[1] & coords[,2]==up[2])
if(length(di)>0)
{
if(occ[di]==0)
{
ec=ec+dxy #this edge is free
}
}
#
di=which(coords[,1]==down[1] & coords[,2]==down[2])
if(length(di)>0)
{
if(occ[di]==0)
{
ec=ec+dxy #this edge is free
}
}
#
di=which(coords[,1]==right[1] & coords[,2]==right[2])
if(length(di)>0)
{
if(occ[di]==0)
{
ec=ec+dxy #this edge is free
}
}
#
di=which(coords[,1]==left[1] & coords[,2]==left[2])
if(length(di)>0)
{
if(occ[di]==0)
{
ec=ec+dxy #this edge is free
}
}
#
}#i
```

```
#
return(ec)
}

##################
#Niche fractal dimension (NF)
NF<-function(mat,env,coords)
{
spnum=dim(mat)[2]
env=scale(env) #standardized!
nbv=vector()
for(i in 1:spnum)
{
occ=mat[,i]
ne=Edge.length(occ,coords,dxy=.5)
na=sum(occ)
#
fd=2*log(.25*ne+1e-10)/log(na+1e-10) #+1e-10 is to avoid zero denominator
#
nbv=c(nbv,fd)
}#i
return(nbv)
}




##################
#Niche spatial autocorrelation (NCO)
NCO<-function(mat,env,coords)
{
pc=princomp(env)$scores[,1]
#

}
#
```