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Quantitative morphometric assessment of *Johnius dussumieri* (Cuvier, 1830) off Ponnani, Southeastern Arabian Sea using bivariate and multivariate approach

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Abstract
This study investigates the variation and interdependence among 20 morphometric characters of the Sciaenid fish *Johnius dussumieri* from Ponnani, on the southwest coast of India. Pearson correlation analysis revealed strong positive correlations between most of the characters, indicating coordinated growth. Simple linear regression analyses further confirmed significant linear relationships between total length and the remaining characters. Standard length exhibited the strongest linear relationship with total length (R^2 = 0.976) and the highest growth rate (b = 0.886). In contrast, caudal fin length showed the weakest relationship (R^2=0.312), and the lowest growth rate was recorded for second anal spine length (b = 0.081). A single principal component, PC1, was extracted, accounting for 80.58% of the total variance, and primarily representing overall body size and shape. These findings reflect strong morphometric integration and provide a valuable baseline for future stock assessment and population studies of *J. dussumieri*, as no existing studies on the species' morphometrics are available.

Keywords: Sciaenids, *Johnius dussumieri*, morphometry, correlation, regression

1. Introduction

Johnius dussumieri (Cuvier 1830), commonly known as the sin croaker, is a small fish that is a significant species in the Sciaenid fishery along the coasts of India [1, 2, 3, 4]. Various aspects of the species, including fishery, biology, stock assessment, and otolith morphology, have been studied along the Indian coast [5]. Morphometric characters, representing quantitative measurements of body parts, are useful in differentiating closely related genera, species, and populations [6]. Analysing morphometric characters from a large sample size allows more precise and reliable identification of species-specific traits in a given area [7]. Bivariate and multivariate analyses of morphometric characters offer insights into growth patterns and the interdependence of growth in different body parts [8]. Furthermore, statistical analysis of these characters enables comparisons within and among species from different geographical regions, thereby enhancing the understanding of intraspecific variation and stock structure [9]. The present study employs bivariate and multivariate statistical approaches to assess the morphometric relationships in *J. dussumieri* collected from the Ponnani coast, southeastern Arabian Sea.

2. Materials and Methods

Samples of *J. dussumieri* were collected from landings at Ponnani harbour, Kerala, between September 2023 and February 2024. In the laboratory, specimens were identified following the standard methods in fish taxonomy [10, 11, 12]. A total of 20 morphometric characters (Figure 1) and 12 meristic characters were recorded from 100 specimens. Total length and standard length were measured using a scale with an accuracy of 0.1 cm, while other morphometric measurements were taken using a digital vernier caliper (Mitutoyo, model no CD-6ASX) with a precision of 0.01mm.

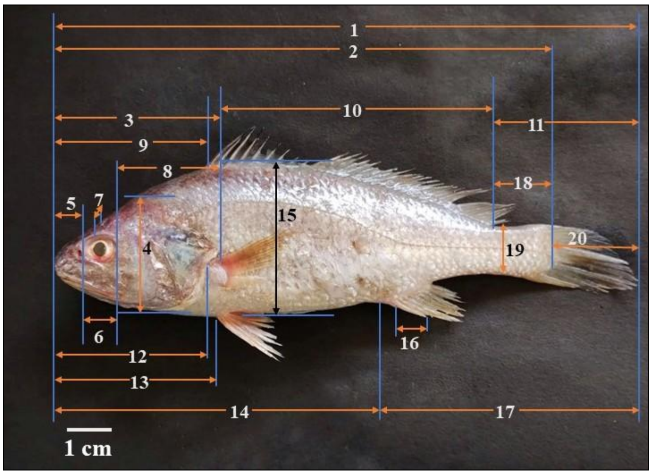

Fig 1: Morphometric characters of *J. dussumieri:* 1. Total Length (TL), 2. Standard Length (SL), 3. Head Length (HL), 4. Head Depth (HD), 5. Snout Length (SnL), 6. Eye Diameter (ED), 7. Interorbital Distance (IOD), 8. Post Orbital Head Length (POHL), 9. Pre Dorsal Length (PDL), 10. Dorsal Fin Base Length (DFBL), 11. Post Dorsal Length (PoDL) 12. Pre-Pectoral Length (PPL), 13. Pre-Pelvic Length (PPlL), 14. Pre-Anal Length (PAL), 15. Body Depth (BD), 16. Second Anal Spine Length (SASL), 17. Post Anal Length (PoAL), 18. Caudal Peduncle Length (CPL), 19. Caudal Peduncle Depth (CPD), 20. Caudal Fin Length (CFL)

The univariate (descriptives), bivariate (Pearson correlation and simple linear regression), and multivariate (Principal Component Analysis- PCA) analyses were conducted using IBM SPSS Statistics (version 30). Total length and head length were used as the independent variables to analyze their relationships with other morphometric characters in regression analysis. To explore the underlying structure and interdependence of morphometric traits in the population, PCA was applied to the 20 morphometric characters. The suitability of the dataset for PCA was first assessed through the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity. Components with Eigenvalues greater than 1 were retained following the Kaiser criterion [13]. The communalities were examined to determine the proportion of variance in each trait that was explained by the extracted components. The scree plot was evaluated to visualize the number of components to retain. The unrotated component matrix was used to identify morphometric characters that contributed most strongly to each principal component.

3. Results

The descriptive statistics of the morphometric characters of *J. dussumieri* are presented in Table 1. The CV (%) for the 20 morphometric characters showed generally low values, ranging from 9.57% for caudal fin length to 16.04% for snout length. The skewness values for all morphometric characters ranged from -0.12 to 0.54, indicating that the distributions were approximately symmetrical with a slight positive skew. The kurtosis values ranged from 0.11 to -0.82, suggesting that the distributions were mildly platykurtic, characterized by slightly flatter peaks and lighter tails compared to a normal distribution. The low skewness and mild platykurtosis observed across the morphometric traits indicate acceptable normality, validating the use of parametric statistical methods, such as Pearson correlation and linear regression.

Table 1: Descriptive statistics of various morphometric characters of *J. dussumieri*

Traits	Mean± SD	Std. error	Range (Min-max)	CV (%)	Skewness*	Kurtosis**
TL	133.01±15.17	1.56	102-170	11.40	0.30	-0.52
SL	111.73±13.61	1.40	84-148	12.18	0.32	-0.42
HL	34.27±4.58	0.47	25.53-46.70	13.37	0.44	-0.43
SNL	7.68±1.23	0.12	4.49-10.80	16.04	0.08	-0.35
HD	27.61±3.29	0.34	20.50-35.61	11.93	0.33	-0.39
ED	7.91±0.88	0.09	6.21-9.82	11.20	0.29	-0.79
IOD	11.14±1.33	0.13	8.55-14.75	11.95	0.34	-0.25
POHL	20.11±3.00	0.31	15.01-26.49	14.93	0.42	-0.82
PDL	36.62±4.60	0.47	28.59-48.59	12.58	0.42	-0.51
DFBL	65.81±7.97	0.82	49.21-85.34	12.12	0.14	-0.43
PoDL	37.65±4.13	0.42	30.19-48.93	10.97	0.42	-0.28
PPL	34.01±4.29	0.44	26.44-46.01	12.61	0.54	-0.10
PPlL	35.87±4.46	0.46	26.99-47.50	12.45	0.40	-0.26
PAL	73.32±9.64	0.99	57.31-98.92	13.15	0.49	-0.22
BD	31.59±4.12	0.42	23.34-40.68	13.05	0.17	-0.81
PoAL	9.15±1.05	0.10	6.17-11.61	11.50	0.14	-0.33
SASL	50.63±5.32	0.54	40.97-64.25	10.51	0.44	-0.36
CPL	15.38±2.34	0.24	10.14-22.64	15.21	0.34	0.11
CPD	9.89±1.43	0.14	6.25-13.40	14.53	-0.12	-0.38
CFL	23.00±2.20	0.22	18.17-28.58	9.57	0.11	-0.32

* Std. error 0.24; ** Std. error 0.49

The meristic characters of *J. dussumieri* (Table 2) exhibited limited variation, aligning with the species-specific range. Some of the meristic characters showed some variation, including dorsal fin rays (CV=4.01%), anal fin rays (CV=6.53%), pectoral fin rays (CV=5.5%), caudal fin rays (CV%=3.48%), gill rakers on lower limb (CV=5.05%), and gas bladder appendages on both left and right sides (CV=4.6%).

Table 2: Descriptive statistics of meristic characters of *J. dussumieri*

Meristic characters	Min	Max	Mean± SD	SE	CV%
Spines on the 1st part of the dorsal fin	10	10	10±0	0	0
Spines on the 2nd part of the dorsal fin	1	1	1±0	0	0
Rays on the 2nd part of the dorsal fin	25	30	27.14±1.09	0.11	4.01
Spines on the anal fin	2	2	2±0	0	0
Rays on the anal fin	7	8	7.35±0.48	0.04	6.53
Pectoral fin rays	15	19	16.89±0.93	0.09	5.5
Caudal fin rays	16	19	17.22±0.6	0.06	3.48
Gill rakers upper limb	8	8	8±0	0	0
Gill rakers middle	1	1	1±0	0	0
Gill rakers lower limb	11	15	12.46±0.63	0.06	5.05
Gas bladder appendages on the left side	11	13	12.15±0.56	0.05	4.6
Gas bladder appendages on the right side	11	13	12.15±0.56	0.05	4.6

The strong and significant positive correlations observed among most of the morphometric characters (r>0.5) suggest a high degree of interdependence (Table 3). This supports the suitability of employing simple linear regression models to establish predictive relationships between individual morphometric characters and standard reference measures. Total length and head length exhibit high positive correlations with most morphometric characters (r = 0.7 to 0.9), indicating that they can be used as independent variables (standard reference measures) for simple linear regression analysis of morphometric characters. The highest growth rate with total length was observed for the standard length (b value is 0.886), followed by pre-anal length (0.618), dorsal fin base length (0.501), and post-anal length (0.325) (Table 4). Low growth rates with the total length were observed for second anal spine length (0.039), eye diameter (0.046), snout length (0.067), inter-orbital distance (0.075), caudal peduncle depth (0.081), and caudal fin length (0.081). The regression models demonstrated statistically significant linear relationships with TL, with coefficients of determination (R^2) ranging from 0.312 to 0.976. The strongest predictive relationships were observed between TL and standard length (R^2=0.976), followed by pre anal length (R^2=0.946), pre-pectoral length and head length (R^2=0.922 each), and dorsal fin base length (R^2=0.909). These high R^2 values indicate that variations in these dependent morphometric traits can be largely explained by total length, confirming their strong linear dependence. Other morphometric traits also exhibited good regression fits with total length, such as pre-dorsal length (R^2=0.890), pre-pelvic length (R^2=0.905), body depth (R^2=0.847), and post anal length (R^2=0.860). In contrast, relatively low R^2 values were found for second anal spine length (0.324), caudal fin length (0.312), caudal peduncle length (0.569), and eye diameter (0.607), suggesting weaker linear dependence on TL.

A subset of five head-related morphometric traits- Snout length, Eye diameter, Interorbital distance, post-orbital head length, and head depth – was regressed against HL to evaluate regional allometry within the head. The results revealed a statistically significant positive linear relationships in all cases, with R^2 values ranging from 0.628 to 0.912 (Table 5). The strongest association was found between HL and post orbital head length (R^2=0.912), similarly head depth (R^2=0.850) and interorbital distance (R^2=0.782) also showed high predictive strength and high correlation coefficients (r=0.955, 0.922, and 0.884, respectively). Moderate regression fits were observed for snout length (R^2 = 0.745) and Eye diameter (R^2 = 0.628), although both still indicated significant positive relationships (r values are 0.863 and 0.793, respectively).

Table 3: Correlation matrix of various morphometric characters of *J. dussumieri* (all correlations at significance 0.01)

	TL	SL	HL	SNL	HD	ED	IOD	POHL	PDL	DFbL	PoDL	PPL	PPlL	PAL	BD	SASL	PoAL	CPL	CPD	CFL
TL	1	.988	.960	.819	.926	.779	.858	.900	.944	.954	.875	.960	.951	.972	.920	.569	.927	.754	.857	.559
SL	-	1	.962	.812	.923	.789	.861	.902	.946	.955	.850	.957	.956	.975	.917	.575	.914	.765	.863	.520
HL	-	-	1	.863	.922	.793	.884	.955	.950	.935	.828	.972	.966	.951	.919	.550	.887	.725	.815	.491
SNL	-	-	-	1	.803	.712	.789	.845	.832	.805	.700	.841	.849	.816	.824	.460	.767	.551	.730	.436
HD	-	-	-	-	1	.730	.808	.872	.917	.899	.815	.905	.917	.921	.904	.540	.879	.724	.818	.493
ED	-	-	-	-	-	1	.749	.732	.797	.765	.659	.873	.789	.788	.750	.427	.730	.618	.718	.387
IOD	-	-	-	-	-	-	1	.835	.883	.861	.730	.900	.879	.857	.837	.415	.799	.664	.717	.379
POHL	-	-	-	-	-	-	-	1	.903	.873	.754	.924	.913	.889	.858	.477	.831	.629	.746	.452
PDL	-	-	-	-	-	-	-	-	1	.932	.812	.950	.955	.946	.906	.533	.892	.750	.813	.455
DFbL	-	-	-	-	-	-	-	-	-	1	.819	.929	.928	.937	.903	.579	.875	.773	.878	.478
PoDL	-	-	-	-	-	-	-	-	-	-	1	.839	.809	.838	.801	.479	.904	.731	.766	.754
PPL	-	-	-	-	-	-	-	-	-	-	-	1	.968	.956	.918	.520	.890	.744	.807	.513
PPlL	-	-	-	-	-	-	-	-	-	-	-	-	1	.954	.916	.526	.886	.742	.830	.463
PAL	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.914	.566	.905	.754	.848	.532
BD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.523	.849	.744	.838	.518
SASL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.550	.457	.541	.392
PoAL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.729	.798	.676
CPL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.730	.421
CPD	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.484
CFL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Table 4: Correlation and linear regression of various morphometric characters with total length

Morphometric characters	r (Pearson)	R^2 (Regression)	Regression equation (Y= a + bX)
Standard length	0.988	0.976	Y=-6.1+0.886X
Head length	0.960	0.922	Y=-4.307+0.29X
Snout length	0.819	0.671	Y= -1.172+0.067X
Head depth	0.926	0.858	Y=0.846+0.201X
Eye diameter	0.779	0.607	Y=1.861+0.046X
Interorbital Distance	0.858	0.736	Y=1.130+0.075X
Post-orbital Head Length	0.900	0.811	Y=-3.597+0.178X
Pre-dorsal Length	0.944	0.890	Y=-1.490+0.287X
Dorsal fin base length	0.954	0.909	Y=-0.852+0.501X
Post-dorsal length	0.875	0.766	Y= 5.948+0.238X
Pre-pectoral length	0.960	0.922	Y=-2.098+0.272X
Pre-pelvic length	0.951	0.905	Y=-1.371+0.280X
Pre-anal length	0.973	0.946	Y=-8.885+0.618X
Body depth	0.920	0.847	Y=-1.666+0.250X
Post-anal length	0.927	0.860	Y=7.369+0.325X
Second anal spine length	0.569	0.324	Y=3.925+0.039X
Caudal peduncle length	0.754	0.569	Y=-0.090+0.116X
Caudal peduncle depth	0.857	0.735	Y=-0.910+0.081X
Caudal fin length	0.559	0.312	Y=12.217+0.081X

Table 5: Correlation and linear regression of various morphometric characters with head length

Morphometric characters	r (Pearson)	R^2 (Regression)	Regression equation (Y= a + bX)
Snout length	0.863	0.745	Y=-0.273+0.232X
Eye diameter	0.793	0.628	Y=2.661+0.153X
Inter orbital distance	0.884	0.782	Y=2.341+0.257X
Post-orbital head length	0.955	0.912	Y=-1.344+0.626X
Head depth	0.922	0.850	Y=4.892+0.663X

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.966, indicating that the data were highly suitable for Principal Component analysis. Bartlett's test of sphericity was highly significant (χ^2 =3477, df = 190, p<0.001), indicating that the variables are significantly intercorrelated, thus suitable for principal component analysis. Principal component analysis (PCA) of 20 morphometric measurements extracted a single dominant component (PC1) with an eigenvalue of 16.117, accounting for 80.58% of variance. The Scree plot (Figure 2) showed a clear "elbow" after the first component, confirming that only PC1 should be retained for further analysis. The component matrix from PCA showed that the majority of morphometric variables loaded strongly on the first principal component, with loadings ranging from 0.572 to 0.983 (Figure 3). Most morphometric traits had strong positive loadings on PC1, including total length (0.983), standard length (0.981), head length (0.977), pre-anal length (0.975), pre-pectoral length (0.974), pre-pelvic length (0.971), and pre-dorsal length (0.965), indicating that PC1 represents overall body size. Traits such as second anal spine length and caudal fin length exhibited lower loadings, suggesting a relatively weaker association with general size. The extracted communalities were generally high (mostly above 0.85), indicating that the principal component effectively accounted for the variance in most morphometric characters. A few traits, such as caudal fin length, exhibited lower communalities, indicating that they contributed less to overall variation in body size.

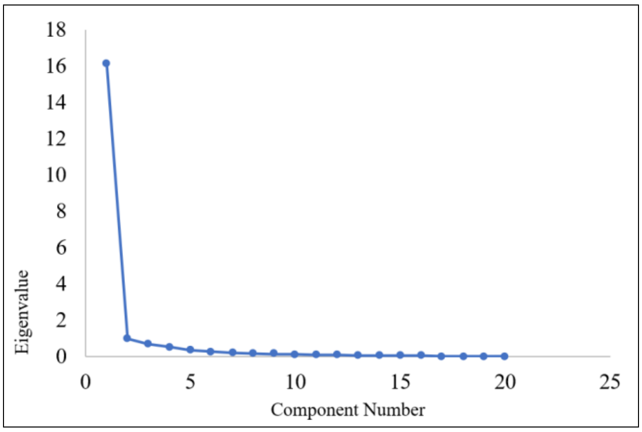

Fig 2: Scree plot showing the eigenvalues of the principal components derived from the morphometric characters of *Johnius dussumieri*. The plot illustrates that only the first principal component has an eigenvalue greater than 1, indicating it explains most of the variance

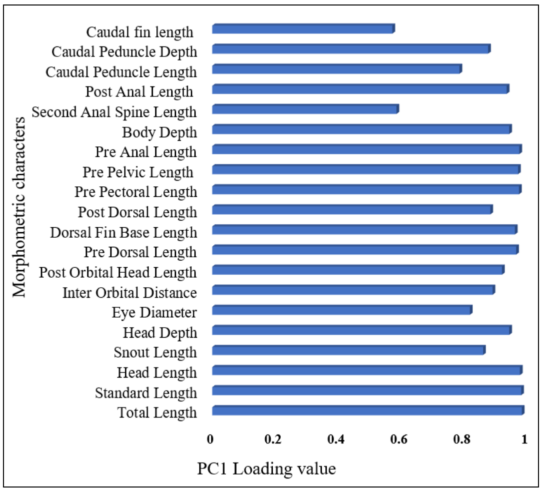

Fig 3: PC1 loading values of morphometric traits in *J. dussumieri*, reflecting contributions to overall size variation

4. Discussion

The present study provides a comprehensive baseline of the morphometric characteristics of *J. dussumieri* from the Ponnani coast, in the southeastern Arabian Sea. Although no prior morphometric studies exist specifically on this species, the findings offer valuable insights for future taxonomic assessments and stock structure studies. The CV% values of morphometric characters (9.57% to 16.04%) indicate low to moderate variability within the population, suggesting that most body measurements were relatively consistent across individuals, and reflecting a uniform body form within the population. The slightly higher variability in snout length indicates the influence of individual or environmental differences on it. Study on *Otolithoides pama* from Hoogly-Matlah estuarine system, West Bengal reported CV% values ranged between 16.15% to 22.63%, and in *O. cuvieri* from Ratnagiri waters (Sandhya et al, 2015) ranged from 16.12% to 27.65% with many traits showing variability of more than 20% [9, 14]. Most of the CV% of morphometric traits in *Chrysochir aurea* from the West Bengal coast were observed to be more than 20% with that of snout length and post-orbital length being 47.16% and 44.35% respectively [15]. The CV% among meristic characters in the present study showed relatively low variability, indicating overall consistency within the population. The constant number of fin spines and the single gill raker observed at the junction of upper and lower limbs are features commonly observed in many Sciaenids [16].

The present study shows good and positive correlations of morphometric characters with head length and total length, with most of them showing very high correlations. Similar findings have been reported in morphometric studies conducted on various other Sciaenid species. The highest correlation was observed between total length and standard length in the present study, as observed in many earlier studies. Studies on *Otolithoides biauritus*, and a biometric study on *Otolithes cuvieri*, *Johnieops vogleri*, and *Johnius macrorhynus* from Bombay waters represent earlier studies on the interdependence of morphometric characters in Sciaenids in India [7, 17]. The study on *O. biauritus* revealed high correlation among the compared characters (r values ranged from 0.898 to 0.996), of which anal length with total length showed the highest, snout length with head length (r=0.898) showed the minimum correlation [7]. For *O. cuvieri*, the correlation coefficient of morphometric characters with total length ranged from 0.485 (pre-ventral length) to 0.992 (standard length), and with head length it ranged from 0.661 (snout length) to 0.888 (body depth) [17]. The coefficient of correlation with total length ranged from 0.895 (pre-dorsal length) to 0.974 (pre-anal length), and with head length ranged from 0.518 (eye diameter) to 0.935 (body depth) in *J. vogleri* [17]. In *J. macrorhynus*, only a few characters showed good correlations with total length, which are standard length (0.974), pre-ventral length (0.815), and pre-anal length (0.801) [17]. Very high positive correlations between various morphometric characters and total length were reported in *O. cuvieri* from Ratnagiri waters, Maharashtra, with the strongest relationship with standard length (r=0.996) [14]. Morphometric studies conducted in *Chrysochir aurea*, from West Bengal, reported correlation coefficient values ranging from 0.679 to 0.994, indicating a high degree of positive (r>0.5) and significant correlations [15]. The study reported that standard length had the fastest growth rate (b=0.879) with total length, and the second anal spine had the slowest (b=0.039). Their study reported that standard length (r=0.994), pre-anal length (r=0.991), and post-pectoral length (r=0.990) showed the highest three correlations with total length, and caudal fin length showed the minimum (r=0.845), exactly similar to the present study. In their study, post-orbital length showed the highest correlation coefficient (0.984), and eye diameter showed the minimum (0.679), with head length similar to the present study.

The b value of simple linear regression analysis in the present study suggests that standard length (0.886) has the highest growth rate, followed by pre-anal length (0.618), with total length and second anal spine length (0.039) having the lowest. The highest growth rate for standard length (0.834), followed by pre-anal length (0.627), was previously observed in *O. pama* [9]. The highest growth rate was observed for standard length (0.879) and the lowest for second anal spine length (0.039) in *C. aurea* [15]. The highest growth rate was observed for standard length (0.879), followed by pre-anal length in *O. cuvieri*, and the lowest growth rate was for caudal peduncle depth (0.087) [14].

The high loadings of most morphometric traits on PC1 indicate that overall body size is the primary source of variation in *J. dussumieri* from Ponnani waters. This suggests strong morphometric integration within the population, reflecting uniform growth patterns. In contrast, traits like second anal spine length and caudal fin length had lower loadings, which may imply a higher degree of independent variation, potentially related to functional or ecological adaptations rather than size alone.

5. Conclusion

The present study demonstrates a high degree of morphometric integration in *Johnius dussumieri* from the southwest coast of India, with strong positive correlations and significant linear relationships among the measured characters. The dominance of a single principal component representing overall body form suggests a coordinated growth pattern within the population. These baseline morphometric findings can serve as a reference for future stock structure analysis, comparative studies, and resource management strategies for *J. dussumieri*, especially given the lack of prior morphometric research on this species.

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