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附录1 垂枝柏、小果垂枝柏和刺柏的采样信息

Appendix 1 Sampling information of *Juniperus recurva*, *J. coxii*, and *J. formosana*

物种 Species	居群 Populations	经度 Longitude (°E)	纬度 Latitude (°N)	海拔 Elevation (m)
垂枝柏 *J. coxii*	BZL	99.09	27.633	3,491
垂枝柏 *J. coxii*	GDT	99.414	27.188	3,335
垂枝柏 *J. coxii*	CGH	98.538	25.84	3,120
垂枝柏 *J. coxii*	MXGL	99.564	26.382	3,414
垂枝柏 *J. coxii*	PMYK	98.685	25.974	3,016
垂枝柏 *J. coxii*	XBS	99.501	26.459	3,379
垂枝柏 *J. coxii*	YBS	99.205	26.117	3,354
垂枝柏 *J. coxii*	YDC	99.622	26.274	2,743
垂枝柏 *J. coxii*	ZBS	99.049	25.746	3,228
垂枝柏 *J. coxii*	GYLC	98.315	25.365	2,081
垂枝柏 *J. coxii*	MGLC	98.539	25.617	1,896
垂枝柏 *J. coxii*	LZE	94.875	29.95	3,810
垂枝柏 *J. coxii*	MLN	94.23	29.097	3,137
垂枝柏 *J. coxii*	LZW	94.708	29.788	3,771
垂枝柏 *J. coxii*	MLS	94.244	29.032	3,212
垂枝柏 *J. coxii*	LZZR	93.361	28.677	3,365
垂枝柏 *J. coxii*	MT	95.845	29.466	2,605
小果垂枝柏 *J. recurva*	JLG	85.217	28.521	3,365
小果垂枝柏 *J. recurva*	NPL-W	85.344	28.115	3,445
小果垂枝柏 *J. recurva*	ZC	85.392	28.403	3,672
小果垂枝柏 *J. recurva*	NPL-E	85.576	28.208	3,888
小果垂枝柏 *J. recurva*	NLM	85.983	28.117	4,083
小果垂枝柏 *J. recurva*	CT-W	87.206	27.967	4,504
小果垂枝柏 *J. recurva*	CT-Z	87.283	27.96	4,748
小果垂枝柏 *J. recurva*	CT-E	87.473	27.917	3,324
小果垂枝柏 *J. recurva*	LZ-ZJ	93.361	28.678	3,198
刺柏 *J. formosana*	GZX	100.863	28.21	2,241

附录2 本研究使用的39个环境变量及其来源

Appendix 2 The 39 environmental variables used in this study

环境变量 Environmental factors	描述 Description	来源 Source
年平均气温 Annual mean temperature (bio_1)	年平均气温 Annual mean temperature [°C*10]	http://www.paleoclim.org/
平均昼夜温差 Mean diurnal range (bio_2)	平均昼夜温差 Mean diurnal range (Mean of monthly (max temp - min temp)) [°C]	
等温性 Isothermality (bio_3)	等温性 Isothermality [Bio_2/Bio_7]	
温度季节性 Temperature seasonality (bio_4)	温度季节性 Temperature seasonality [standard deviation*100]	
最暖月最高温 Max temperature of warmest month (bio_5)	最暖月最高温 Max temperature of warmest month [°C*10]	
最冷月最低温 Min temperature of coldest Month (bio_6)	最冷月最低温 Min temperature of coldest month [°C*10]	
气温年较差 Temperature annual range (bio_7)	气温年较差 Temperature annual range (BIO5-BIO6) [°C*10]	
最湿季平均温度 Mean temperature of wettest quarter (bio_8)	最湿季平均温度 Mean temperature of wettest quarter [°C*10]	
最干季平均温度 Mean temperature of driest quarter (bio_9)	最干季平均温度 Mean temperature of driest quarter [°C*10]	
最暖季平均温度 Mean temperature of warmest quarter (bio_10)	最暖季平均温度 Mean temperature of warmest quarter [°C*10]	
最冷季平均温度 Mean temperature of coldest quarter (bio_11)	最冷季平均温度 Mean temperature of coldest quarter [°C*10]	

年降水量 Annual precipitation (bio_12)	年降水量 Annual precipitation [mm/year]	
最湿月降水量 Precipitation of wettest month (bio_13)	最湿月降水量 Precipitation of wettest month [mm/month]	
最干月降水量 Precipitation of driest month (bio_14)	最干月降水量 Precipitation of driest month [mm/month]	
降水量变异系数 Precipitation seasonality (coefficient of variation) (bio_15)	降水量变异系数 Precipitation seasonality (coefficient of variation) [mm/month]	
最湿季降水量 Precipitation of wettest quarter (bio_16)	最湿季降水量 Precipitation of wettest quarter [mm/month]	
最干季降水量 Precipitation of driest quarter (bio_17)	最干季降水量 Precipitation of driest quarter [mm/quarter]	
最暖季降水量 Precipitation of warmest quarter (bio_18)	最暖季降水量 Precipitation of warmest quarter [mm/quarter]	
最冷季降水量 Precipitation of coldest Quarter (bio_19)	最冷季降水量 Precipitation of coldest quarter [mm/quarter]	
年潜在蒸散量 Annual potential evapotranspiration (annualPET)	年潜在蒸散量 Annual potential evapotranspiration: a measure of the ability of the atmosphere to remove water through evapotranspiration processes, given unlimited moisture [mm yr^{-1}]	http://envirem.github.io/
Thornthwaite干旱指数Thornthwaite aridity index (thornthwaitearidityindex)	Thornthwaite干旱指数 Thornthwaite aridity index: index of the degree of water deficit below water need a metric of relative wetness and aridity	
气候湿度指标 Climatic moisture index (climaticmoistureindex)	气候湿度指标 Climatic moisture index: a metric of relative wetness and aridity	
气温大陆度指数 Continentality (continentality)	气温大陆度指数 Continentality: average temp. of warmest month – average temp. of coldest month [°C]	
Emberger光热系数 Emberger's pluviothermic quotient (EmbergerQ)	Emberger光热系数 Emberger's pluviothermic quotient: a metric that was designed to differentiate among Mediterranean	
0°C 生长度日 Sum of mean monthly temperature for months with mean temperature greater than 0°C multiplied by number of days (Growingdegdays0)	0°C 生长度日 Sum of mean monthly temperature for months with mean temperature greater than 0°C multiplied by number of days	
5°C生长度日 Sum of mean monthly temperature for months with mean temperature greater than 5°C multiplied by number of days (Growingdegdays5)	5°C生长度日 Sum of mean monthly temperature for months with mean temperature greater than 5°C multiplied by number of days	
最冷月最高气温 Max temperature of the coldest month (Maxtempcoldestmonth)	最冷月最高气温 Max temperature of the coldest month [°C x 10]	
最冷月最低气温 Min temperature of the coldest month (Mintempwarmestmonth)	最冷月最低气温 Min temperature of the coldest month [°C x 10]	
平均气温大于10°C的月份数 Count of the number of months with mean temp greater than 10°C (Monthcountbytemp10)	平均气温大于 10°C 的月份数 Count of the number of months with mean temp greater than 10°C [months]	
最冷季度平均潜在蒸散量 Mean monthly potential evapotranspiration of coldest quarter (PETcoldestquarter)	最冷季度平均潜在蒸散量 Mean monthly potential evapotranspiration of coldest quarter [mm $month^{-1}$]	
最干旱季度平均潜在蒸散量Mean monthly potential evapotranspiration of driest quarter (PETdriestquarter)	最干旱季度平均潜在蒸散量 Mean monthly potential evapotranspiration of driest quarter [mm $month^{-1}$]	
潜在蒸散量的月度变化 Monthly variability in potential evapotranspiration (PETseasonality)	潜在蒸散量的月度变化 Monthly variability in potential evapotranspiration [mm $month^{-1}$]	
最热季度的月平均蒸散量 Mean monthly potential evapotranspiration of warmest quarter (PETwarmestquarter)	最热季度的月平均蒸散量 Mean monthly potential evapotranspiration of warmest quarter [mm $month^{-1}$]	
最湿季度的月平均蒸散量 Mean monthly potential evapotranspiration of wettest quarter (PETwettestquarter)	最湿季度的月平均蒸散量 Mean monthly potential evapotranspiration of wettest quarter [mm $month^{-1}$]	
补偿热度指数 Compensated thermicity index (Thermlnd)	补偿热度指数 Compensated thermicity index: sum of mean annual temp, min.temp.of coldest month, max.temp.of the coldest month, x10, with compensations for better comparability across the globe [°C]	
地形粗糙度指数 Terrain roughness index (Tri)	地形粗糙度指数 Terrain roughness index	
SAGA-GIS 地形湿润指数 SAGA-GIS topographic wetness index (topo wet)	SAGA-GIS 地形湿润指数 SAGA-GIS topographic wetness index	
年平均太阳辐射 Annual mean solar radiation (sard)	年平均太阳辐射Annual Mean Solar Radiation	https://worldclim.org/
海拔 Elevation (elev)	海拔 Elevation	https://www.gscloud.cn/

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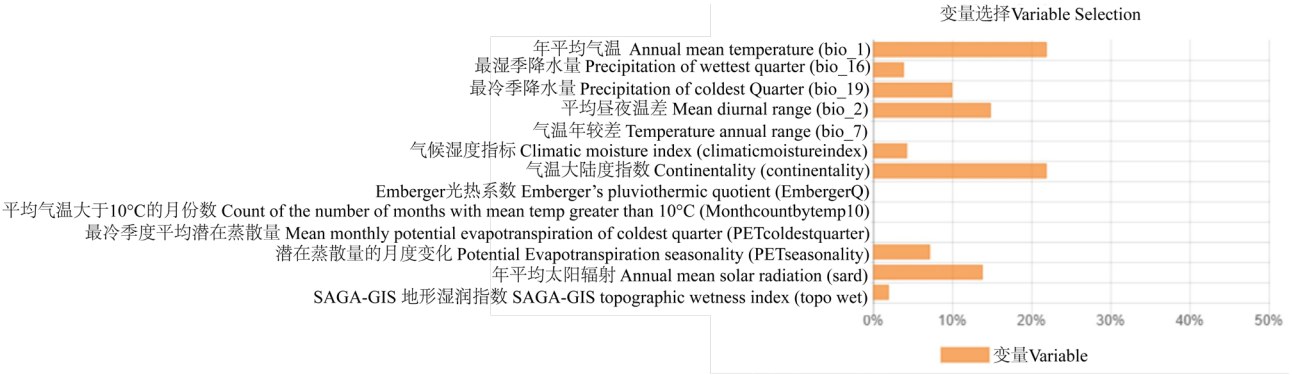
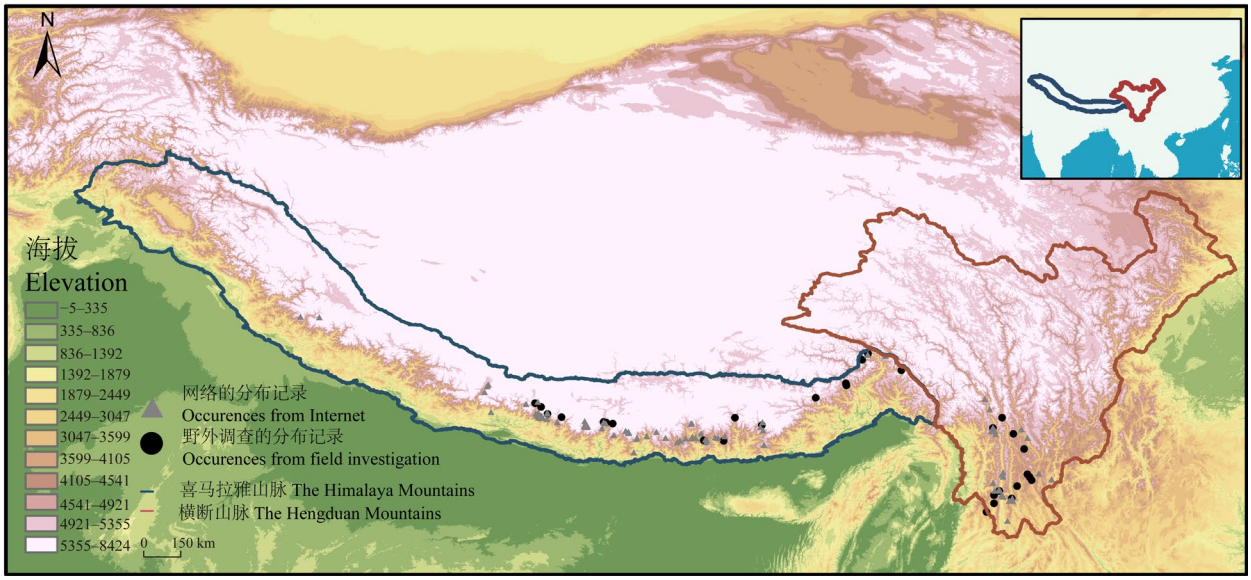
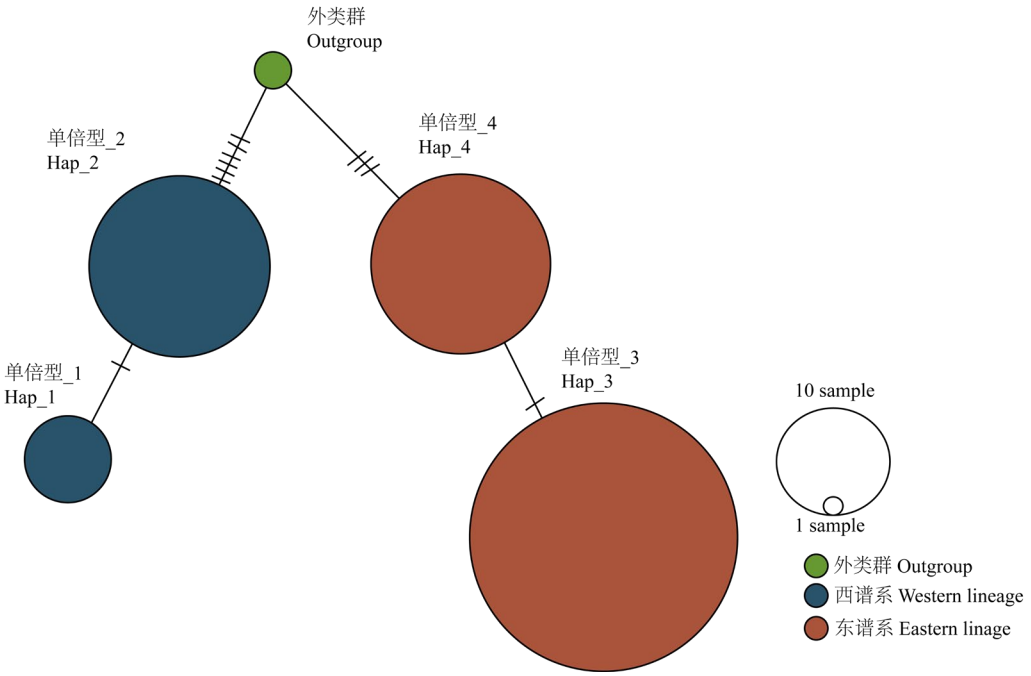
https://www.biodiversity-science.net/CN/10.17520/biods.2025373



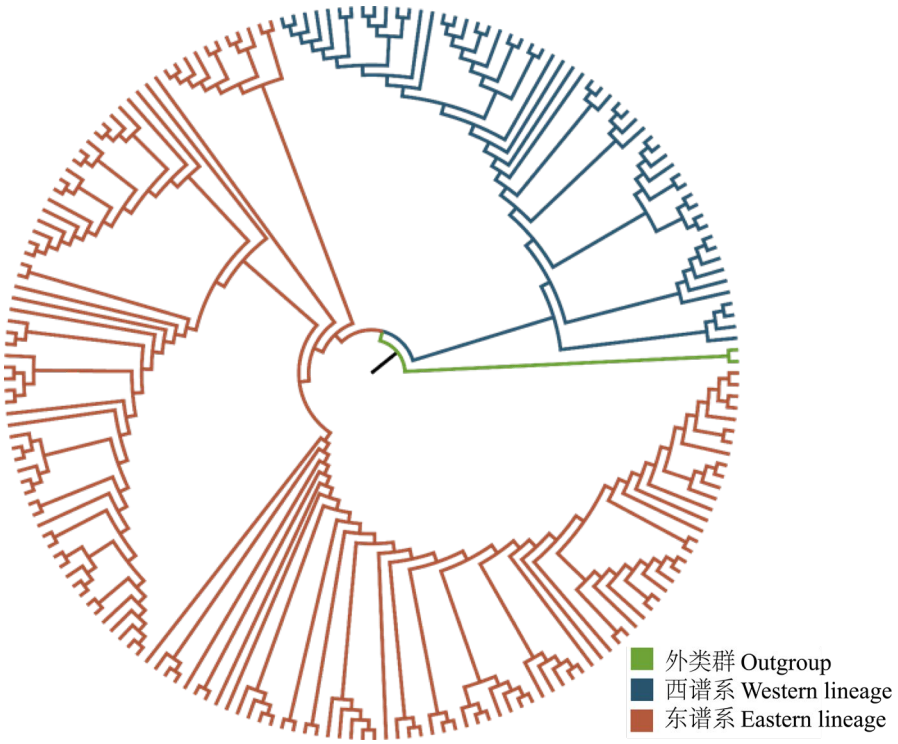
附录 3 SDMtune 选取垂枝柏和小果垂枝柏生态位模型环境变量。横坐标为 varSel 函数计算的环境变量的贡献百分比。
Appendix 3 SDMtune selection of environmental variables for ecological niche model of *Juniperus recurva* and *J. coxii*. The x-axis represents the contribution percentage of environmental variables calculated by the varSel function.



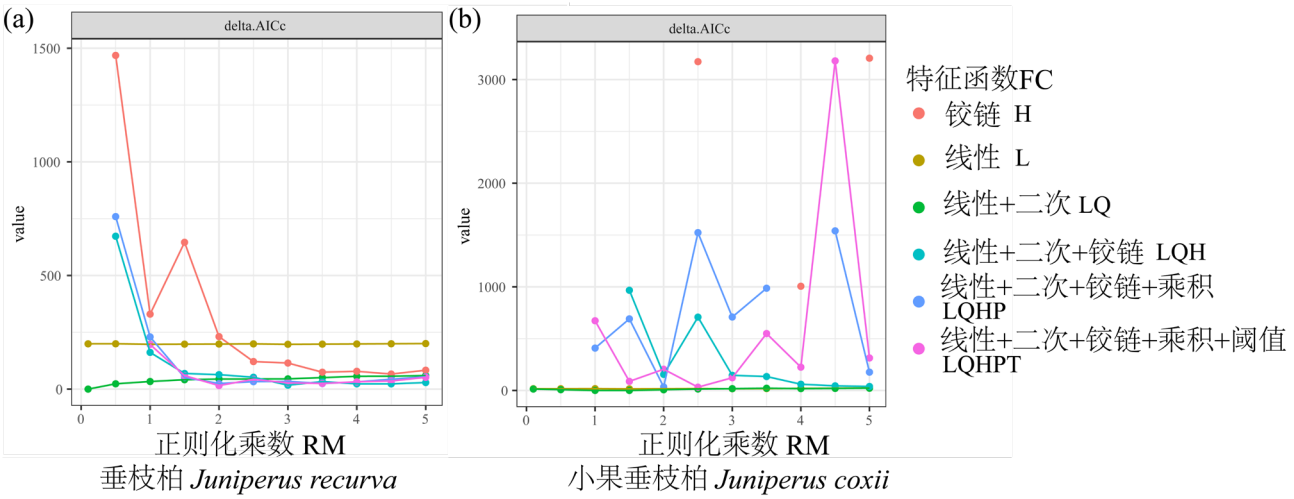
附录 4 垂枝柏复合体的地理分布记录。灰色三角形为网络记录, 黑色圆形为田野调查记录。
Appendix 3 Geographical distribution map of *Juniperus recurva* complex. Gray triangles represent online records; black circles indicate field investigation.



附录 5 基于SNP数据集II进行单倍型网络分析。蓝色为西谱系, 棕色为东谱系, 绿色为外类群。圆圈大小代表个体数目。
Appendix 4 Haplotype network analysis based on SNP dataset Ⅱ. Blue represents the western lineage, brown represents the eastern lineage, and green represents the outgroup. The size of the circle represents the number of individuals.

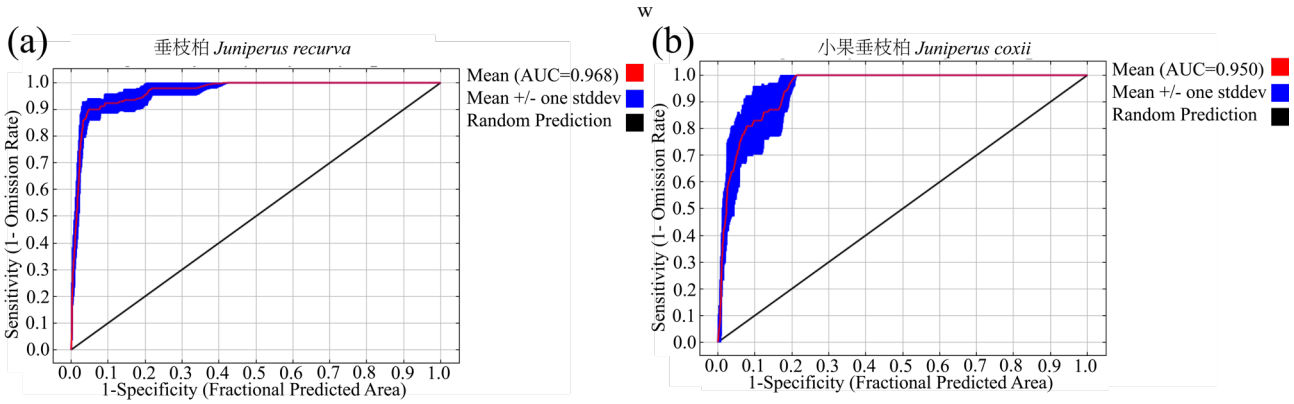


附录 6 基于叶绿体基因组进行的系统发育分析。蓝色为西谱系, 棕色为东谱系, 绿色为外类群。
Appendix 5 Phylogenetic analysis based on the chloroplast genome. Blue represents the western lineage, brown represents the eastern lineage, and green represents the outgroup.



附录 7 ENMeval 对垂枝柏(a)和小果垂枝柏(b)的MaxEnt模型参数优化。横轴为MaxEnt模型的正则化乘数RM, 纵轴为模型的delta AICc值, 不同颜色代表MaxEnt模型的特征函数FC。

Appendix 7 ENMeval parameter optimization for *Juniperus recurva* (a) and *J. coxii* (b) MaxEnt Models. The x-axis represents the regularization multiplier (RM) of the MaxEnt model, the y-axis represents the delta AICc values of the model, and different colors represent the feature classes (FC) of the MaxEnt model.



附录 8 垂枝柏(a)和小果垂枝柏(b)生态位模拟AUC值

Appendix 8 Ecological niche model AUC of *Juniperus recurva* (a) and *J. coxii* (b)