

RESEARCH ARTICLE

Analysis of the population structure and physiological status differences of yangtze finless porpoises (*Neophocaena asiaeorientalis*) across habitats in Poyang lake

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Data availability statement: All relevant data are within the paper and its [Supporting Information](#) files. Raw data are available from the resource conservation department of Jiangxi Provincial Aquatic Biology Protection

Abstract

To investigate the physiological status of Yangtze finless porpoises (YFPs) in Poyang Lake and assess health conditions across different habitats at a mesoscale geographical level, physical examination data from 25 individuals were collected from two habitats: Piaotou (PT, 19 individuals), Jinxi Lake (JX, 6 individuals). Independent samples t-test and Mann-Whitney U test were used to compare blood parameters between PT and JX population. Robust M-estimation was applied to conduct stratified tests on the independent effects of factors. Robust PCA was used to characterize the overall physiological differences between the two habitats. Using the ranges of healthy YFPs blood parameters as the reference group, Games-Howell test was used for multiple group comparisons. Results revealed significant differences in physiological status between YFPs inhabiting Piaotou and Jinxi Lake. Piaotou population exhibit better physiological status, characterized by higher oxygen-carrying capacity, nutritional status, and metabolic activity levels, while those in Jinxi Lake showed enhanced coagulation function or inflammatory responses. In hematological parameters, the PT population showed significantly higher red blood cell-related indices than the JX's. The JX population exhibited higher platelet-related parameters and extremely low Eosinophil counts and percentages. More parameters in the JX population differed significantly from the range of healthy physiological indicators, with Monocyte count and percentage, and Plateletcrit exceeding normal physiological ranges. For blood biochemical parameters, Aspartate amino Transferase and Triglyceride in the PT population, and Alkaline Phosphatase and Triglyceride in the JX population exceeded reference ranges. This study revealed significant physiological differences among YFPs inhabiting different habitats within the same lake system, indicating that the Piaotou population can serve as high-quality germplasm

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resources, while the Jinxi Lake population shows certain health risks in their physiological status.

Introduction

The Yangtze finless porpoise (*Neophocaena asiaeorientalis*, YFP) is an endemic freshwater cetacean species unique to China and represents one of the world's most critically endangered small toothed whales [1], with current estimates suggesting approximately 1,249 individuals remain as of the 2022 basin-wide survey [2]. This species is exclusively distributed in the middle and lower reaches of the Yangtze River mainstream, as well as in the two major connected lakes—Poyang Lake and Dongting Lake—and their associated tributaries [2,3].

Poyang Lake, as China's largest freshwater lake, serves as the most important habitat for YFP, supporting approximately 450 individuals, making it a critical area for species conservation [4,5]. Subject to the combined influence of riverine inflows and Yangtze River floods, Poyang Lake exhibits pronounced seasonal variations in water level [6]. Historical sand mining activities have left numerous pits of varying sizes across the lakebed, creating a complex underwater topography. Altered precipitation patterns, extreme weather events, and temperature fluctuations affect lake hydrology, prey availability, and overall habitat quality [7,8]. The complex hydrological dynamics and habitat characteristics of Poyang Lake significantly influence population distribution patterns [9]. Long-term acoustic surveys and visual monitoring of the YFP in Poyang Lake have revealed the species distribution and migration patterns across varying water levels. Owing to the great challenges inherent in wild aquatic animal surveys, our understanding of the physiological health of its wild populations remains very limited.

Physiological assessment is crucial for understanding how endangered species respond to environmental changes and identifying factors constraining population growth [10,11]. For cetaceans, physical examinations, hematological and biochemical parameters serve as key indicators of individual and population health, reflecting individual variation as well as metabolic, nutritional, and immunological statuses, and are thus widely applied in health assessment and disease diagnosis for various marine mammals [10–13]. Previous studies have demonstrated that hematological and biochemical parameters in cetaceans are influenced by individual nutritional health, reproductive cycles, fishery resources, and habitat utilization [14–16]. In cetaceans such as the common bottlenose dolphin (*Tursiops truncatus*), beluga whale (*Delphinapterus leucas*), pantropical spotted dolphin (*Stenella attenuata*), and finless porpoise, habitat can influence their lipid profiles through diet [17–19]. A study on blood parameters of captive beluga whales (*Delphinapterus leucas*) from three different locations in the United States demonstrated the predominant influence of geographical location [20,21]. Studies focusing on the hematological and biochemical parameters of YFPs have demonstrated that inhabiting different environments exhibit significant behavioral and physiological differences [22–24]. Furthermore, Dai *et al.* conducted hematological comparisons on a total of 136 semi-captive and wild YFPs

and established a health assessment system based on blood parameters. Existing comparative studies have reflected, to a certain extent, the physiological plasticity of cetaceans and might potentially provide an indirect reflection of environmental quality across distinct habitats. However, in most studies on the hematological parameters of YFPs, comparisons have primarily been made between wild populations and those reared in semi-natural water captive. Few studies have explored the combined effects of age, sex, and habitat on variations in the hematological parameters of YFPs.

Based on blood samples of YFPs collected from emergency rescue in two different habitats of Poyang Lake, this study focuses on the core question of whether significant differences exist in the physiological status of porpoises inhabiting seasonally connected waters within a mesoscale geographical context. The study aims to deepen the understanding of the physiological status of wild porpoise populations, evaluate potential risks, and provide scientific support for the conservation of the YFP.

Materials and methods

Area of study and emergency rescue

The Piaotou sand pit waters (PT), located in the center of Poyang Lake with minimal human disturbance, is hydrologically isolated during the dry season, as its sand pits are only connected to the main navigation channel via narrow, shallow waterways. It serves as a natural habitat and breeding ground for YFPs, sustaining a stable local population (Fig 1) [1,25].

Jinxi Lake (JX), belongs to the Poyang Lake basin and serves as a satellite lake of Poyang Lake (Fig 1). The left branch of the Fu River flows into Jinxi Lake and then runs northward through Yugan County before converging into Poyang Lake [26]. During the dry season, YFPs disperse from the main lake area into major tributaries, with Jinxi Lake being one of their migration corridors. In recent years, frequent YFP activities have been observed in this area. However, little is known about the status of the populations inhabiting these waters.

In the dry seasons of February 2023 and March 2024, to translocate YFPs at risk of stranding and entrapment due to falling water levels, activities including area monitoring, safe capture, health examinations, and translocation were carried out in the PT habitat and Jinxi Lake. All appropriate ethics and protocol approvals were obtained for this research from the Ministry of Agriculture of the People's Republic of China.

Both capture operations were performed by professionals specialized in conservation, as well as experienced fishermen, following well-established porpoise capture protocols. Prior to each operation, the water area was surveyed to select safe capture sites, and animals were gently herded using soft nets and acoustic guidance without physical force, motorboats were turned off to reduce disturbance. Once guided to shallow shoals, the animals were carefully lifted and placed onto specialized stretchers, then transferred to flat ground and placed on a 15 cm-thick sponge mat for physical examination. During the examination, water was gently sprinkled on the animal continuously to keep its skin moist, and its respiratory rate was recorded to assess the stress level. No experimental or surgical procedures were performed on the animal other than physical examination, and no sedative drugs were administered to the animal. A total of 19 individuals were examined in the Piaotou habitat, and 6 in Jinxi Lake. All individuals were released into safe deep-water refuge promptly post-examination, with monitoring to confirm normal behavior.

Physical examination and sample collection

Examinations and sampling were performed only after animals were calm and exhibited no signs of distress, like no vocalizations of agitation and normal breathing. Each animal received a complete physical and ultrasound examination. Blood samples were collected aseptically from the main caudal vein using blood collection needles, with blood collected into EDTA anticoagulant tubes. After collection, blood samples were stored at 4°C and transported to the nearest hospital within 2 hours for complete blood count and blood biochemistry analysis.

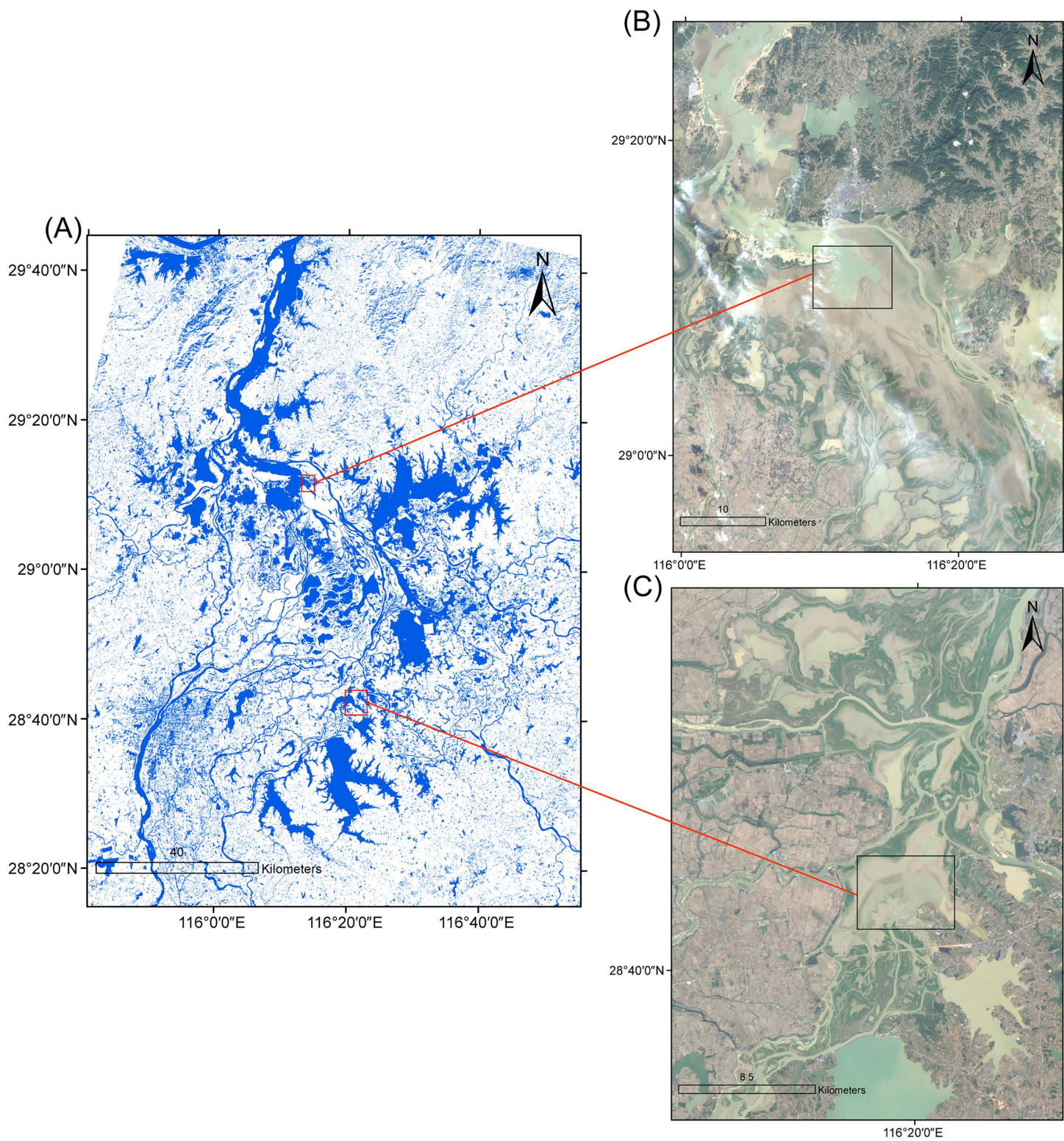


Fig 1. Map of Poyang Lake. The red rectangles showing the locations where YFPs were rescued at Piaotou (B) and Jinxi Lake (C). Landsat 8 image data from November 2021.

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Environmental parameters. Environmental parameters data for the Piaotou habitat were obtained from a habitat survey by Rao *et al* [25], in which water temperature, depth, turbidity, pH, and dissolved oxygen (DO) were measured in April 2023 using a YSI multiparameter sonde, while nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and total dissolved phosphorus (TDP) were analyzed in the laboratory. For Jinxi Lake, environmental parameters data, including water temperature, depth, turbidity, pH, dissolved oxygen (DO), were measured using YSI during a pre-capture water survey in March 2024.

Physical parameters. Physical examination indicators, including body length, body weight, blubber thickness (BT), maximum girth measurements and pregnancy status, serves as a crucial foundation for determining the physiological condition. Age estimation, body mass index (BMI) and girth index (BGI) calculation formulas referenced previous studies [27,28], with BMI standards based on Dai *et al.* [17]. Using body length greater than 130 cm as the criterion for porpoise maturity [29,30].

Blood parameters. A total of 25 blood samples were obtained, among the samples, the female to male ratio was 9:16, and the juvenile to adult ratio was 8:17. Complete blood count parameters included: White Blood Cell count (WBCs), Neutrophil count (#NEUT), Neutrophil percentage (%NEUT), Lymphocyte count (#LYMPH), Lymphocyte percentage (%LYMPH), Monocyte count (#MONO), Monocyte percentage (%MONO), Eosinophil count (#EOS), Eosinophil percentage (%EOS), Basophil count (#BASO), Basophil percentage (%BASO), Hemoglobin (HGB), Red Blood Cell count (RBCs), Hematocrit (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC), Red Blood Cell Distribution Width-Standard Deviation (RDW-SD), Red Blood Cell Distribution Width-Coefficient of Variation (RDW-CV), Platelet count (PLT), Platelet Crit (PCT), Mean Platelet Volume (MPV), Platelet Distribution Width (PDW), and Large Platelet Ratio (P-LCR), totaling 24 parameters.

Blood biochemical parameters were categorized into liver function indicators, blood lipids, electrolytes, and others. Liver function indicators included: Alanine amino Transferase (ALT), Aspartate amino Transferase (AST), Alkaline Phosphatase (ALP), Gamma-glutamyl Transferase (GGT), Total Bilirubin (TBIL), Direct Bilirubin (DBIL), and Indirect Bilirubin (IBIL). Blood lipids included: Total Cholesterol (CHOL), Triglycerides (TG), High-Density Lipoprotein cholesterol (HDL-C), and Low-density Lipoprotein Cholesterol (LDL-C). Electrolytes included: K^+ , Na^+ , Cl^- , and Ca^{2+} . Other biochemical parameters included: Total Protein (TP), Albumin (ALB), Globulin (GLOB), Albumin/Globulin ratio (A/G), Glucose (GLU), Uric Acid (UA), and Creatinine (CREA).

Statistical analysis

The Shapiro-Wilk normality test was used to assess data normality for grouped data, and Levene's test was used to assess homogeneity of variance. Independent samples t-test and Mann-Whitney U test were respectively applied for normally distributed data with equal variance and non-normally distributed data for comparisons between habitats, with effect sizes calculated. Robust M-estimation analysis to ensure the robustness of the results. For each hematological/biochemical indicators, a robust linear model was constructed to test the independent effects of three key factors (gender, age and habitat). Robust PCA was applied to integrate multi-dimensional hematological/biochemical indices. Ten key indicators screened by PCA are tested for significance using Welch's t-test.

Games-Howell test was utilized for multiple group comparisons between PT, JX population and the healthy reference group. The data from 136 YFPs established by Dai *et al.* were used as the healthy reference group [17]. Based on normality test results, data were presented as mean \pm standard deviation or median (IQR).

Results

Environmental parameters

Water quality parameters at the two habitats are summarized in [Table 1](#). At Piaotou habitat in April 2023, water temperature averaged 25.98 °C, depth was 8.2 m, turbidity was relatively high (233.5 ± 155.86 NTU), and pH was neutral to slightly

Table 1. Environmental parameters at the two habitats of Poyang Lake.

	Temp	Depth	Turi	pH	DO	NO ₃ ⁻	NO ₂ ⁻	NH ₄ ⁺	TDP
unit	°C	m	NTU	\	mg/L	mg/L	mg/L	mg/L	mg/L
PT (n = 12)	25.98 ± 1.47	8.20 ± 1.72	233.5 ± 155.86	7.74 ± 0.333	8.82 ± 0.66	1.16 ± 0.073	0.016 ± 0.00	0.26 ± 0.04	0.039 ± 0.014
JX (n = 1)	15.6	4.5	68	5.9	10.14	NA	NA	NA	NA

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alkaline (7.74 ± 0.33). DO averaged 8.82 ± 0.66 mg/L. Nutrient concentrations were generally low, with NO₃⁻ at 1.16 ± 0.07 mg/L, NO₂⁻ at 0.016 ± 0.00 mg/L, NH₄⁺ at 0.26 ± 0.04 mg/L, and TDP at 0.039 ± 0.014 mg/L.

Water quality of Jinxi Lake in March 2024 as follows: temperature was 15.6 °C, depth was 4.5 m, turbidity was 68 NTU, pH was 5.9, and dissolved oxygen was 10.14 mg/L.

Population structure

For the Piaotou samples, gender, body length, weight and blubber thickness were collected from all individuals, while maximum girth measurements were available for 16 individuals (Table 2). The population showed a female to male ratio of 5:14, with three pregnant individuals identified. The average age was 6 years, with most individuals being 0–4 years old. Average body length was 136.76 ± 15.73 cm, average body weight was 39.29 ± 13.3 kg, average axillary BT was 2.33 ± 0.61 cm, average anal BT was 1.95 ± 0.42 cm, average maximum girth BT was 2.42 ± 0.37 cm, average maximum girth was 94.28 ± 10.85 cm, average BMI was 20.63 ± 4.78 kg/m², and average BGI was 69.44 ± 4.85. Physical examination revealed superficial abrasions in three individuals, severe tail fin injury in one individual, and minor skin conditions in very few cases.

For the JX samples, complete gender, weight and body length data available for all individuals, while maximum girth and BT measurements were obtained from four and three individuals, respectively (Table 2). The female to male ratio was 2:4, with an average age of 3 years, maximum age of 9 years, minimum age less than 1 year, and one pregnant individual. Average body length was 125.65 ± 15.45 cm, average body weight was 41 ± 15.9 kg, and average axillary BT for three individuals was 1.81 ± 0.18 cm. For four individuals, average maximum girth was 84 ± 5.76 cm, average maximum girth BT was 1.98 ± 0.26 cm, and average BGI was 60.05 ± 13.6. Average BMI was 25.05 ± 6.17 kg/m², with three individuals reaching obesity standards. Physical examination revealed that most individuals had extensive skin lesions around the eyes, mouth, and fins.

Blood parameters

Hematological parameters. The results from inter-group analysis (Table 3,4) and robust M-estimation (Fig 2) revealed significant differences existed in hematological parameters between PT and JX population. For red blood cell-related

Table 2. Individual measurement results of Yangtze finless porpoises in the Piaotou and Jinxi Lake habitat.

	body length	body weight	maximum girth	axillary BT	anal BT	max girth BT	BMI	BGI
Unit	cm	kg	cm	cm	cm	cm	kg/m ²	\
PT (n = 19)	136.76 ± 15.73 (n = 19)	39.29 ± 13.3 (n = 19)	94.28 ± 10.85 (n = 16)	2.33 ± 0.61 (n = 19)	1.95 ± 0.42 (n = 19)	2.42 ± 0.37 (n = 19)	20.63 ± 4.78 (n = 19)	69.44 ± 4.85 (n = 16)
JX (n = 6)	125.65 ± 15.45 (n = 6)	41 ± 15.9 (n = 6)	84 ± 5.76 (n = 4)	1.81 ± 0.18 (n = 3)	1.68 (n = 1)	1.98 ± 0.26 (n = 4)	25.05 ± 6.17 (n = 6)	60.05 ± 13.6 (n = 4)

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Table 3. Independent sample t-test of hematological parameters.

	Unit	PT (n = 19)	JX (n = 6)	p	Cohen's d
WBC	*10 ⁹ /L	7.93 ± 2.55	9.13 ± 3.6	0.371	0.427
%NEUT	%	61.75 ± 12.03	69.55 ± 13.41	0.190	0.632
#LYMPH	*10 ⁹ /L	1.85 ± 0.79	2.43 ± 1.8	0.270	0.529
%LYMPH	%	24.31 ± 10.23	25.92 ± 14.	0.763	0.143
RBCs	*10 ¹² /L	4.82 ± 0.62	4.59 ± 0.37	0.406	0.396
MCV ***	fL	98.78 ± 3.23	92.22 ± 2.29	< 0.001	2.155
RDW-SD	fL	48.39 ± 4.48	48.18 ± 4.7	0.923	0.046
P-LCR **	%	39.11 ± 7.5	50.47 ± 5.28	0.002	1.605

PT = Piaotou population, JX = Jinxi population. Significant difference with * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$.

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Table 4. Hematological parameters of Mann-Whitney U test.

	Unit	PT (n = 19)	JX (n = 6)	p	Cliff's Delta
#NEUT	*10 ⁹ /L	4.60 (2.40)	5.31 (3.40)	0.221	0.351
#MONO	*10 ⁹ /L	0.13 (0.12)	0.34 (0.36)	0.121	0.439
%MONO	%	1.60 (1.00)	4.30 (2.88)	0.138	0.412
#EOS ***	*10 ⁹ /L	0.79 (1.00)	0.01 (0.00)	0.001	0.982
%EOS ***	%	10.50 (6.40)	0.15 (1.63)	0.001	0.965
#BASO	*10 ⁹ /L	0.00 (0.00)	0.00 (0.00)	0.828	0.061
%BASO	%	0.00 (0.00)	0.00 (0.03)	0.877	0.053
HGB **	g/L	164.00 (12.00)	145.00 (19.00)	0.009	0.693
HCT **	%	49.00 (4.50)	42.20 (4.50)	0.009	0.702
MCH *	pg	33.30 (2.10)	31.10 (1.47)	0.014	0.667
MCHC *	g/L	334.00 (8.00)	342.00 (7.75)	0.036	0.57
RDW-CV	%	13.40 (1.30)	14.50 (2.48)	0.176	0.386
PLT ***	*10 ⁹ /L	133.00 (27.00)	202.00 (54.00)	<0.001	0.979
PCT ***	%	0.16 (0.04)	0.26 (0.08)	<0.001	1.000
MPV **	fL	11.80 (1.10)	13.20 (0.75)	0.004	0.746
PDW*	%	16.80 (0.50)	16.10 (11.33)	0.014	0.667

PT = Piaotou population, JX = Jinxi population. Significant difference with * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$. The data are presented using the median and interquartile range, but the test indicates the difference in distribution position rather than the difference in median values.

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parameters, the PT population showed significantly higher MCV, MCH, HGB, and HCT compared to the JX's, while MCHC was significantly lower than the JX's. For platelet-related parameters, the JX population showed significantly higher P-LCR, PLT, PCT, and MPV compared to the PT's. Additionally, the JX population showed extremely low #EOS and %EOS.

Robust PCA (Fig 3) demonstrated good separation of hematological parameters between habitats. PC1 and PC2 cumulatively explained 59.9% of the variance. Among the 10 key indicators (Fig 3), 5 showed significant habitat differences, and these 5 indicators were consistent with the robust M-estimation results.

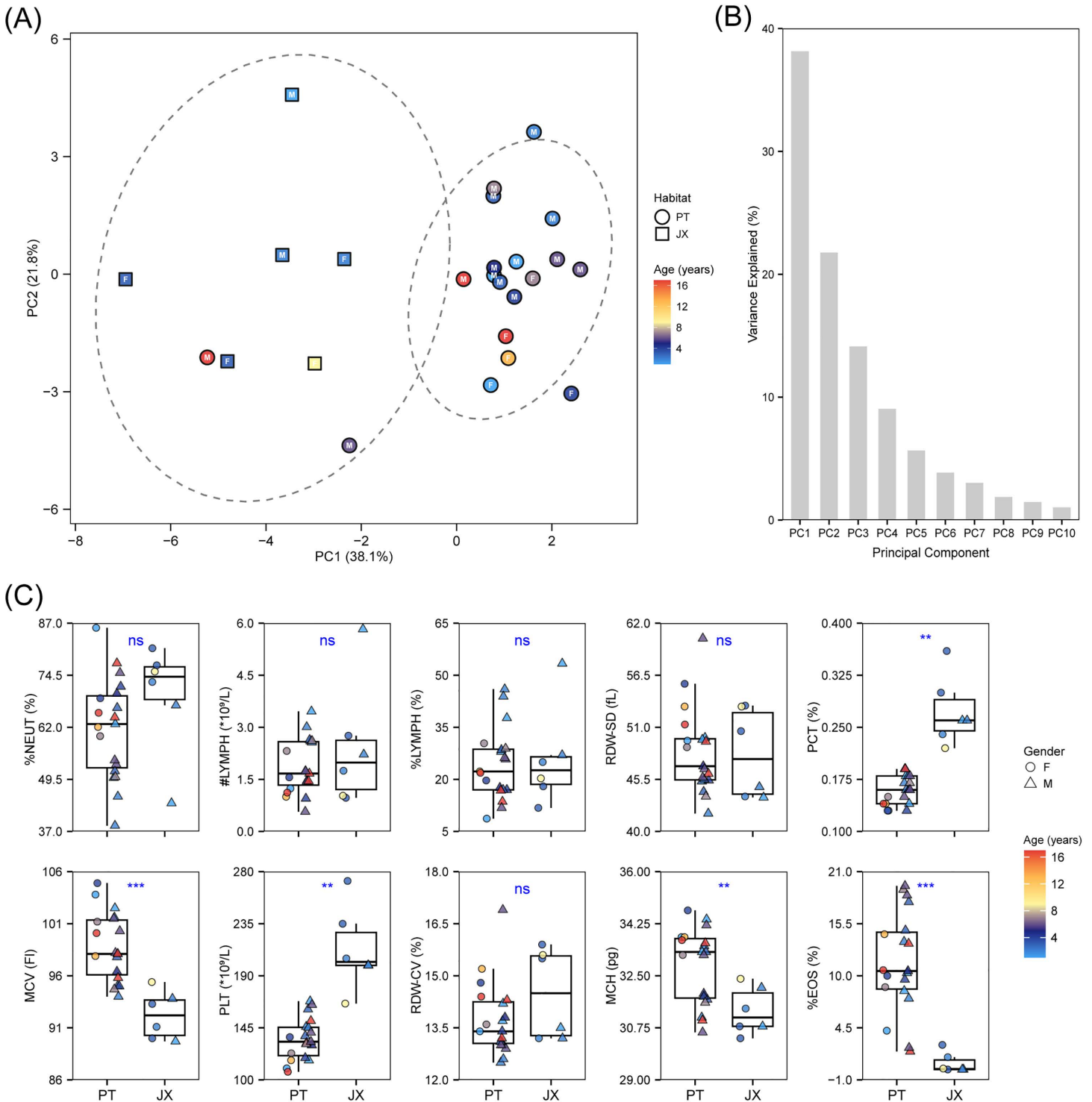


Fig 3. Robust PCA and comparative analysis of key hematological parameters across habitats. (A) Robust PCA score plot. Points are colored by age (years), and dashed 90% confidence ellipses visually delineate habitat-specific clustering patterns. (B) Scree plot of Robust PCA, which quantifies the proportion of variance explained by each of the first 10 principal components. (C) Distribution of ten key hematological indices of Robust PCA. Symbols denote biological sex (circle = female, triangle = male), color encodes age, and statistical significance is indicated as * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$, or *ns* (not significant).

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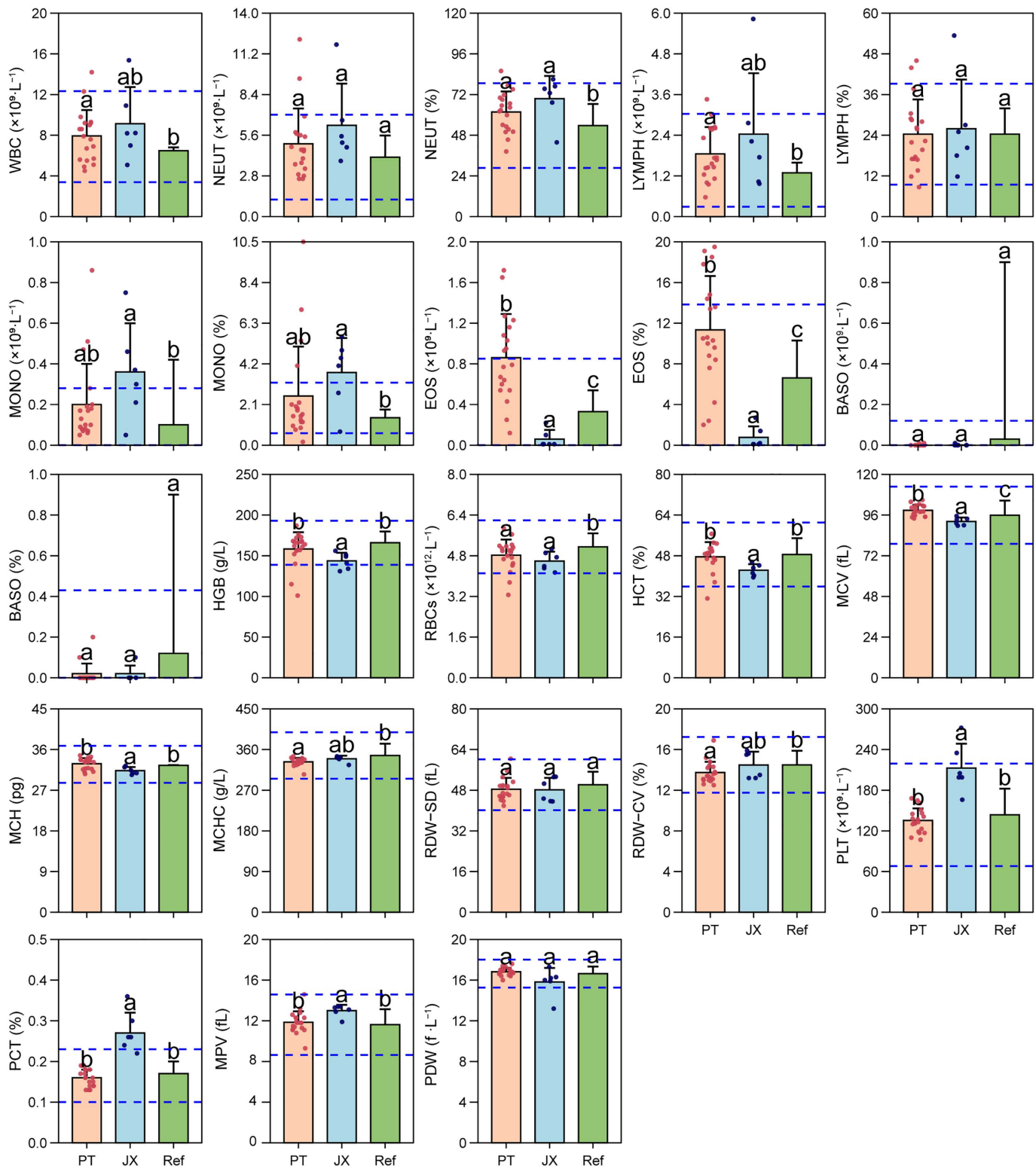


Fig 4. Comparison of mean values of hematological parameters for PT population (n=19), JX population (n=6), and reference group (Ref, n=136). Error bars represent standard deviations. The blue dotted line indicates the physiological range of the indicators. Different letters indicate significant differences ($p < 0.05$).

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Table 5. Independent sample t-test of biochemical parameters.

	Unit	PT (n=19)	JX (n=6)	p	Cohen's d
CHOL	mmol/L	4.68±0.59	5.13±0.73	0.399	0.402
LDL-C	mmol/L	0.84±0.18	0.73±0.16	0.179	0.649
TP	g/L	72.61±7.75	76±6.12	0.143	0.71
ALB *	g/L	43.17±4.00	39.10±1.97	0.027	1.106
GLU ***	mmol/L	9.27±1.46	6.8±1.29	0.001	1.816
CREA	μmol/L	44.89±10.67	50±13.46	0.346	0.45
K ⁺	mmol/L	4.89±0.48	4.66±0.63	0.311	0.485

PT=Piaotou population, JX=Jinxi population. Significant difference with * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$.

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Table 6. Mann-Whitney U test for biochemical parameters.

	Unit	PT (n=19)	JX (n=6)	p	Cliff's Delta
ALT	U/L	45.00 (14.00)	36.00 (20.75)	0.156	0.404
ALP	U/L	173.00 (101.50)	152.00 (434.25)	0.828	0.07
AST **	U/L	267.00 (76.50)	185.50 (39.75)	0.006	0.737
GGT	U/L	36.00 (12.00)	37.00 (20.25)	0.642	0.132
TBIL***	μmol/L	1.80 (1.75)	0.65 (0.30)	< 0.001	0.904
DBIL**	μmol/L	0.50 (1.45)	0.20 (0.17)	0.003	0.781
IBIL	μmol/L	1.10 (1.10)	0.58 (0.37)	0.101	0.471
TG	mmol/L	1.53 (0.89)	1.78 (1.18)	0.303	0.298
HDL-C *	mmol/L	2.03 (0.58)	3.60 (1.11)	< 0.001	0.991
GLOB*	g/L	28.80 (7.95)	39.35 (12.23)	0.011	0.675
A/G *	%	1.52 (0.61)	0.95 (0.23)	0.007	0.719
UA ***	μmol/L	47.00 (12.50)	15.00 (17.75)	< 0.001	1.000
Na ⁺ ***	mmol/L	156.00 (3.50)	149.50 (3.25)	< 0.001	0.93

PT=Piaotou population, JX=Jinxi population. Significant difference with * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$. The data are presented using the median and interquartile range, but the test indicates the difference in distribution position rather than the difference in median values.

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CREA were lower. The JX population showed higher TG, GLOB, and K⁺ levels, while TBIL, DBIL, IBIL, CHOL, ALB, A/G, CREA, and Na⁺ were lower.

Discussion

Habitat quality

The 2023 survey on the Piaotou habitat showed that the comprehensive trophic state index of the waters ranged from 44.6 ± 1.8 to 49.8 ± 1.5 , corresponding to a mesotrophic state across all four seasons. Overall, the water quality was rated at Grade II level. Species distribution models (SDMs) indicated that cyanobacterial density and total phosphate concentration had relatively high contribution rates to the models, which may exert a potential influence on the distribution of YFPs [25].

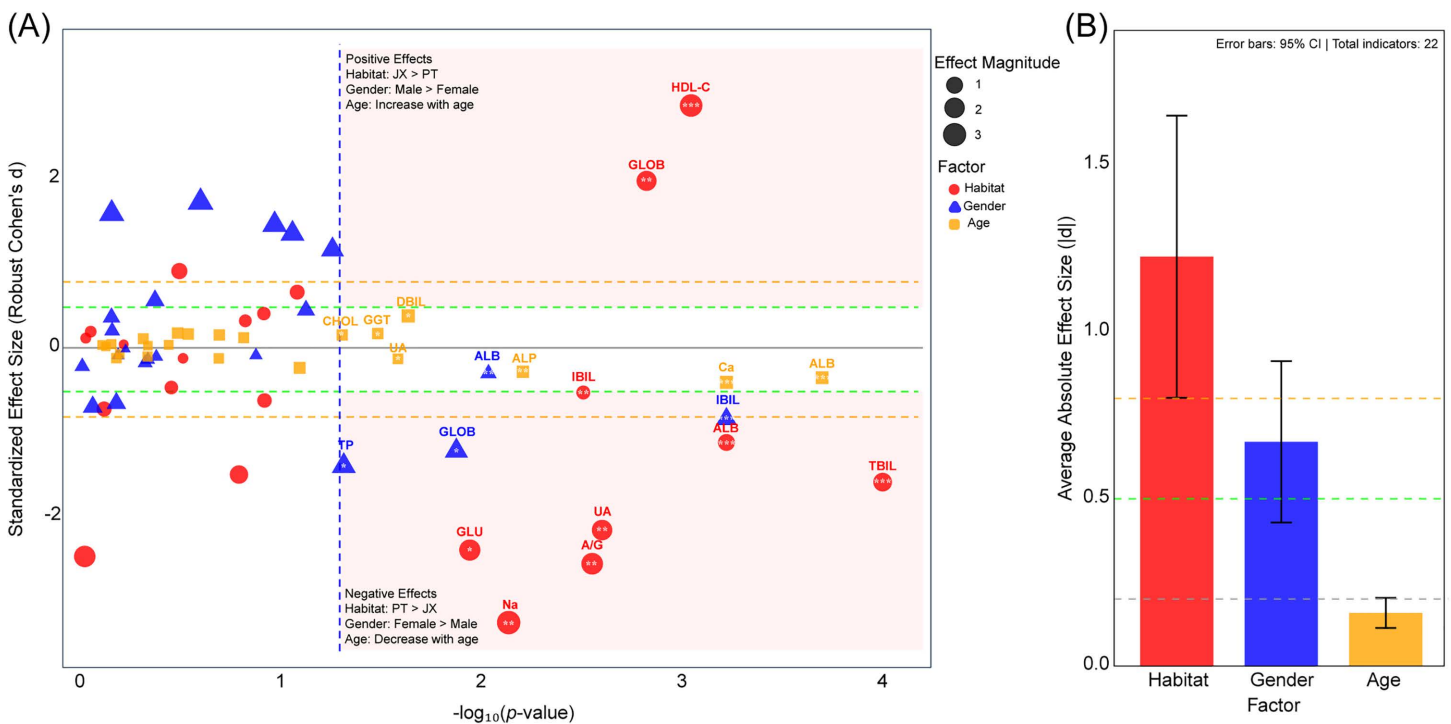


Fig 5. Robust M-estimation and multi-factor effects of biochemical parameters. (A) Robust multi-factor effects. The high-impact zone was defined as $p < 0.05$ & $|d| \geq 0.5$. A positive effect ($d > 0$) indicated that the mean value of the indicator in the JX population was higher than that in the PX population, the indicator value in males was higher than that in females, or the indicator value increased with age. A negative effect ($d < 0$) indicated the opposite. The blue dashed line represented $p = 0.05$, the green dashed line represented Cohen's $|d| = 0.5$, and the orange dashed line represented Cohen's $|d| = 0.8$. Significant difference with * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$. (B) Average robust effect sizes by factors.

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A water quality survey conducted in Jinxi Lake from April to May 2009 classified the water body as eutrophic. Biomonitoring results revealed the presence of *Anabaena* sp. and *Microcystis aeruginosa* in the lake estuary. The poor water quality of Jinxi Lake may be attributed to the narrow riverbed, low water discharge at the Xizhi Estuary, as well as its proximity to urban and industrial zone [26]. A survey of the Fuhe River Basin conducted from 2017 to 2018 indicated that the water body was in a eutrophic state and at a mesosaprobic level during the flood and dry seasons, respectively. Furthermore, the water environmental quality of the Fuhe River Basin—into which Jinxi Lake drains—has exhibited a declining trend over the past decade [31].

Population structure

The population structure of a species provides critical insights into its demographic viability, genetic diversity, and adaptive potential. Key indicators include gender ratio, age distribution, reproductive status, and group composition (e.g., solitary individuals, mother-calf pairs, or social groups) [32]. The age structure analysis revealed differences between the two populations. The Piaotou population exhibited a balanced age structure, and three pregnant individuals were recorded, indicating a stable population development. This finding is consistent with the results of previous studies [28]. Jinxi Lake serves as a fixed migration corridor for the YFPs, where are mostly observed engaging in small-population activities. The six individuals captured in Jinxi Lake were female-dominated and composed of young individuals, which may partly reflect the population trait of YFPs for migratory behavior.

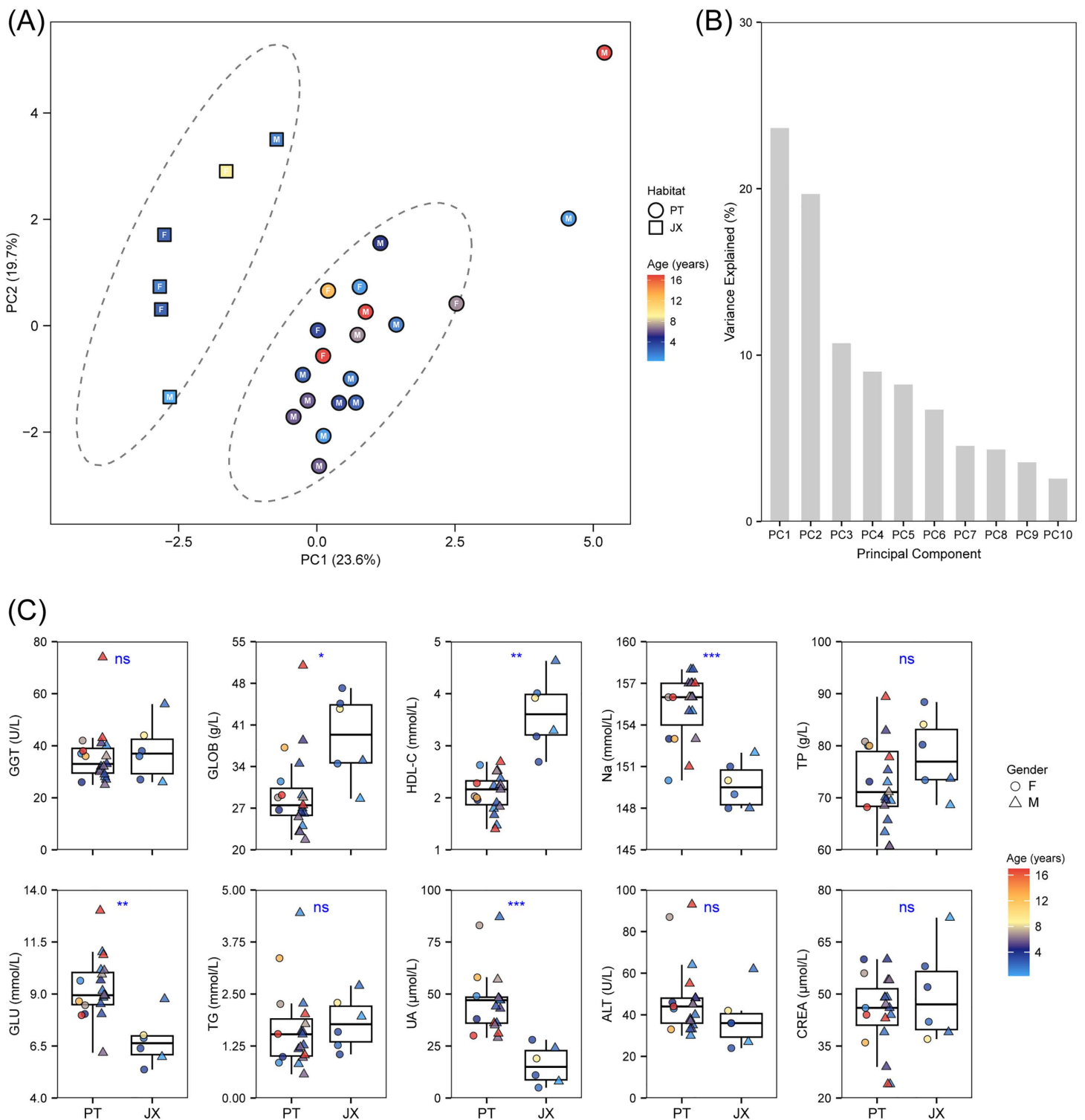


Fig 6. Robust PCA and comparative analysis of key biochemical parameters across habitats. (A) Robust PCA score plot. Points are colored by age (years), and dashed 90% confidence ellipses visually delineate habitat-specific clustering patterns. (B) Scree plot of Robust PCA, which quantifies the proportion of variance explained by each of the first 10 principal components. (C) Distribution of Ten Key Hematological Indices of Robust PCA. Symbols denote biological sex (circle = female, triangle = male), color encodes age, and statistical significance is indicated as * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$, or *ns* (not significant).

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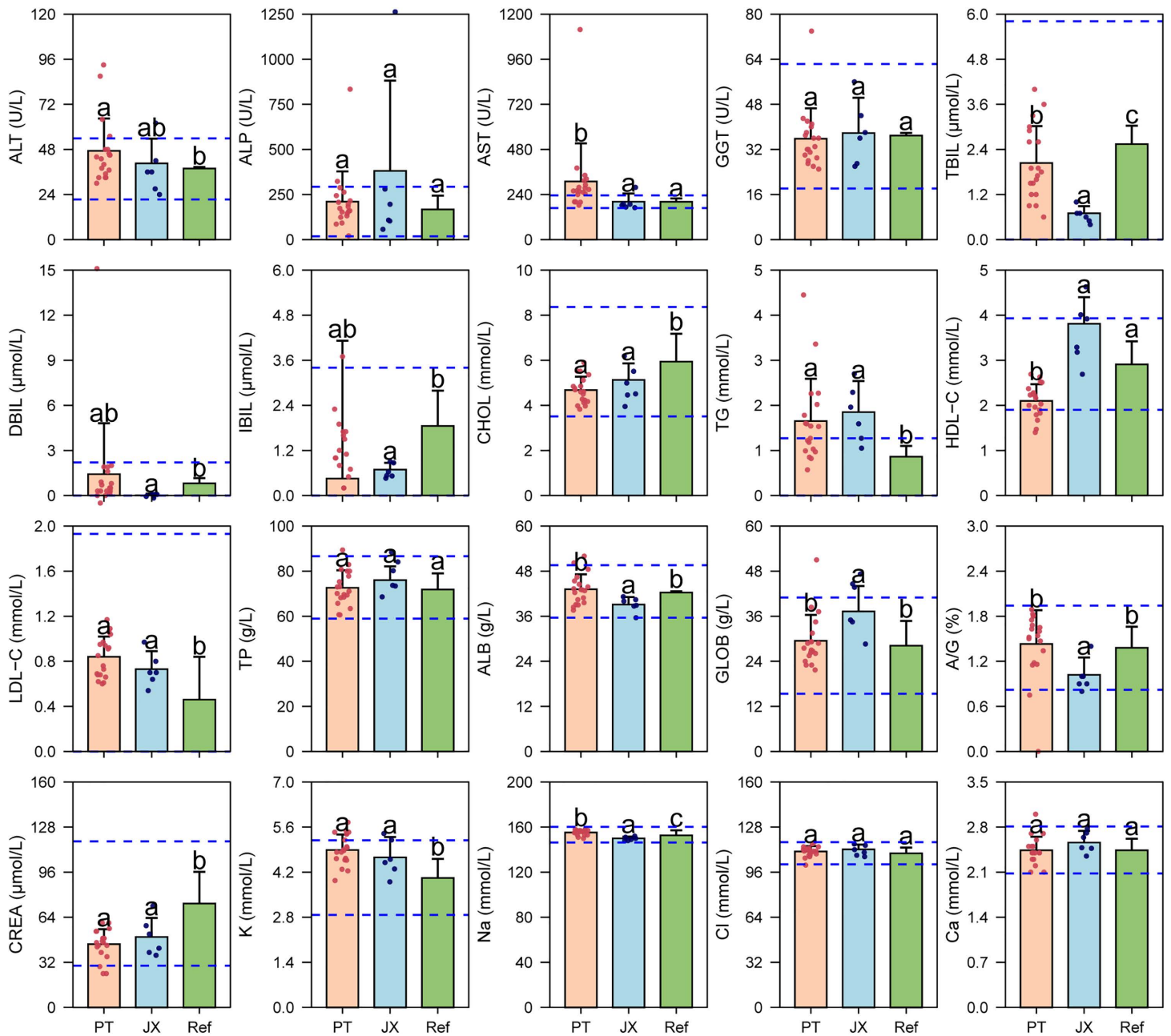


Fig 7. Comparison of mean values of biochemical indicators for PT population (n=19), JX population (n=6), and reference group (Ref, n=136). Error bars represent standard deviations. The blue dotted line indicates the physiological range of the indicators. Different letters indicate significant differences ($p < 0.05$).

<https://doi.org/10.1371/journal.pone.0346095.g007>

Animal body condition shows a dependent relationship with body weight [33,34]. In La Plata dolphins (*Pontoporia blainvillei*) and minke whales (*Balaenoptera acutorostrata*), positive correlations were found between girth, blubber weight, and body weight, supporting their value as body condition indicators [35,36]. The body size and BMI has been established as a reliable indicator for assessing nutritional status and overall health condition in marine mammals [37]. The higher BMI

observed in the JX population, with three individuals reaching obesity standards, may reflect different foraging strategies or food quality between habitats, such as excessive food intake, imbalanced nutrient composition [38].

Blubber thickness is related to season and age factors. The mean BT of normal YFPs ranged from 1.80 ± 0.03 cm to 2.65 ± 0.19 cm [39]. The PT population showed consistently higher fat thickness values across all measurement sites, indicating better energy storage capacity, which can be attributed to the abundant fish resources in the Piaotou habitat that provide optimal nutrition for maintaining body condition. The JX population have a high BMI but a relatively low fat thickness, which deserves attention.

Skin lesions in delphinids and other small cetaceans are geographically widespread and generally considered nonfatal [40]. In the JX population, the higher prevalence of skin lesions infections at multiple sites may reflect compromised animal health or exposure to anthropogenic or environmental threats. The status of water quality and pathogenic bacteria of YFPs in Jinxi Lake warrants concern.

Blood parameters

Hematological parameters. The PT population demonstrated better physiological health status, characterized by higher oxygen-carrying capacity, nutritional status, and metabolic activity levels. The significantly higher red blood cell-related parameters (RBCs, HGB, HCT, MCV, MCH) suggest enhanced oxygen transport capacity, which is crucial for diving marine mammals [41]. Although elevated hematocrit values often indicate dehydration, these values remained within the clinically healthy range, and no other severe related symptoms were observed [42].

The JX population showed physical examination evidence of three individuals with old or new abrasions, and blood parameters indicating stronger coagulation function or inflammatory responses and abnormal immune function. This may be related to surface wounds, strong capture stress responses, and water quality conditions. The extremely low eosinophil counts and percentages in the JX are particularly noteworthy, as eosinophils play crucial roles in allergic reactions and parasite defense [43,44]. This suppression may indicate chronic stress or immunosuppression [45]. The elevated platelet-related parameters (PLT, PCT, MPV, P-LCR) suggest enhanced coagulation activity, which may represent a physiological response to injury risk or chronic inflammation. The combination of elevated platelet parameters and low eosinophil counts may indicate a complex immune response and suggest the presence of abnormal physiological conditions, potentially associated with varying degrees of skin disorders. Decreased RBC, HGB, and HCT levels may be associated with anemia caused by malnutrition, inflammatory responses, or other factors [46]. This finding is consistent with previous health surveys of YFPs in the wild, which have reported varying degrees of anemia [47]. White blood cell differentials serve as important indicators for assessing inflammation and stress responses [20]. The elevated monocyte count observed in the JX population is particularly noteworthy, as monocytes play a central role in chronic inflammatory processes and tissue remodeling. This finding is consistent with the earlier report by Nabi et al., which showed that significantly higher counts of white blood cells, lymphocytes, and monocytes in porpoises from Poyang Lake indicate chronic exposure to infectious agents, particularly parasites and viruses [46]. Evidence of parasitic infections in harbor porpoises (*Phocoena phocoena*) indicates a potential similar risk for YFPs in Poyang Lake [48].

Biochemical parameters. Blood biochemical parameter analysis revealed significant metabolic differences between the two habitat populations. Higher serum albumin and glucose levels in the PT population indicate better protein synthesis capacity and glucose metabolic homeostasis, typically associated with adequate nutritional intake and good liver function [49]. Conversely, elevated GLOB and decreased A/G ratio in the JX population may suggest chronic inflammation or immune activation states [50–52].

The primary function of TG is energy storage, which can be utilized for high-energy activities such as migration and foraging in YFPs [53]. The levels of TG can vary widely with dietary changes, and higher triglyceride levels may reflect higher lipid intake [54,55]. In the Piaotou and Jinxi Lake population, certain parameters such as TG, ALP, and AST exceeded normal physiological ranges. The JX population was dominated by ALP, with one male juvenile porpoise younger than

1 year age showing an extremely high ALP value of 1263 U/L (far exceeding the normal range). The PT population was characterized by abnormally high AST, where one 17-year-old male adult individuals had an AST value of 1118 U/L. Both types of extreme outliers raised the group means of the corresponding indicators in their respective population. The ALP abnormalities are most likely attributed to hepatobiliary system abnormalities (e.g., may induced by parasitic infections or pollutants). Juvenile individuals, with immature organ development and higher sensitivity to environmental stress, may exacerbate this elevation. Abnormal bone metabolism could be a secondary contributing factor. The habitat- and age-specific abnormal indicators may reflect differences in environmental pressures between the two habitats.

Environmental factors have multiple influences and mechanisms of action on YFPs physiological status. The discharge of industrial wastewater and domestic sewage along the river damages the survival environment of YFPs [56]. Studies have found that harbor porpoises (*Phocoena phocoena*) in more polluted waters exhibit a higher incidence of bacterial infections [57]. Natural water pollution may affect hormone secretion in YFPs by altering endocrine gene expression patterns, interfering with normal endocrine activities; noise pollution may induce oxidative stress and inflammatory responses, potentially damaging hearing [58]. Chronic exposure to suboptimal conditions can lead to cumulative health impacts, reduced reproductive success, and increased susceptibility to disease [59,60].

Notably, due to the migratory behavior of the JX population, its poorer physiological indices when compared with the PT population inhabiting the main lake area may reflect that wild populations face higher physiological risks during migratory activities in Poyang Lake. Therefore, when assessing and analyzing the physiological status and health of YFPs in Poyang Lake, attention should be paid not only to the habitat quality of their primary habitats but also to their migratory behavior and the risks associated with migratory activities.

Future directions

Physiological differences in YFPs between the two habitats were identified in this study, with habitat having a more significant impact on such differences than gender and age. Owing to the small sample sizes (19 and 6 individuals), the statistical results may be confounded by randomness, this exploratory conclusion nonetheless highlights the need for increased attention to habitat quality in the conservation of endangered species. Notably, the lack of integrated analysis of environmental and physiological health data made it difficult to determine whether the abnormal status of the small Jinxi Lake population stemmed from habitat quality or was attributed to habitat differences due to an incidental group disease infection. Nevertheless, heightened monitoring of water environments and population health should be implemented for YFP migratory corridors of tributaries during the dry season.

Future research should involve regular habitat surveys and population monitoring in Jinxi Lake to explain how water quality modulates the physiological health of YFPs over a longer temporal scale. Additionally, the sample size should be further expanded to include comparisons across more habitat populations, thereby enabling a more comprehensive understanding of the mechanisms and key factors underlying the effects of habitat on the physiological status of YFPs.

Conclusion

In this study, provides the first systematic comparison of the population structure and hematological parameters of the YFPs between the Piaotou and Jinxi Lake habitat in Poyang Lake. The results demonstrate significant physiological status differences between YFPs inhabiting different habitat environments within Poyang Lake. The Piaotou populations exhibiting favorable physiological conditions and a relatively stable structure, making it a valuable germplasm resource for the species. Jinxi Lake, new hotspot for the porpoise in Poyang Lake and an area included in populations surveys for the first time, exhibits several health-related concerns such as skin lesions, potential for inflammation or immune responses, which suggest elevated health risks. The observed physiological status disparities between habitats emphasize the importance of maintaining connectivity between high-quality core habitats and improving conditions in secondary habitats, with particular prioritize the physiological health risks faced by wild migratory populations.

Institutional Review Board Statement: This study did not involve animal experimentation or harm. All appropriate ethics and protocol approvals were obtained for this research from the Ministry of Agriculture of the People's Republic of China.

Supporting information

S1 Data. Support Data.
(CSV)

Author contributions

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