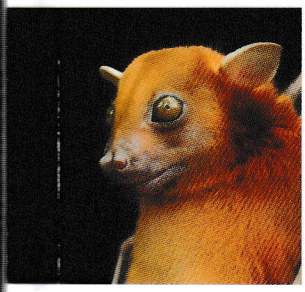
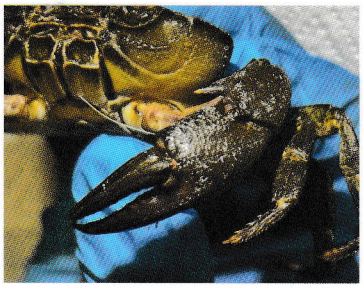
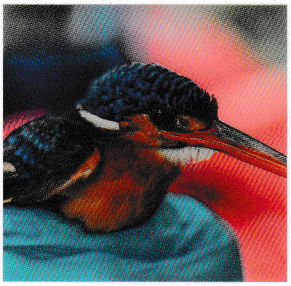
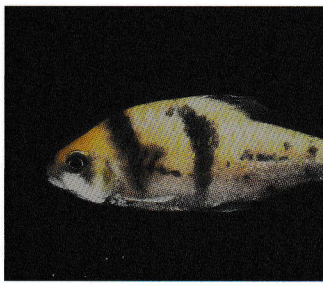
EXPLORING NATURE'S RECOVERY


BIODIVERSITY RESILIENCE



SABAL FOREST RESERVE

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Biodiversity Resilience: Exploring Nature's Recovery Sabal Forest Reserve

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Water Quality and Solid Wastes

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Mustafa Kamal @ Harris Norman & Besar Ketol

Sabal Forest Reserve (SFR) encompasses several highland streams and is bordered by oil palm plantations. This chapter presents findings from a recent expedition aimed at evaluating the status of water resources within SFR. The study was motivated by growing concerns over anthropogenic pressures, climate variability, and land-use changes that may compromise water quality. By systematically collecting and analyzing data across multiple sampling sites, this work seeks to establish baseline conditions for future monitoring, detect spatial variations, and identify areas requiring urgent intervention.

Water quality (WQ) is a critical indicator of ecosystem health, influencing biodiversity, human well-being, and socio-economic activities. Monitoring WQ parameters provides insights into the physical, chemical, and biological conditions of aquatic environments, enabling researchers and policymakers to assess environmental integrity and identify potential threats. It is also essential for safeguarding human health, protecting ecosystems, and supporting industries dependent on water resources. Increasing anthropogenic pressures, particularly solid waste mismanagement, pose significant threats to aquatic systems. Improper disposal of plastics, organic waste, and hazardous materials can lead to leachate formation, nutrient loading, and microplastic contamination, degrading water quality and disrupting ecological balance. Given the proximity of oil palm plantations to SFR, it is crucial to assess whether this activity impacts the conserved area. Accordingly, this expedition aimed to: (1) assess *in-situ* physicochemical water parameters of streams, and (2) survey the types and abundance of solid wastes from anthropogenic activities within or near the streams.

Daytime sampling was conducted over three consecutive days (23–25 November 2024) at nine stations (Table 1, Figure 1 and Figure 2). Stations 1–6 were located inside SFR, while Stations 7–9 were outside, enabling comparative analysis. A multi-probe water quality sensor (AQUAREAD) measured six parameters: temperature (°C), dissolved oxygen (DO, mg/L), pH, electrical conductivity (EC, µS/cm), turbidity (NTU), total dissolved solids (TDS, mg/L), and oxidation-reduction potential (ORP, mV). Stream morphology (width and depth) and water current (m/s) were also recorded. All readings were expressed as mean values and compared against Malaysia's National Water Quality Standards (NWQS), which classify rivers based on suitability for various uses.

Solid waste sampling was performed concurrently, recording items >1.5 cm in categories such as paper, plastic, rubber, glass, aluminum, metal, organic waste, e-waste, and hazardous waste. When possible, the country of origin was identified from barcodes or manufacturer details printed on the label.

Stream characteristics (Tables 2 and 3) varied across stations: widths ranged from 2.99 to 7.90 m, depths from 16 to 57 cm, and currents from 0.16 to 0.63 m/s showing both slow moving to fast flowing water. Temperatures were relatively stable (25.20–26.13 °C), typical of tropical streams. Turbidity showed marked spatial variability, with Stations 2 and 3 recording high values (43.3 and 52.6 NTU), likely due to sediment disturbance during the rainy season and fast currents. DO ranged from 4.45 to 5.34 mg/L, with Stations 6 and 7 recording the lowest values (<5 mg/L), possibly linked to organic matter decomposition (tea-coloured water at Station 6) and plantation drainage at Station 7 suggesting oxygen consumption by microbial activity. The pH ranged from 5.08 to 7.81, with Station 6 exhibiting the most acidic condition, indicative of peat influence. EC and TDS were generally low, except at Station 7 (EC = 44 µS/cm; TDS = 28 mg/L), suggesting higher ionic content from plantation runoff, likely due to fertiliser use. Usage of fertilisers containing nitrate, phosphate and potassium can cause high ionic content in water. Station 8, near workers' housing, also showed elevated EC and TDS since there were some agricultural activities going on. ORP values ranged from -15.6 mV (Station 7) to +75.1 mV (Station 6), reflecting contrasting redox conditions: positive ORP indicates oxidizing environments typical of oxygenated waters, while negative ORP suggests localized reducing conditions associated with organic accumulation. Most stations exhibited positive values.

Comparison with NWQS (Table 4) revealed that only temperature, EC, and TDS consistently met Class I standards across all stations. Other parameters varied: DO was Class II at most stations but Class III at Stations 4, 6, and 7; pH was Class I at six stations (Station 1, 2, 3, 5, 7 and 9), Class II at two, and Class III at Station 6; turbidity met Class I only at Station 6, while Station 3 exceeded Class II limits. Meanwhile, turbidity at other stations exceed Class I but are still well under Class II limit. Overall, DO, pH, EC, and TDS values resemble typical peatland streams—slightly acidic, low in DO, and low in ionic content.

During the expedition, solid waste observations were minimal: two PET bottles (500 mL) were found outside SFR (Stations 8 and 9), and one cigarette butt was found inside the reserve near the base camp. Both bottles were locally manufactured. Cigarette butts, composed of synthetic plastic fibers, degrade slowly and pose long-term environmental risks.

These findings are relevant for scientific understanding and management strategies. Streams in SFR exhibit characteristics suitable for hardy aquatic species but may

stress sensitive taxa due to low DO and acidic conditions. Solid waste pollution is currently minimal, but awareness campaigns for plantation workers and visitors are recommended. A key limitation of this study is that sampling occurred only once during the wet season; seasonal variations remain unassessed. Regular monitoring is essential to capture temporal dynamics and inform sustainable water resource management and conservation efforts.

Table 1. Brief description of the station

Station	Coordinates	Site Description
1	N 00° 59' 56.33" E 110° 52' 09.17"	Has many large rocks creating a few small waterfalls and pools with pebble substrate and clear water. It is approximately 100 m from ladies' camp.
2	N 00° 59' 57.10" E 110° 52' 05.30"	The confluence of four streams, has fast flowing water and pebbles are its bottom substrate. It is approximately 50 m from dining hall area.
3	N 01° 00' 00.75" E 110° 52' 04.51"	It is located near the parking area, approximately 250 m downstream from the base camp. Left bank is part of the plantation whereas right bank is the forest reserve.
4	N 01° 01' 33.03" E 110° 52' 32.16"	The first small, fast flowing stream for Transect 3 and has many large rocks.
5	N 00° 59' 54.00" E 110° 52' 07.91"	A stream with sand bars and ripples. It is about 100 m from men' camp.
6	N 00° 59' 55.46" E 110° 52' 04.81"	A stream with big rocks and a pool of tea-coloured water. Formation of bubbles can be seen within small pool. It is located near the field laboratory.
7	N 01° 00' 40.77" E 110° 52' 09.64"	It is merged with the plantation drainage system.
8	N 01° 00' 01.40" E 110° 51' 44.57"	It is located near the houses of plantation's workers. They use this stream for bathing. Vegetables plots and chicken coups can be observed.
9	N 01° 00' 06.08" E 110° 51' 59.88"	It is located at downstream of the base camp.

Table 2. Mean values of physicochemical parameters according to stations.

Station	Temp (°C)	Turb (NTU)	DO (mg/l)	(%)	pH	EC (µS/cm)	TDS (mg/l)	ORP (mV)
1	25.40	7.1	5.05	61.73	7.67	11	6	+13.7
2	25.90	43.3	5.15	63.80	7.81	15	9	+11.3
3	25.90	52.6	5.24	65.33	7.20	15	9	+12.2
4	25.20	26.8	4.70	58.17	6.47	9	5	+9.0
5	25.60	14.2	5.23	64.43	6.71	10	6	+14.7
6	26.13	3.4	4.45	55.50	5.08	12	8	+75.1
7	25.60	5.1	4.96	61.16	7.51	44	28	-15.6
8	25.60	6.9	5.34	65.80	6.39	25	16	+26
9	25.50	7.0	5.22	64.20	6.76	14	8	+19.5

Notes: Temp = temperature; Turb = turbidity; DO% = dissolved oxygen; EC = specific electrical conductivity; TDS = total dissolved solids; ORP = oxidation-reduction potential

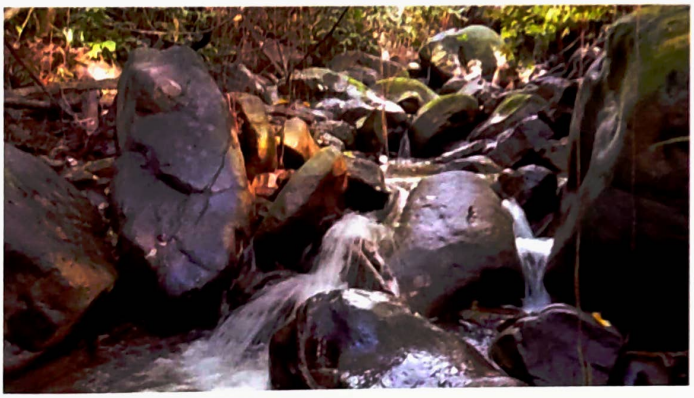
Table 3. The physical characteristics of nine stations involved in this study.

Station	Mean Stream Width (m)	Mean Stream Depth (cm)	Mean Current Flow (m/s)
1	2.99	43	0.16
2	7.10	50	0.63
3	4.50	21	0.46
4	2.97	50	0.48
5	6.03	25	0.33
6	3.05	57	0.35
7	3.43	25	0.28
8	7.13	35	0.22
9	7.90	16	0.36

Table 4. National Water Quality Standards (NWQS) for Malaysia.

Parameter	CLASS					
	I	IIA	IIB	III	IV	V
Temperature (°C)	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity (NTU)	5	50	50	-	-	-
DO (mg/l)	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
EC (µS/cm)	1000	1000	-	-	6000	-
TDS (mg/l)	500	1000	-	-	4000	-

Notes: DO = dissolved oxygen; EC = specific electrical conductivity; TDS = total dissolved solids

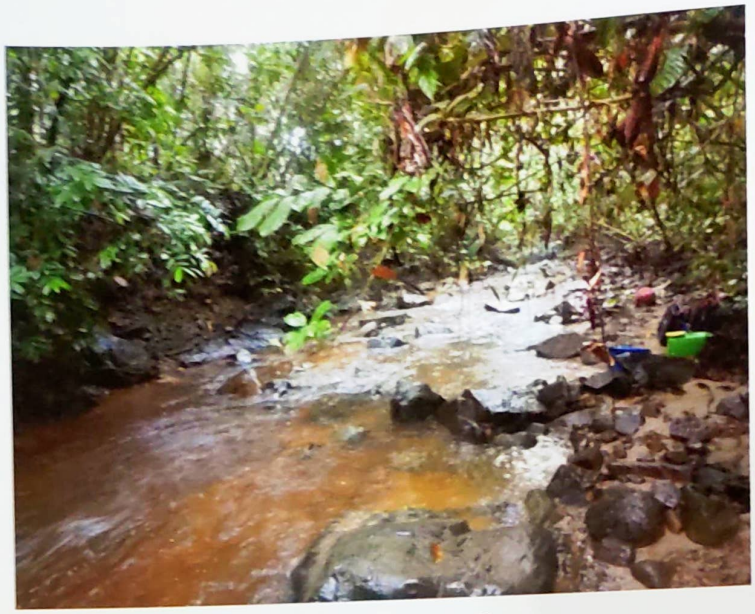


a) Station 1

b) Station 2

c) Station 3

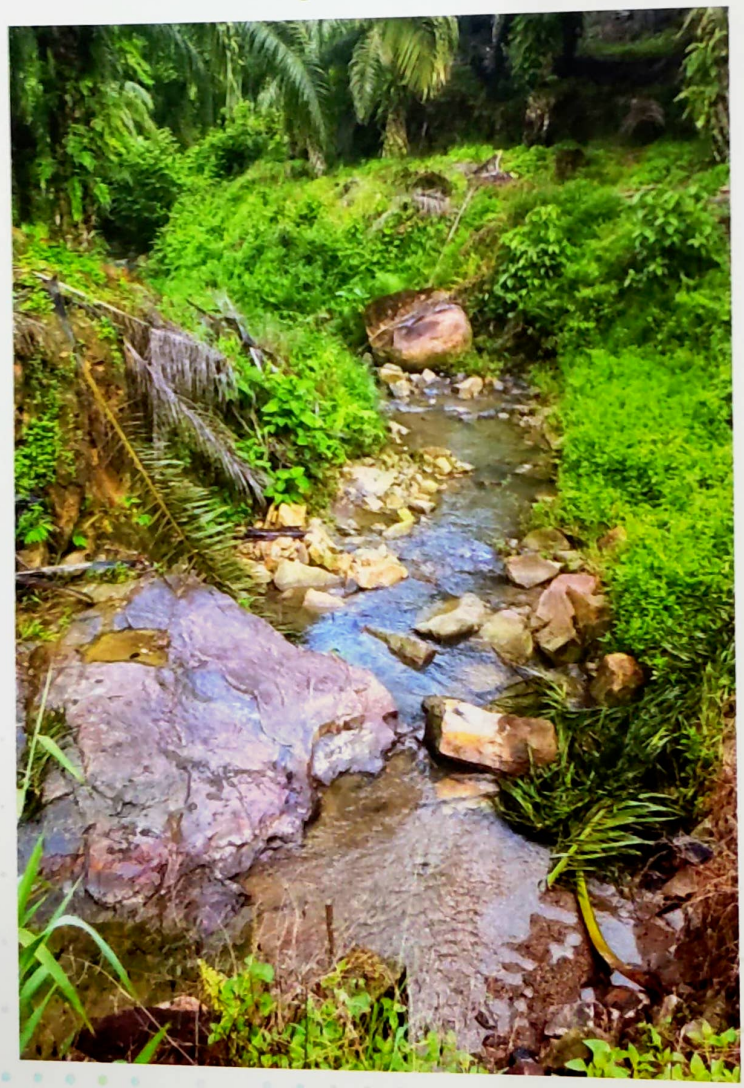
d) Station 4



e) Station 5

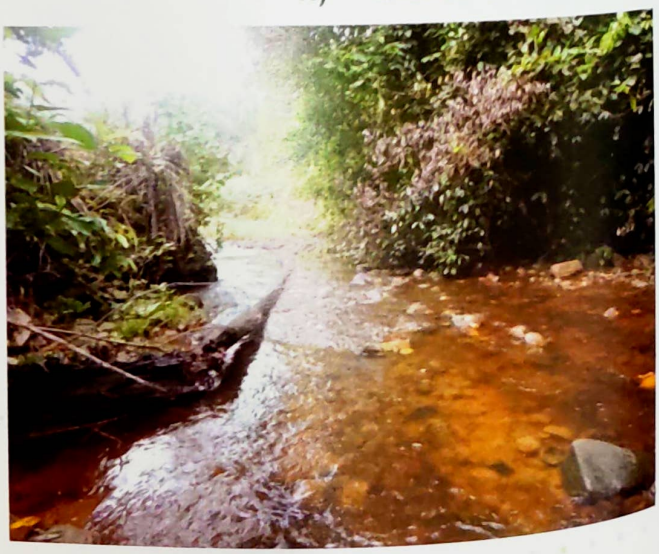
f) Station 6

Figure 1. The morphology of streams within Sabal Forest Reserve.



g) Station 7

h) Station 8



i) Station 9

Figure 2. The morphology of streams outside the Sabal Forest Reserve.