KOPEL FOREST ENVIRONMENT MONITORING REPORT 2022

KOPEL Background

KOPEL Bhd is a community organisation incorporated as a co-operative under the Malaysia Co-operative's Commission Act 1994. KOPEL Bhd is located in the community of Batu Puteh in the heart of the Kinabatangan Floodplain. The community of Batu Puteh consists of four villages, with the village of Batu Puteh at its centre. The entire community is surrounded by the Pin-Supu Forest Reserve, one of the largest protected forest reserves along the Lower Kinabatangan River.

KOPEL's main purpose is to support the generation of income and employment in the local community from the surrounding forests in an ecologically sustainable manner. This entails operating activities that generates income in a manner that supports the conservation of the forest ecosystem, the aquatic ecosystem, the biodiversity of this area, and the wildlife that makes its home in these habitats.

KOPEL's Forest Conservation Work

The community of Batu Puteh has been working with the Sabah Forestry Department since 1997 to establish sustainable community-based tourism and forestry activities within the Pin-Supu Forest Reserve. In 1998 the community got involved with fighting forest fires within the reserve. This led to the first community-led forest restoration activities in the wetland forests of the Lower Kinabatangan in 1999.

Major advancements in the forest restoration techniques were made in the following years with support and grants from Ricoh Corporation (Japan), the International School Brunei, Alexander Abraham Foundation and America Forests. LEAP, WWF, Raleigh International, Intrepid Travel, Outlook Expeditions, Camps International, World Challenge, Rakuno Gakuen University, Bring the Elephant Home, Borneo Explorer Club, and Danau Girang Field Centre are just some of the many NGOs and companies that have supported KOPEL's restoration and monitoring initiatives over the years. In 2021, KOPEL Bhd partnered with M Style Malaysia SB by funded to support ecological restoration, the monitoring of habitat and ecosystems, and to enhance the conservation of wildlife and biodiversity of the Lower Kinabatangan Forest Corridor of Life.

In the year 2004 the conservation efforts turned to tackle the Invasive waterweed *Salvinia molesta* after this weed completely covered the Tungog Lake in 2003. Through the ingenuity and hard work of the local community, KOPEL cleared the Tungog Lake of the weed Salvinia in March 2007. The work from there-on was funded by the community-based tourism (CBT) programs run by KOPEL bhd. More recently, in the year 2018, KOPEL signed an MOU with Sabah Agriculture Department to release and monitor a biological control program to combat the invasive water weed *Salvinia molesta* on the Tungog Lake.

In the year 2009 the Sabah Forestry Department signed an agreement (MOU) with KOPEL Bhd to co-manage the Pin-Supu Forest Reserve (PSFR), there-in recognising and strengthening the community's long-running efforts to protect and restore the forest and habitats of this reserve. The agreement is designed to ensure that the overall management of this reserve is in-line with the comprehensive 10-year Forest Management Plan. Key partnership activities include forest and habitat restoration, enhancing monitoring functions, and increasing revenue collection to the State Government via entrance fees.

In the year 2010 KOPEL embarked on protecting the caves in the northwest part of the Pin-Supu Forest Reserve vis a vis an agreement with the Sabah Wildlife Department. In 2012, through support from University Rakuno Gakuen (Japan), KOPEL Bhd began a long-term environmental monitoring program involving water quality monitoring, wildlife monitoring, and forest restoration monitoring.

In this 2022 Report

In this reporting period 2022, conservation activities and monitoring efforts were scaled-up again after the COVID19 pandemic lockdowns and the collapse of tourism markets and income generated from tourism across the 2020-2021 years. Key take home message from this report should be that the core monitoring activities continue to be maintained by KOPEL, and KOPEL is extremely grateful for the support provided by the Sabah Forestry Department, Yayasan Hasanah, Cardiff University, M Style Malaysia SB, Camps International, Intrepid DM, and many other organisations and individuals throughout the year 2022.

This report is designed to provide an overview and summary of the monitoring outcomes in 2022. This is a key part of KOPEL's commitment towards continued monitoring, transparency, and feedback into the Sustainable Forest Management of Pin Supu Forest Reserve in partnership with the Sabah Forestry Department and other supporting agencies.

1. Forest Restoration & Restoration Monitoring

Forest Restoration efforts in 2022 were two pronged. Firstly, KOPEL continued facilitating forest restoration efforts through the active involvement of volunteers and ecotourists. This still forms the backbone of KOPEL's forest restoration work. These tourism activities are carried out year-round, and generate revenue to support a full-time restoration team, tree nursery team, and management teams to facilitate the restoration, monitoring & reporting work. Secondly KOPEL continued larger scale forest restoration activities, partnering with Sabah Forestry Department and several agencies including the Danau Girang Field Centre, M Style Malaysia SB, and Borneo Samudera Sdn Bhd (Sawit Kinabalu).

In 2022, a total of 9.1ha of degraded forests have been opened for restoration activities including tree planting. The sites are at Kaboi Lake 3.0 (3.5ha) and Sg. Pin Stumping (5.6ha). Kaboi lake 3.0 is located within the Pin Supu Forest Reserve (PSFR) area, while Sg. Pin Stumping site is located within the Sungai Pin Conservation Area (SPnCA) to the west and upstream of PSFR.

A total of 7,386 trees were planted in 2022. This combines trees planted through ecotourism and voluntourism activities, as well as trees planted through externally funded planting projects. After the COVID19 lockdown and the cancellation of all tourism activities in 2020-2021, KOPEL tourism activities started to rebound again in 2022, whereby tree planting was a daily event at KOPEL.

A total of 19 species of trees were planted in 2022, with the bulk of the trees coming from flood tolerant pioneer species such as Bongkol (*Nauclea sp*. = 4232 trees), Salungapid (*Mallotus muticus* = 1347 trees), Kelompang (*Sterculia sp.* = 752 trees), Binuang (*Octomeles sumatrana* = 447 trees), and Sepat (*Mitrogyna sp.* = 144 trees)

Refer to Table 1 (next page, below), for a full list of tree species planted in 2022.

Table 1: Tree Species Planted at Forest Restoration Sites for the year 2022.

	Local Name	Scientific name	Kaboi Stumping 2.0	Kaboi Lake 3.0	Ladang K	Sg. Pin Stumping 1.0	Sg. Pin Stumping 2.0	Sg. Pin Stumping 3.0	Sg. Pin Stumping 4.0	Sg. Pin Stumping 5.0	Kaboi Stumping	Kaboi Lake	Total
											Tourist Planting		
1	Bayur	Pterospermum sp.						1					1
2	Belian	Eusideroxylon zwageri				1							1
3	Binuang	Octomeles sumatrana	25		44	97	8	129	77	40	26	1	447
4	Bongkol	Nauclea sp.	139	505	249	138	55	334	215	2566	28	3	4232
5	Durian merah	Durio graveolens							1	3			4
6	Durian putih	Durio sp.							1	4			5
7	Kelompang	Sterculia sp.	8	1	27	126	6	281	111	155	37		752
8	Keranji	Dialum spp.							6	87			93
9	Kerodong	Microcos crassifolia							12				12
10	Keruing	Dipterocarpus sp.				5	1	1	6	3			16
11	Nangka	Artocarpus heterophyllus								1			1
12	Payung-Payung	Terminalia sp.	7	1	4	22	3	6	18	24	7		92
13	Rambutan	Nephelium lappaceum L.							2	2			4
14	Resak	Vatica rassak					1		13				14
15	Salungapid	Mallotus muticus	130	445		63	52	352	138	152	13	2	1347
16	Sepat	Mitragyna speciosa	14	25		4	8	40	45	3	4	1	144
17	Tangkol	Ficus racemosa			62	1			1		2	1	67
18	Tarap	Artocarpus odoratissimus							1	2			3
19	Terosob	Dracontemelon sp.	10		38	2	4	53	36	5	3		151
		GRAND TOTAL	333	977	424	459	138	1197	683	3047	120	8	**7386**

Four keys area were planting in 2022, as follows:

1. Kaboi Lake Restoration Site (Alluvial Seasonally Flooded Forest)

Kaboi Lake Restoration Sites are situated in degraded alluvial seasonally flooded forest, in Pin-Supu Forest Reserve adjacent to the Kaboi Lake. The site is 1km walk from the Kinabatangan River. There is no road access to this site. The site is accessible by boat, but only during high water events (flooding) via the Kaboi River Tributary (Creek). Work on this site has been funded by the Cardiff University Regrow Borneo Initiative and is the one of five sites focusing on forest restoration and the long-term monitoring of carbon sequestration and restoration ecology across a variety of floodplain forest types.

A new restoration site/block (Kaboi Lake 3.0 - 3.5ha) was opened at this site in 2022 (see Figure 1, next page below). A total of 977 trees (five species) were planted, namely flood tolerant pioneer tree species such as Bongkol (*Nauclea sp.* = 505 trees), Salungapid (*Mallotus muticus* = 445 trees), Sepat (*Mitrogyna sp.* = 25 trees), Payung-payung (*Terminalia sp*. = 1 tree), and Kelompang (*Sterculia sp*. = 1 tree). The work at Kaboi Lake 3.0 is fully funded by Cardiff Universities Regrow Borneo project and KOPEL Bhd.

Kaboi lake is a problematic site for restoration because it experiences seasonal flooding of over 1m in depth at this site. In 2022, high water events, caused repeated mortality of small seedlings planted at this site. Based on ongoing site monitoring it is estimated that more than 90% of the trees were lost during a single major flood event in 2022. Post-flood monitoring also highlighted additional mortality and damage caused by wildlife predation.

2. Kaboi Stumping Restoration Site (Alluvial Seasonally Flooded Forest)

Kaboi Stumping Restoration Sites are riparian and seasonally flooded sites within Pin Supu Forest Reserve. A total 453 trees were planted as replacement planting efforts in 2022. Trees at Kaboi stumping sites were planted by ecotourists and volunteers through 2022. A total of 453 trees has been planted at Kaboi Stumping 2.0 (333 trees) alongside plantings in small gaps around this site (120 trees).

3. Ladang Kinabatangan Restoration Site (Riparian Reserve Forest)

Ladang Kinabatangan is a riparian reserve site providing a narrow but vital riparian corridor for wildlife on the south side of the Kinabatangan River - adjacent to Pin-Supu Forest Reserve. The site is a gazetted Riparian Reserve that was deforested for farmland by the adjacent plantation company. In 2022, KOPEL planted a total 424 trees (six species) as gap plantings at this site. Most of the tree species were Bongkol (*Nauclea sp.* = 249 trees), with Tangkol (*Ficus racemosa* = 62 trees), Binuang (*Octomeles sumatrana* = 44 trees), Terosob (*Dracontomelon sp.* = 38 trees), Kelompang (*Sterculia sp.* = 27 trees), and Payung-payung (*Terminalia copelandii* = 4 trees) trees also being planted.

4. Sg. Pin Stumping Restoration Site (Sungai Pin Nature Conservation Area - SPnCA)

Sg. Pin Stumping Restoration Site is new forest restoration site for KOPEL in 2022. The area is a degraded site within a privately owned conservation area managed by Borneo Samudera Sdn Bhd, as subsidiary of Sawit Kinabalu Sdn Bhd. The conservation area is called Sungai Pin Nature Conservation Area (SPnCA). The broader agricultural land holding is considered marginal land for agriculture due to low-lying and swampy terrain, severe flooding that happens periodically, and illegal land encroachment across the area. Sawit Kinabalu Group has planted the higher elevation sites with oil palm across the Sungai Pin Estate. However, a large portion of this area is low-lying and regularly flooded and therefore unsuitable for cropping or oil

palm. KOPEL collaborated with Sawit Kinabalu Group starting in 2021 to carry out forest restoration across degraded sites within the Sungai Pin Nature Conservation Area (SPnCA).

In 2022, a total of 5.6 hectare (in 5 blocks) of degraded forest was opened for restoration work and tree planting at the Sungai Pin Stumping site. A total 5,524 trees were planted, across 19 tree species. The majority of tree species planted were Bongkol (*Nauclea sp*. = 3308 trees), with other species such as Salungapid (*Mallotus muticus* = 757 trees), Kelompang (*Sterculia sp.* = 679 trees), Binuang (*Octomeles sumatrana* = 351 trees), Terosob (*Dracontomelon sp*. = 100 trees), Sepat (*Mitragyna sp.* = 100 trees), and Payung-payung (*Terminalia copelandii* = 73 trees). All these tree species planted are noted for their flood tolerant behaviour. Additional floodplain climax tree species included Keruing (*Dipterocarpus sp.* = 16 trees) and Resak (*Vatica rassak* = 14 trees) (both from the Dipterocarpaceae family), as well as one ironwood tree (*Eusideroxylon zwageri* = 1 tree).

The site was opened from July 2022 which is KOPEL peak season for visitors and ecotourists. Several groups of international students from a variety of countries. KOPEL's forest restoration and tree planting projects are one of the main activity for the tourists to KOPEL.

Figure 1: Kaboi lake 3.0 – Tree planting activity by students from Cardiff University 2022

Figure 2: Example of Site Preparation and tree planting by tourist program - Kaboi Stumping 2022

Figure 3: International Student Groups supporting KOPEL's forest restoration work at Sungai Pin restoration sites

Figure 4: Site Map –Kaboi Lake 3.0

Figure 5: Site Map – Kaboi Stumping plantings 2022

Figure 6: Site Map – Ladang Kinabatangan

Figure 7: Site Map – Sg. Pin Stumping

Pole Planting Methodology

At the Sg. Pin Stumping Restoration Site (Sungai Pin Nature Conservation Area (SPnCA)), two methods were used to plant the trees. Method #1 used seedlings from KOPEL's tree nursery with the second method utilising cuttings from selected tree species following the pole planting method. The second method was carried out because of the risk of flooding at the Sungai Pin sites. Pole planting/stem cutting method were applied as first experiment in SPnCA area, with promising results based on first round monitoring and maintenance. Only two tree species were used in pole planting method, Bongkol (*Nauclea sp.* = 99) and Sepat (*Mitragyna sp.* = 1 tree).

Figure 8: After 1 month of pole planting, the leaf started to emerge from the stem.

2. Monitoring of Carbon Sample Plots (PSP) in 2022

KOPEL has six permanent sample plots, which are KP01, KP02, KP03, KP04, KP05, and KP06. Plots number KP01, KP04, KP05, and KP06 located in Pin Supu Forest Reserve (PSFR), while KP02 and KP03 located at riparian reserve adjacent to PSFR on the south side of the Kinabatangan River. The later sites KP02 and KP03 are located in the riparian corridor restoration site known as Ladang Kinabatangan. Refer to Figure 9 below.

Figure 9: Location map – KOPEL six permanent sample plots.

Plot KP01, is the riparian corridor on the north side of the River in Pin-Supu Forest Reserve downstream of the small Kaboi River. The site KP01 is known locally as Kaboi Stumping Ground because in the early 1980s it was a large log scaling and loading depot (a.k.a. "stumping ground"). Tree planting on the Kaboi Stumping Ground started in 2006 with most of the planting occurring between 2007-2008. Three (3) tree species were planted in this plot in 2008. Enumeration of the PSP KPO1 in 2019 showed there were nine (9) tree species, not including shrubs, vines, and grasses, within the KP01. In 2022, a total of 778 trees (7 species) were remeasured, while 144 trees were found dead due to natural causes (e.g., storm damage), with some trees damaged by wildlife. The height average is 17.2m and DBH average is 37.9cm.

Plot KP02 & KP03 are located within the riparian corridor on the south side of the Kinabatangan River adjacent to PSFR. This site was planted between 2014-2015. Both study plots at KP02 and KP03 have experienced an increase in species through natural regeneration from 3 species planted to 9 species in KP02, and from 4 species planted to 8 species in KP03. In 2022, 324 trees on KP02 were measured, the height average is 12.7m and DBH average is 48.4cm. A total of 443 trees in KP03 were measured, the height average is 12m, and DBH average is 39.9cm.

Plot KP04 are the riparian terrace forest and located in Pin Supu Forest Reserve (Block A) which is at Tungog Rainforest EcoCamp. This year, 130 trees were measured which is the height average is 15.5m and DBH average 54.3cm.

Plot KP05 are the alluvial swamp forest and located in Pin Supu Forest Reserve (Block B). This type of forest is a forest that grows and develops in areas that are inundated by fresh water, it is important to

have a plot carbon at this forest to see the difference. In 2022, 172 trees were measured which is the height average is 13.7m and DBH average is 41.5cm.

Plot KP06 also alluvial swamp forest, but located in Pin Supu Forest Reserve block A. This year, 112 trees were measured which is the height average is 15.5m and DBH average is 64.2cm.

Figure 10: Plot carbon monitoring activities by KOPEL staff.

3. Wildlife Monitoring

Wildlife Monitoring within Pin-Supu Forest Reserve is carried out by the community cooperative KOPEL Bhd using camera trap methodology. The monitoring of wildlife via camera traps has been ongoing for more than 10 years, since 2012, and has compiled a large bank of data on the wildlife within Pin Supu Forest Reserve. In 2022 a total of 6 camera traps were deployed semi-permanently within Pin Supu Forest Reserve, some for multiple short duration monitoring periods, and some for single longer duration monitoring periods.

The wildlife monitoring is designed primarily to determine wildlife species diversity within the Pin Supu Forest Reserve. Species diversity per se is fundamental to establish the significance of this forest management unit for protection. The list of species is likewise used to highlight the presence of vulnerable, threatened, or endangered species within the forest management unit. Species diversity is also an important component of the forest reserve's HCVF assessment because diversity is a determinant of conservation value.

In addition to the basic inventory of wildlife within the reserve, the wildlife data is being analysed to determine trends or changes in the presence of target species, to help ensure their conservation.

The monitoring of wildlife within Pin Supu Forest Reserve is made possible because of the long-term monitoring program run by KOPEL. Long-term monitoring of wildlife is vital to determine the use of the reserve as habitat - over time (this is otherwise known as "temporal use"). Short-term (snap-shot) studies, are less able to separate short-term changes from the impacts caused by factors such as climatic events (e.g. droughts), which can last for 1-2 years, and dramatically impact the food availability for wildlife during this time, and hence wildlife numbers. Hence the ongoing work of KOPEL is vital for the long-term management of this forest unit.

Importantly, the monitoring by KOPEL within PSFR has determined the presence of several critically endangered, vulnerable, and threatened species of wildlife within this forest management unit (see Table 2, p.16, below). Based on the preliminary analysis of data, **it is extremely important,** for the management of the Pin Supu Forest Reserve, that any activities within the reserve proceed based on a "precautionary approach", and that all activities should only be carried out with the strictest sensitivity towards wildlife. This will require an ongoing strong policy around minimising negative impacts to critical habitats within the reserve, and the restoration of degraded forests to restore habitat for wildlife.

Further to this, the current monitoring outcomes **indicates against** the development of mass tourism within the critical habitats of Pin-Supu Forest Reserve. This is imperative, given that the broader forest landscape, and wildlife habitat of the Lower Kinabatangan already faces bottlenecks, fragmentation, and many other threats.

Forest management planning has already taken into consideration the sensitivity of the PSFR through the establishment of HCVF values, HCVF zonation, the establishment of species conservation targets, and the institutionalisation of monitoring mechanisms. Moving forward the monitoring methodology itself (primarily using camera traps) will need to be refined and improved based on the latest available camera technology, and expanded to meet the ongoing monitoring requirements of the forest managers of PSFR. Much of this is dependent on funding and/or viable business revenue streams at KOPEL. Since the onset of COVID, KOPEL and the ongoing monitoring program has been very fortunate to have gained the support of the Sabah Forestry Department and the Sabah Wildlife Department, alongside vital financial support provided from the Hasanah Foundation, and ongoing tourism industry partners.

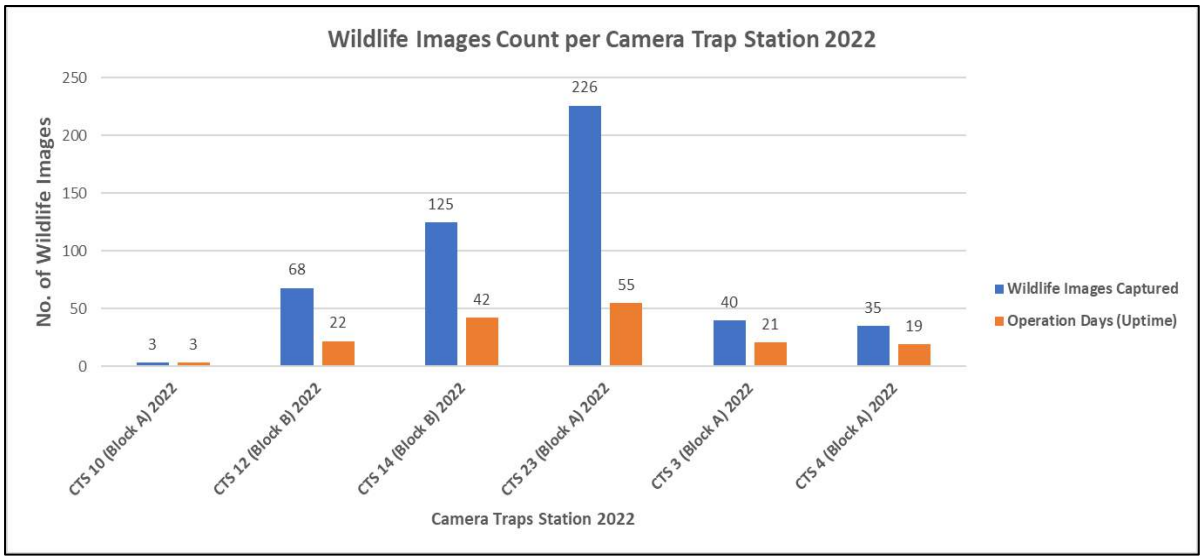


Figure 11: Number of Wildlife Pictures and Operation Days at 6 Camera Trap Stations 2022

Figure 12: Camera trap stations 2022 (left: Block B, right: Block A)

Camera Trap Monitoring in 2022

This report is a short summary of the analysis and findings for the monitoring year 2022. This report also concludes with a list of implications for management, designed to provide feed-back into the annual revisions of the PSFR Forest Management Plan.

In 2022, four out of the six camera trap stations (CTS) are located in the southern part of Block A of the Pin Supu Forest Reserve (PSFR). These four CTS were set-up all in Riverine Dipterocarp Forest or Seasonally Flooded Alluvial Swamp Forest. Other notable features of this area are the Tungog Lake and the Kaboi Lakes (see CTS locations Figure 12, above).

Two of the six CTS was located on the ridge of Supu Hill (CTS12 & CTS14). This is very different habitat (Limestone Forest) to the other camera trap locations in Block A of the Pin-Supu Forest Reserve.

All data gathered is analysed for (a) Relative Abundance Index (RAI) to record the species abundance, and (b) the Shannon and Simpson index to compare species diversity.

Analysis of Data 2022

I. This year, many notable species were captured, including the Critically Endangered Orangutan (*Pongo pygmaeus*) and the endangered Proboscis monkey (*Nasalis larvatus*), as well as the Asian Elephant (*Elephas maximus*). See species list captured (see Table 2, Figure 20, p.16, below).

II. Camera traps stations number 23, 3, and 4 experienced higher diversity based on both Simpsons and Shannon's indexes (See Figure 13 below). The location is situated in Meander belt forest (a form of Riverine Dipterocarp Forest).

III. Long-tailed Macaques (*Macaca fascicularis*) are the most abundant sightings in the RAI analysis (relative abundance) (See Figure 21, p.17 below). Seven of the eight stations captured notable numbers of images of this species, indicating that there is a prominent population in this area (BLOCK A). Further research into the potential positive or negative impacts of this high population density is suggested to be pursued in future.

IV. The clear absence of Bearded Pigs (*Sus barbatus*) within PSFR is one of the most noticeable and alarming changes over the last 3 years. The mass die-back of this species was attributed to an exotic disease in the year 2020-2021 and this species is yet to recover. The long-term survival of this species is currently a major question for ongoing wildlife conservation in this region. Refer to Table 2 (p. 16) and Figure 21 (p. 17) below.

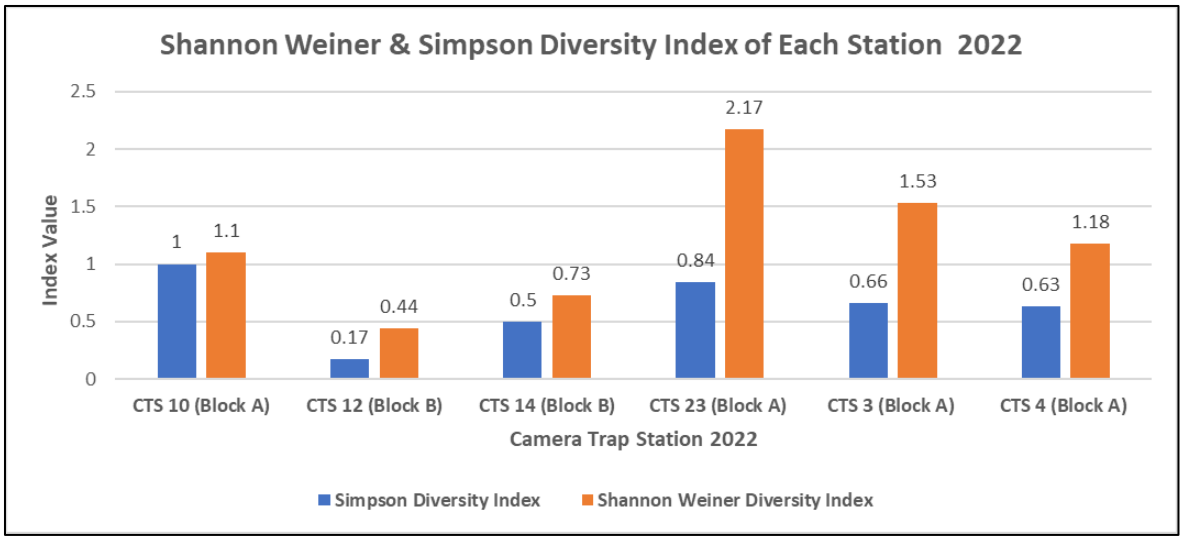


Figure 13: Diversity (Simpsons Index of Diversity or Shannon's diversity index) by camera trap

Figure 14: Image captured of Proboscis monkey, *Nasalis larvatus* (Listed Endangered species (IUCN) primate active by day (CTS 4 2/4/2022)

Figure 15: Image captured of Orang Utan, *Pongo pygmaeus*, listed as Critically Endangered by the IUCN. (CTS 14 1/5/2022)

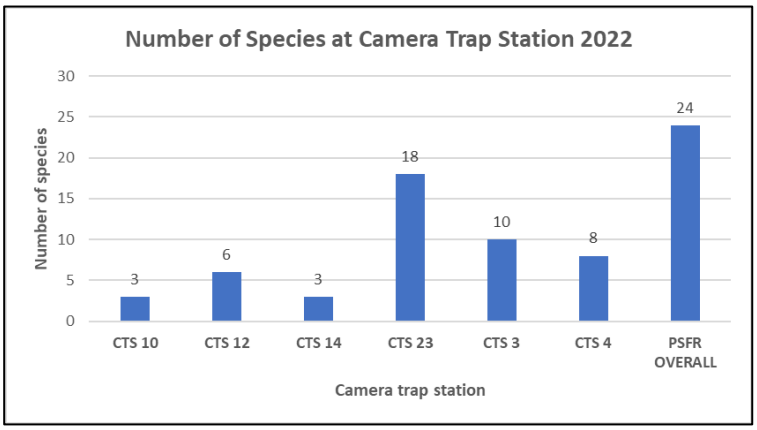
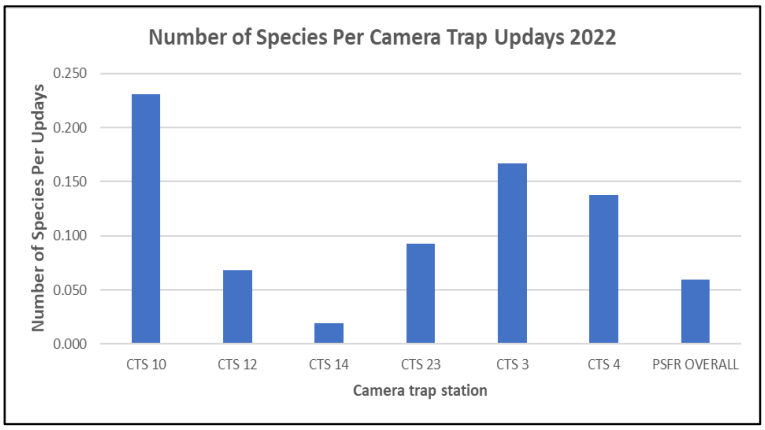


Figure 16: Total species captured per camera trap stations.

Figure 17: Total Species Per Camera Trap Operational Days (Updays).



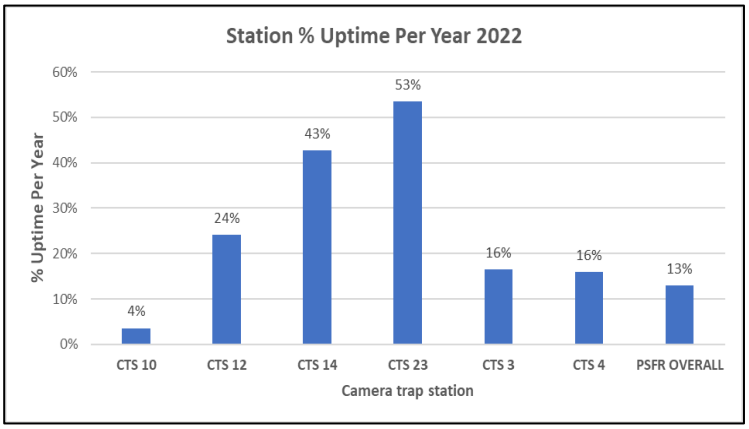
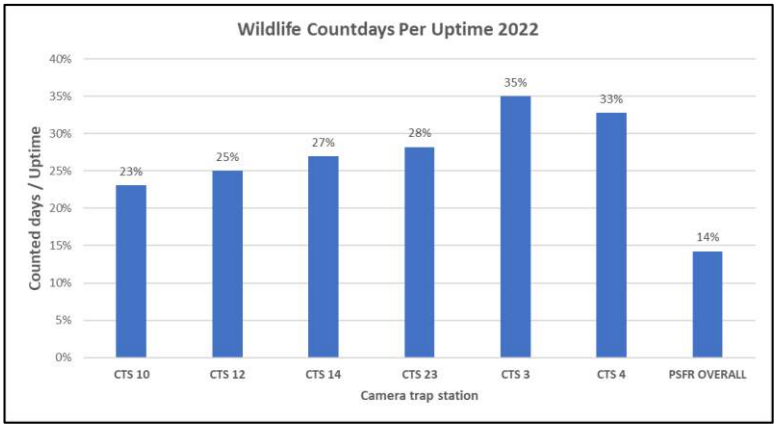


Figure 18: Camera Trap Station Updays Per Year.

Figure 19: Camera Trap Station Wildlife Individuals Per Uptime.



Conclusions & Management Implications

I. The existing methodology of utilising camera traps to monitor wildlife within the PSFR is still considered the best method for keeping track of wildlife numbers in PSFR. This is essentially because the technique has very little direct impact on the ecosystem of the forest and little risk to wildlife.

II. Even so, based on the analysis of "measurable effectiveness indicators" for the camera trapping methodology the following recommendations should be noted within revised FMP action plans:
    a. The camera trapping needs to be expanded and implemented more consistently over a wider range and broader diversity of forest ecosystems within the PSFR and across different levels (layers) of the forest and also aquatic ecosystems.
    b. Refined camera trapping methods or alternative methods should be developed to monitor the impacts of the main road (Sandakan Lahad Datu Highway) which divides and fragments the Kinabatangan Forest Corridor (and the Pin Supu Forest Reserve).
    c. The camera trapping needs to be upgraded, revised and improved to stay abreast of the latest available technology, and to avoid theft of the cameras (to combat these unfortunate incidents, which has occurred repeatedly within the PSFR). Minimizing detection of camera traps, a red filter over the infrared flash to reduce visible glow of infrared flashes or utilising cables and padlocks have been successful in other studies and may be potential methods to consider.
    d. In the past KOPEL has consistently moved camera traps after a few months. This practice needs to be changed, so that longer-term (permanent) stations are established to ensure the camera traps can continue functioning more consistently for a longer period at each station (location) to ensure adequate data is collected over the long-term to determine temporal changes and trends. Consistent monitoring of the same locations for multiple years enables more detailed analysis (and greater accuracy when analysing trends and patterns).
    e. Technique for avoiding floodwaters is critical and should be developed to protect camera traps from being flooded. Examples could also include the installation of hydrological monitoring stations, which can be used to both protect equipment from flooding and provide corelating hydrological data.

III. Based on the analysis of camera trap data and consistent with the Shannon and Simpson (diversity) index values, a diverse list of high conservation value species has been recorded for PSFR, hence it is highly recommended to expand the conservation species targets for Pin-Supu Forest Reserve.

IV. Based on consistent findings over the last 6 years, namely the long-term absence of large groups of Borneo Pygmy Elephants for much of the monitoring period. It is suggested that Borneo Pygmy Elephant be removed as one of the conservation targets for PSFR, mostly because this species is migratory and not a permanently resident within the reserve.

V. Based on consistent findings over the last 6 years, namely the absence of large groups of Proboscis monkeys in camera trap data for much of the monitoring period. It is suggested that a different methodology be developed to monitor this primate within PSFR. Monitoring using river surveys or arboreal camera traps may be feasible options for future consideration.

VI. More broadly there is insufficient data to concur that restoration efforts or tourism activities are having a positive or negative impact on wildlife. It suggested that the monitoring be modified to include comparison sites and control sites to compare the current data sets. This will need to be implemented consistently over several years to monitor temporal changes.

VII. It is recommended that the **raw data** be share more broadly with students, select scientific experts, or select technical people within the conservation community, to provide a broader analysis of the data. This is likewise envisaged to encourage local capacity building through the sharing of technical expertise, and likewise encourage further collaboration in the wildlife management aspects of PSFR.

VIII. It is recommended that some changes are made to the database structure and data logging process to ensure accurate analysis and reduce confounding effects. One such example is adding a standardised 'sighting' variable to reduce confounding effects of the sighting of a specific wildlife individual, that being recorded multiple times in the database.

IX. In summary ongoing monitoring work has been effective and continues to have consistent outcomes, no other major changes are suggested apart from what has already been outlined in this document. It is important that this work continues into the long-term hence ensuring reliable and consistent income into this program is paramount to its success. Income generation mechanisms are hoped to be expanded to benefit expanded monitoring activities to the local community and KOPEL as an organisation providing employment to the local community in the future.

Species name	**IUCN Status**	**Total Individuals sighted**
Long-tailed Macaque (*Macaca fascicularis*)	LC	163
Orang Utan (*Pongo pygmaeus*)	CR	75
Pig-tailed Macaque (*Macaca nemestrina*)	VU	64
Common Porcupine (*Hystrix brachyura*)	LC	51
Crested Fireback (*Lophura ignita*)	NT	38
Malay Civet (*Viverra tangalunga*)	LC	17
Lesser Mouse Deer (*Tragulus javanicus*)	DD	16
Sambar Deer *(Rusa unicolor*)	VU	12
Squirrel (*unknown*)	Unknown	9
Asian Elephant (*Elephas maximus*)	EN	7
Moon Rat (*Echinosorex gymnura*)	LC	6
Short-Tailed Mongoose (*Herpestes brachyurus*)	NT	6
Storm's Stork (*Ciconia stormi*)	EN	5
Malayan Sunbear (*Helarctos malayanus*)	VU	5
Common Treeshrew (*Tupaia glis*)	LC	5
Banded Palm Civet (*Hemigalus derbyanus*)	NT	4
Malay Badger (*Mydaus javanensis*)	LC	4
Great Argus (*Argusianus argus*)	NT	2
Proboscis Monkey (*Nasalis larvatus*)	EN	2
Common Palm Civet (*Paradoxurus hermaphroditus*)	LC	2
Chestnut Necklaced Partridge (*Arborophila charltonii*)	VU	1
Banded Linsang (*Prionodon linsang*)	LC	1
Bearded Pig (*Sus barbatus*)	VU	1
Common Water Monitor (*Vavanus salvator*)	LC	1
	TOTAL	**497**
Taxonomic Class	Species Total	Individual Total
Mammal	19	450
Bird	4	46
Reptile	1	1

Figure 20, Table 2: Number of individual wildlife captured per species 2022 (Pin Supu Forest Reserve)

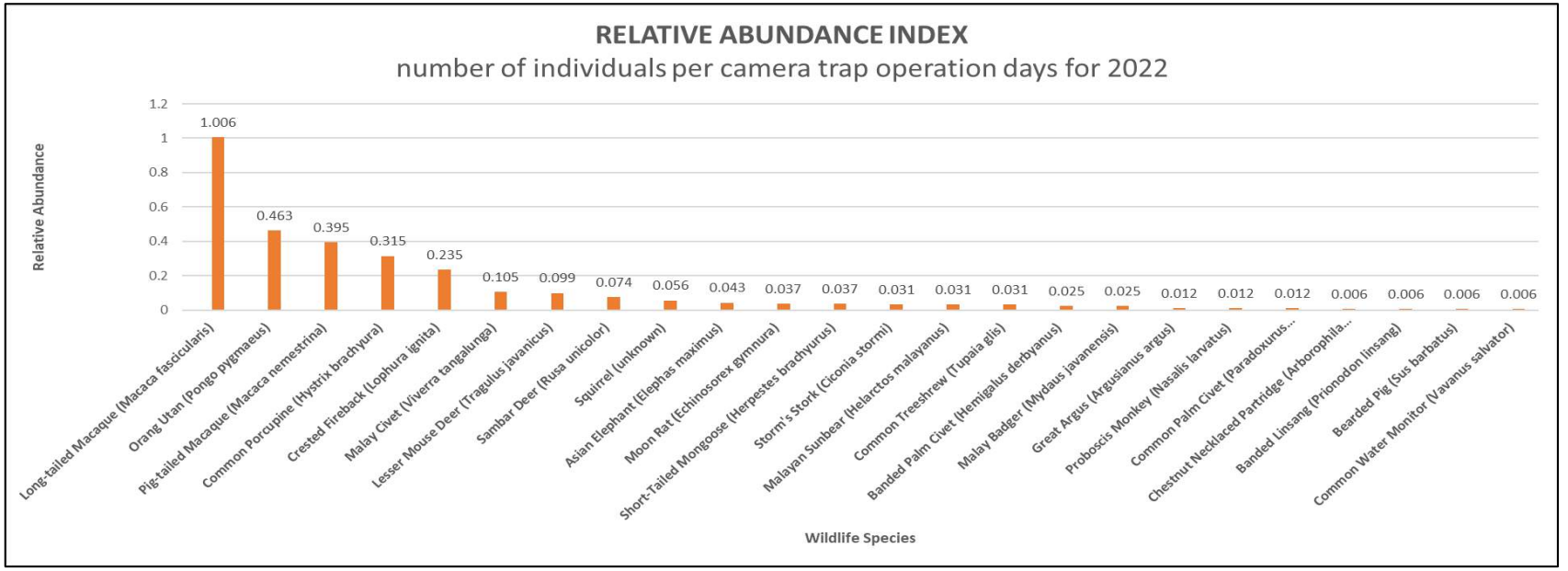


Figure 21: Relative Abundance Rate (RAI) (number of individuals per camera trap operation days)

Figure 22: Image captured of Storms stork (*Ciconia stormi*) (Listed Endangered species (IUCN) (CTS 4 06/10/2022)

Figure 23: Image captured of Sambar Deer, *Rusa unicolor*, listed as Vulnerable (IUCN) (CTS 3 11/4/2022)

Figure 25: Image captured of Orang Utan, *Pongo pygmaeus*, listed as Endangered by the IUCN. (CTS 10 23/01/2022)

3. Water Quality Monitoring

Pin-Supu Forest Reserve water quality monitoring is conducted by community cooperative KOPEL Bhd. This work has been ongoing since 2012 and compiles water quality parameter data from a total of 6 sample points since 2021 until now. These include a point of discharge from the Kg Mengaris, Tungog Lake, as well as at the confluence of the Kaboi River, the Biandong River, the Takala River, and the Pin River - refer Location Map to Figure 26.

KOPEL's monitoring work is normally funded by revenue generated through KOPEL's ecotourism programs, however in the absence of tourism due to the COVID19 pandemic, the water quality monitoring program has been funded by grants funds from Yayasan Hasanah starting in the end of 2020 till the end of 2022. KOPEL has been extremely grateful for this support to keep KOPEL's critical monitoring programs running.

Data collected is compared with the National Water Quality Standards for Malaysia to determine the status of water quality in the sampled area – refer to Figure 33, p.22 below (National Water Quality Index).

Figure 26: Garmin BaseCamp Map of Water Quality Sample Points, 2022

Kinabatangan River confluence to Pin River	SK1
Kinabatangan River confluence to KOPEL jetty	SK2
Tungog Rainforest Eco Camp (Tungog Lake)	TREC
Kinabatangan River confluence to Kaboi River	KB1
Kinabatangan River confluence to Takala River	ST2
Kinabatangan River confluence to Biandong River	BI

Analysis of Data 2022

I. **pH** values are stable amongst all sample points, SK1 (Sg. Kinabatangan/Sg. Pin), SK2 (Sg. Kinabatangan/Jetty KOPEL), SK3 (Sg. Kinabatangan/Sg. Takala), KB1 (Kuala Kaboi), B1 (Biandong) and TREC (Tungog Lake) – refer to figure 27, p.20. pH values ranging from 5.0 -7.0 and lie within class III of the National Water Quality Standards (refer to figure 33, p.22), indicating no detrimental effects of the quality of both the River and the Lake. Sample site TREC occupies the

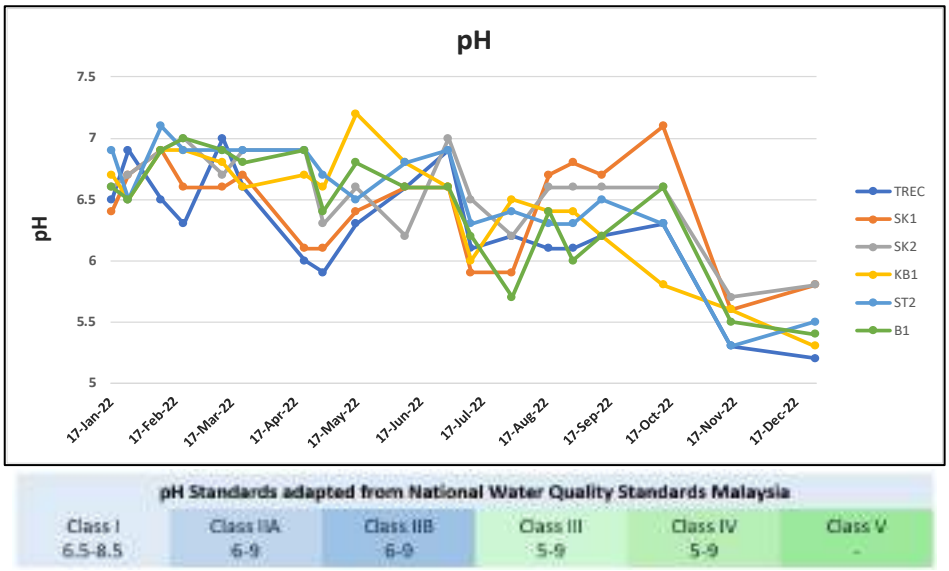
lower values, although the values are still neutral, neither acidic nor alkaline, therefore show no area of major concern regarding pH at this site.

II. **Dissolved oxygen** (DO) levels for sample points SK1, SK2, B1, and ST2 all remain relatively consistent occupying class IIA – class III in the national water quality standards – refer to figure 28, p.20. This is not that surprising given the location of the sampling points are located within the main channel of the Kinabatangan River. Even so, for a river of this magnitude the levels of D.O. are not a high standard, and an area of concern, to be watched into the future. Sample points KB1 values range from less than 1.0mg/L to 5.8mg/L – refer to figure 28**,** mostly occupying class III of the Malaysian Standard. This is attributed to influences of the peat swamp upstream from this point within the Pin Supu Forest Reserve. DO at KB1 dropped below 1 in end of April. At these times water quality drops to Class IV-V (worst quality) based on this parameter and is considered unusable based in the National Water Quality Standards. All samples at TREC were notably low, however, this has improved compared to the previous year 2021. Dissolved oxygen levels at TREC are consistently extremely low, the values range from 0.7mg/L – 2.5mg/L **–** refer to figure 28, p.20. This is mostly hypoxic (<2mg/L) and occupies class V of the MNWQS – refer to figure 33, p.22. At present the situation on the lake is attributed to the ongoing impacts of the Salvinia and Grass Sudds that cause excessive amounts of organic matter decaying within the lake's ecosystem. Although some fish are still present in Tungog lake, the levels of dissolved oxygen sampled in 2022 continue to pose a huge threat to biodiversity as well as aquatic dependent wildlife and birdlife species.

III. **Chemical Oxygen Demand** (COD): Across all sample sites in 2022, the Chemical Oxygen Demand (COD) data ranged predominantly between 10mg/L-25mg/L – refer to figure 30, p.21, fluctuating within class I, class IIA and class IIB – refer to figure 33, p.22, amongst all sample sites throughout the entirety of the year. A large spike in COD was observed during November 2022 which is SK1. At present it is not clear why this outlier result occurred and KOPEL is currently reviewing its internal reporting mechanisms to be more responsive to unusual results like this in the future.

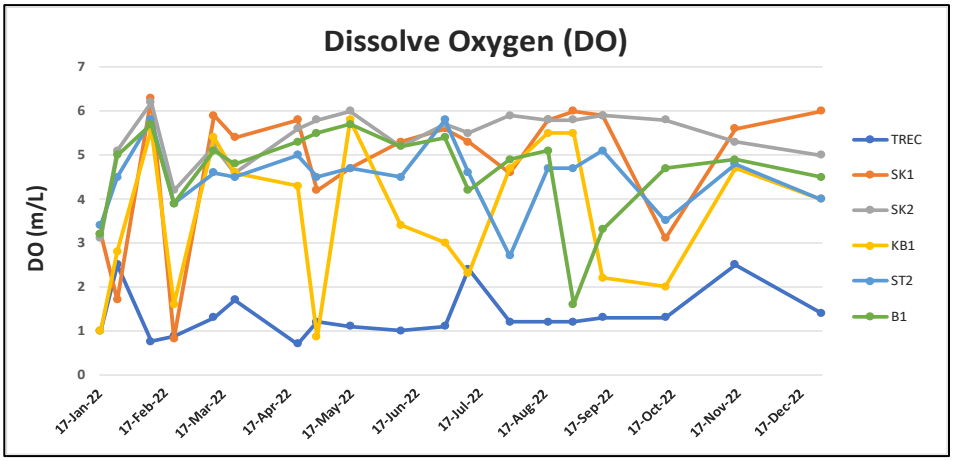
IV. **Clarity**: Water clarity, turbidity and suspended solids are directly related, being caused by the presence of suspended and dissolved matter, such as clay, silt, finely divided organic matter, plankton and other microscopic organisms, organic acids, and dyes. Even so, there is no direct conversion unit between these parameters. KOPEL measures water clarity in a water clarity tube, and is measured in cm. This is a good indicator of water quality, given the impact of sediment and light penetration on water quality. Even so, it has no direct point of reference measure in the Malaysian Water Quality Standard. Figure 31, p.21 shows water clarity measurements across all sampling locations.

V. **Ammoniacal Nitrogen**: NH4-N (ammonium), alongside NO2 (nitrite) concentrations were relatively stable for most of 2022 at all sampling sites. NH4-N remained consistent at 0.2mg/L for most sites, which means for this parameter these sampling sites fall into Class IIA or Class IIB – refer to figure 32, p.21. Ammonium, Nitrites (NO2) are closely related within the aquatic Nitrogen Cycle. Of these compounds only NO2 is of specific concern in terms of immediate toxicity for aquatic life such as fish. In this case NO2 did was measured consistently at 0.2mg/L. Based on national water quality standards this means the water quality falls within Class IIA or Class IIB. – refer to figure 33, p.22.



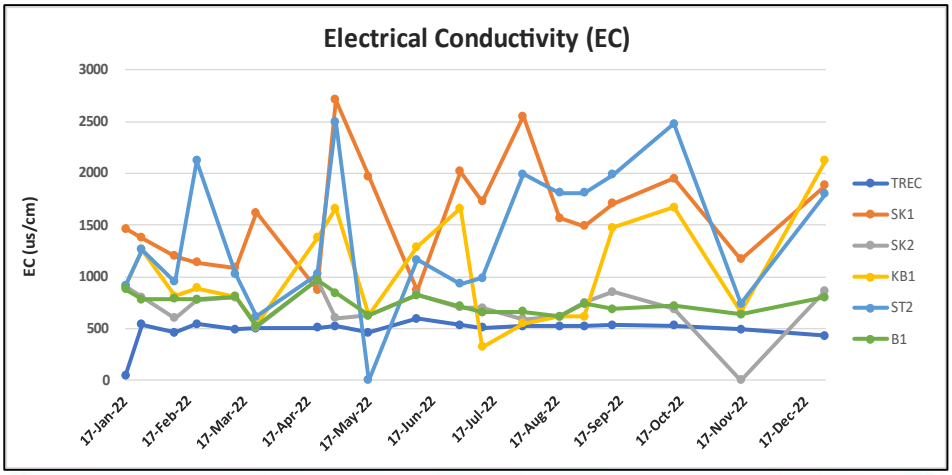
pH Standards adapted from National Water Quality Standards Malaysia					
Class I	Class IIA	Class IIB	Class III	Class IV	Class V
6.5-8.5	6-9	6-9	5-9	5-9	-

Figure 27: Water pH bimonthly analysis, 2022.



Dissolved Oxygen classes adapted from National Water Quality Standards for Malaysia					
Class I	Class IIA	Class IIB	Class III	Class IV	Class V
7 mg/L	5-7 mg/L	5-7mg/L	3-5mg/L	<3mg/L	<1mg/L

Figure 28: Dissolved Oxygen bimonthly analysis, 2022



Electrical conductivity Standards adapted from National Water Quality Standards Malaysia.					
Class I	Class IIA	Class IIB	Class III	Class IV	Class V
1000 µS/cm	1000 µS/cm	-	-	6000 µS/cm	-

Figure 29: Electrical Conductivity (EC) bimonthly analysis, 2022

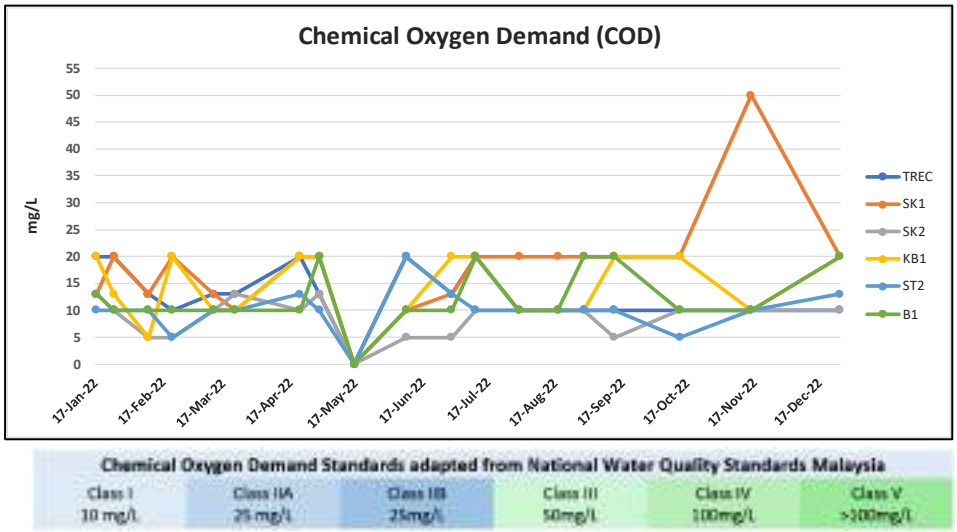


Figure 30: Chemical Oxygen Demand bimonthly analysis, 2022

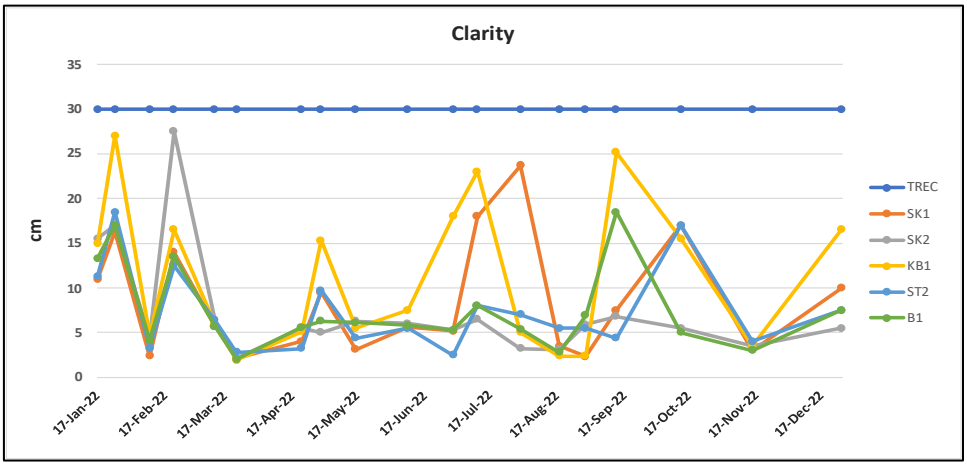


Figure 31: Clarity bimonthly analysis, 2022. Clarity is a measure of visibility to the human eye in meters, turbidity is measure of light scattered off particles in the water measured in nephelometric turbidity units (NTU), and TSS is a physical measure of dry weight of solids in mg/L. KOPEL compares water clarity across all sites. Note clarity at Tungog Lake compared to the river sampling points.

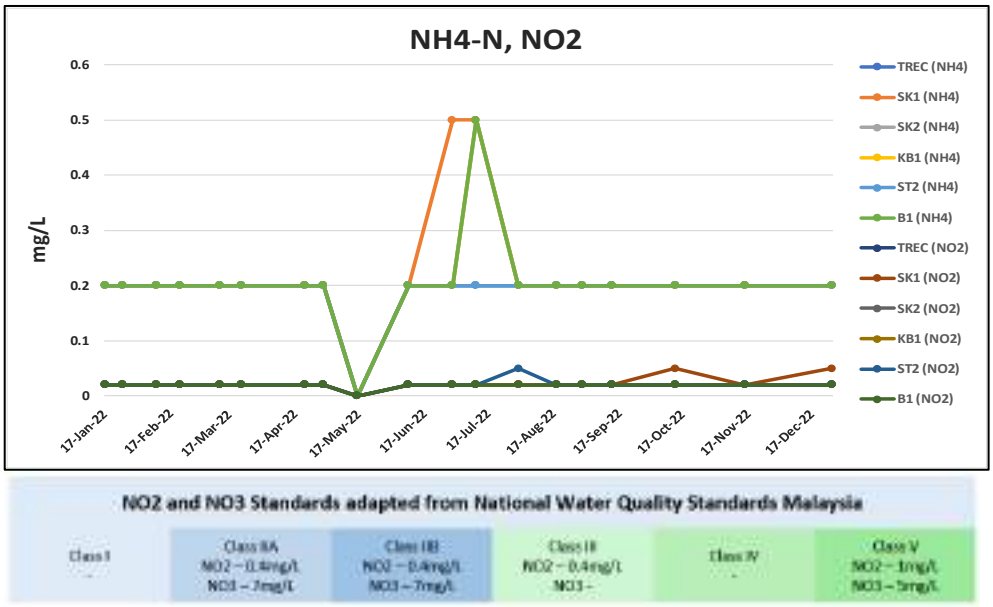


Figure 32: NH4-N and NO2 bimonthly analysis, 2022

CLASS	USES
Class I	Conservation of natural environment. Water Supply I - Practically no treatment necessary. Fishery I - Very sensitive aquatic species.
Class IIA	Water Supply II - Conventional treatment.
Class IIB	Fishery II - Sensitive aquatic species. Recreational use body contact.
Class III	Water Supply III - Extensive treatment required. Fishery III - Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation.
Class V	None of the above.

Figure 33: Table 3: Water classes and uses adapted from National Water Quality Standards for

Conclusions and Management implications

I. Based on water quality monitoring data and analysis for year 2022 there is insufficient evidence to suggest major pollution occurrence at the sampling points, nor is there need for immediate corrective action within any of the immediate surrounding areas upstream or adjacent to Pin-Supu Forest Reserve (i.e., in the headwaters of Pin- Supu Forest Reserve).

II. Tungog Lake continues to be a site with critical condition in terms of Dissolved Oxygen. This is attributed to the invasive weed *Salvinia molesta*, Grass Sudds, and excessive amounts of organic matter decaying within the lake. The aquatic life is threatened by the low oxygen conditions and imbalance in the ecology of the lake. Continuing the long-term integrated pest management approach involving the Salvinia weevil (*Cyrtobagous salviniae*) alongside physical removal is still recommended to improve the water quality and aquatic environment at the Tungog Lake.

III. The water quality monitoring program involves 100% the local community and supports (a) local awareness-raising, (b) employment benefits to the local community, and (c) inclusivity of local community in the co-management of Pin Supu Forest Reserve. For these reasons it is highly recommended that that the water quality monitoring should continue to be used for outreach programs and environmental educations programs moving forward.

IV. Based on the outcomes of measurable effectiveness indicators it is highly recommended that the water quality monitoring be revised, improved, and expanded to provide more effective feedback for management of PSFR. Improvements suggested including (a) the prevention of scientific error when sampling sites; (b) further training; (c) the establishment of a laboratory at KOPEL; (d) upgrading of sampling equipment; (e) installing auto logging monitoring stations; (f) installing hydrological stations across the surrounding PSFR and automatic weather station to corelate results, and; (g) the expansion of these efforts to partner with local research institutions to ensure the inclusion of other closely related monitoring such as hydrology monitoring.

Images and other references shown below:

Images below show snippets from water quality monitoring activities July-September 2022. The data collected is uploaded to KOBO Collect for recording purposes. Any significant issues found during the bimonthly monitoring are reported immediately to the relevant Authorities. Otherwise, the data is recorded for long-term trend analysis, which is done on a yearly basis (e.g., this report).

Figure 34: KOPEL HSG2.0 Water quality monitoring activities July-Sept 2022 – Kuala Sungai Takala

Figure 35: KOPEL HSG2.0 Water quality monitoring activities July-Sept 2022 at Kuala Sungai Kaboi

Figure 36 & 37: KOPEL HSG2.0 Water quality monitoring activities July-Sept 2022, Sg Kinabatangan

Figure 38 & 39: KOPEL HSG2.0 Water quality monitoring activities 2022, Analysing Water Sampling tools in action at Tungog Lake (July-Sept 2022)

KOBO Collect

KOPEL initiated online form data collection with KOBO Toolbox and KOBO Collect across all projects. The online data collection utilises handphones as data entry devise and enables all field staff to go paperless with their field data collection. This improves the accuracy of data collection because all form fields have built in data validation protocols. This also improves efficiency, as it eliminates the need for secondary data entry (for example in the office) after field work is complete.

The KOBO Collect form outcomes below are **examples** (only) of the field water quality data collected during September 2022.

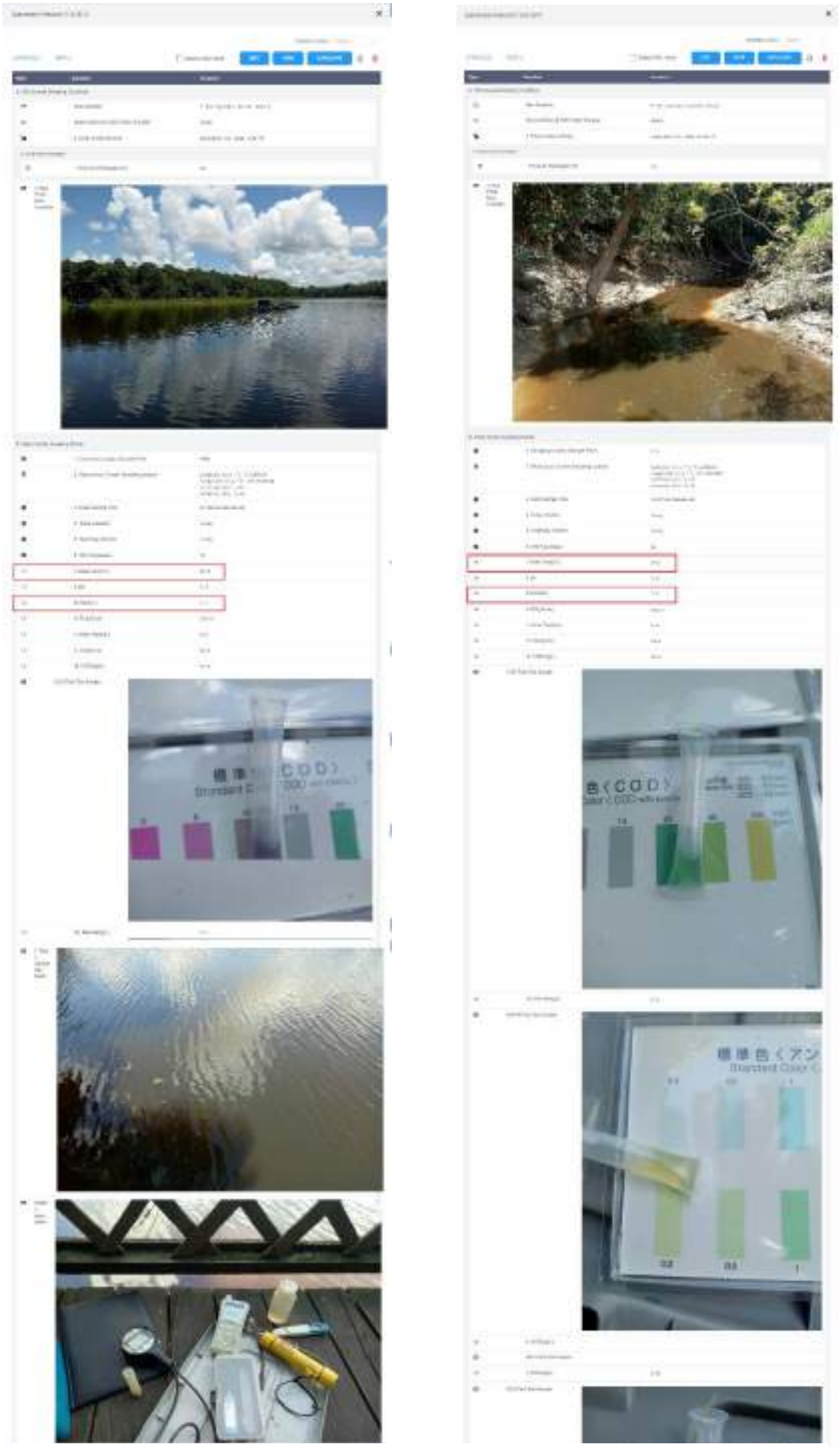


Figure 40 (above): KOPEL HSG2.0 Water quality monitoring data entry outputs July-Sept 2022. Water sample form entry results entered to KOBO Collect online form.

4. Lake Tungog Salvinia Removal Project

Background to Invasive Water Weed Removal Project at Tungog Lake

Salvinia (*Salvinia molesta*) is an invasive aquatic fern that originates from South America. In the Sabah context this plant is a harmful aquatic weed that has spread rapidly over the last 10-15 years across the freshwater lakes of the Lower Kinabatangan and other areas of Sabah. Salvinia weed infested the Tungog Lake between 2001-2002 during a major flood event. Enclosed ecosystems such as the Tungog Lake provide an abundance of nutrients at the perfect temperature for Salvinia growth. In these conditions the Salvinia grows extremely rapidly, forming thick floating mats that envelop the entire surface of the water. At the beginning of 2020, the Tungog Lake was 90% covered by the Salvinia weed.

The presence of Salvinia, covering the Tungog Lake, has caused major negative impacts on the overall aquatic ecosystem, aquatic biodiversity, species abundance, and the aesthetics of the Lake. Monitoring of the Tungog Lake water quality has been ongoing since 2012. The outcome of the monitoring demonstrates the toxic impacts of the Salvinia weed on this lake's ecosystem. Salvinia has had a direct negative impact on water quality such as dissolved oxygen, chemical oxygen demand, pH, clarity, and electrical conductivity (see Figure 51, p.30 below). In the Tungog Lake the Salvinia is a disaster for local fisheries and likewise the food abundance for many wildlife species.

Efforts to remove the Salvinia has been ongoing since 2005. In 2007 KOPEL completely cleared the lake of the Salvinia weed and had an active monthly maintenance program until 2013. For this work, KOPEL received a Sabah Environmental Award in 2009. During this period, the lake was completely open and clear of Salvinia, whereby many of the native wildlife species such as Otter (*Lutrogale perspicillata*, and *Aonyx cinereus*), Oriental Darter (*Anhinga melanogaster*), and Buffy Fish Owl (*Ketupa ketupu*) returned and were present at Tungog Lake.

Unfortunately, maintenance work ceased in 2013 for five months due to the Tanduo Crisis. The Tanduo issue inadvertently caused the closure of KOPEL operations during this time. During the five months closure, the Salvinia weed rapidly spread covering approximately 25% of the lake. Even though KOPEL reinitiated the manual removal activities, the Salvinia weed continued to spread, outpacing KOPEL's monthly maintenance programs (manual removal).

In **2014** efforts to rid the Tungog Lake of Salvinia water weed were expanded and shifted to a more integrated approach. This meant, in parallel with the manual weed removal work, KOPEL Bhd began a partnership with the Sabah State Government (namely the Sabah Agriculture Department), to initiate alternative ecologically sustainable approaches, such as the use of a biological control that is host specific to Salvinia. One such proven biological control agent is the beetle/weevil *Cyrtobagous salviniae*. This species has proven repeatedly to be **biologically host specific to Salvinia weed.**

Much of 2015, 2016 and 2017 was devoted to preparatory work, such as research, consulting, training, site comparisons, beetle sourcing, beetle collection, quarantine, and the breeding of sufficient population of beetles at the Agricultural Research & Quarantine Station at Tuaran. After this initial three years of preparatory work, and the subsequent establishment of release protocols, the weevil was released at the Tungog Lake on October 27th, 2018.

In parallel with the development of the biocontrol program grass began to colonise the thicker older growth salvinia to form thick floating islands (Grass Sudds). The formation of Grass Sudds is one of the notable and major environmental implications caused by delays to remove the Salvinia weed from the surface of Tungog Lake, and it began to appear as early as 2017. By the end of 2018 most of the Salvinia on Tungog Lake was covered by grass.

The implication of the Grass Sudds for the biocontrol is that the grass growth on top of the Salvinia thickens the weed mat and destroys the habitat for breeding and spread of the biocontrol agent (*Cyrtobagous salviniae*), lessening the impacts of the biocontrol program. Over time the grass and its roots bind the salvinia into extremely thick floating mats compounding the negative impacts of the floating weed on the ecosystem and lake environment.

Through the support of the Hasanah Foundation HSG Grant Program, KOPEL was able to re-initiate Salvinia and Grass Sudds removal from the Tungog Lake. This work began in late 2020 and has continued through to the end of 2022. During this period the KOPEL Salvinia Teams have cleared 77% of the Salvinia and Grass Sudds from the surface of the Tungog Lake. At the and of 2022 the reopening of the surface of the lake appears to have halted the declining water quality and it is now hoped that the lake will begin the process of recovery. Ongoing monitoring will continue to provide feedback on the lake health.

For the duration of the Hasanah Foundation HSG2.0 project, a total of **27 people** from the local community of Batu Puteh have been employed in the Salvinia Sudds removal (Salvinia component of this project only). A total of **6.74ha** of Salvinia was removed throughout the HSG2.0 Project in 2022. This brings the total Salvinia Sudds removed from the Tungog Lake to **11.95ha** (or 77% of the lake surface) through the support of Hasanah Foundation (See Figure 41 below).

It is important to recognise and note in this report that the Salvinia and Grass Sudds removal work is extremely difficult and laboursome. The work is carried out manually by boat and by hand. The KOPEL Salvinia team, work for long hours submerged in the water at the lakes edge (see Figure 45-50 below p.28-29). The large floating grass islands (Grass Sudds) are initially cut into small blocks using long-handled farm sickles and local jungle knives (parangs). These floating Grass Sudds are dragged directly to the edge of the lake using small wooden boats, where they are subsequently netted and hauled out of the lake via a rope and pulley-system. During flood events the Salvinia Sudds can be cut into small blocks and floated directly into the forest manually by the KOPEL Salvinia workers.

Figure 41 (above) BEFORE & AFTER KOPEL HSG2.0 Salvinia Removal Work (at Jan 31 2023)

Total Area Cleared HSG1.0 & HSG2.0 (January 2021 – January 2023) = 11.95ha

Figure 42 (above): KOPEL HSG2.0 Salvinia Team 1 – Sept 2021 – Feb 2022.

Figure 43 (above): KOPEL HSG2.0 Salvinia Team 2 – May - Nov 2022.

Figure 44 (above):: KOPEL HSG2.0 Salvinia Team 3 – December 2022.

Figure 45 (above): KOPEL HSG2022 Salvinia Team - Floating dragged by boat & pulley block system.

Figure 46 (above): KOPEL HSG2022 Salvinia Team – Dragging with **boat** & pulley block system.

Figure 47 (above): KOPEL HSG2022 Salvinia Team – Dragging with **boat** & pulley block system.

Image 48 (above): KOPEL HSG2022 Salvinia Team - Dragging with **boat** & pulley block system HSG2022

Figure 49 (above): KOPEL HSG2022 Salvinia Team - Dragging with **boat** & pulley block system HSG2022

Figure 50 (above): Tungog Lake North End – Jan 2023 – 3.6ha remains covered by Grass sudds

Tungog Lake's Response to Salvinia and Grass Sudds Removal: Water Quality Monitoring

Monitoring the freshwater aquatic ecosystem at Tunog Lake is an extremely important component of KOPEL's water quality monitoring program. Monitoring has been ongoing since 2012. KOPEL is extremely grateful to have had funding support from the Hasanah Foundation to continue the water quality monitoring program through the COVID19 pandemic period (2020-2022). The Tungog Lake monitoring program is an important part of these monitoring activities. Monitoring in the year 2022 included testing key water quality parameters as per the national standard (see previous section on KOPEL's water quality monitoring program, p.18-24 of this document). The monitoring program at Tungog Lake also includes sampling and analysis of the biocontrol beetle/weevil *Cyrtobagous salviniae*. The monitoring of the Biocontrol release program has been ongoing since 2018 (see biocontrol update report next page, p31)

Analysis of key water quality parameters tested on Tungog Lake in 2022 indicate that the water quality in the Tungog Lake has turned a corner and is trending towards improvement. Results were very promising in 2022, given the average the situation with water quality on the lake has been in decline over the last 10 years, since 2013 (see Figure 51 below). The previous trend of decline in water quality correlates with the increasing cover of Salvinia weed and Grass Sudds during that period. The peak cover of Salvinia and Grass Sudds on the Tungog Lake (almost 90% cover) was in the year 2020. The return to pre-Salvinia water quality will likely take considerable time, given the extent of the organic material decaying within the lake ecosystem. Even so, given that opening the lake surface (now 80% open) provides additional mechanisms for oxygenation it is expected that the lake will begin to recover.

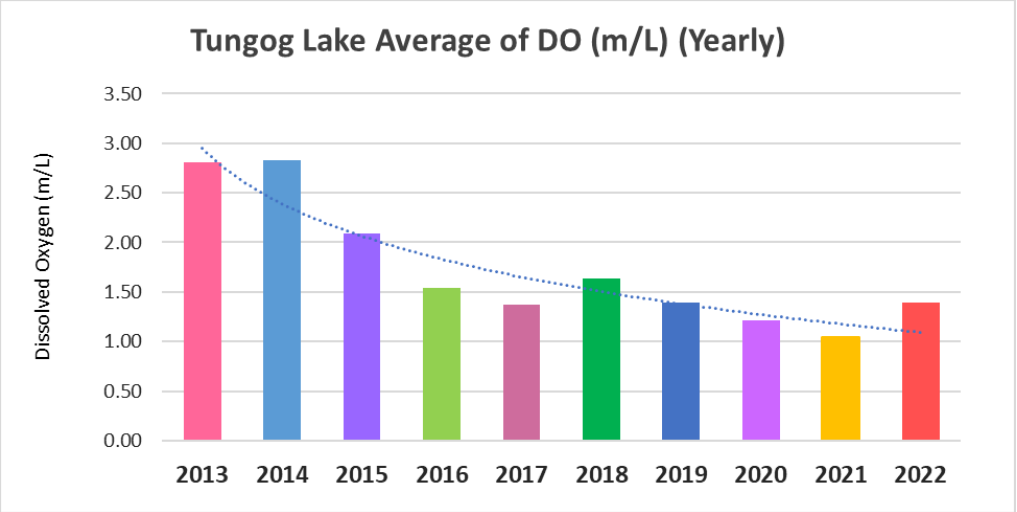


Figure 51: Tungog Lake comparison of average annual Dissolved Oxygen (DO) measurements 2013 - 2022.

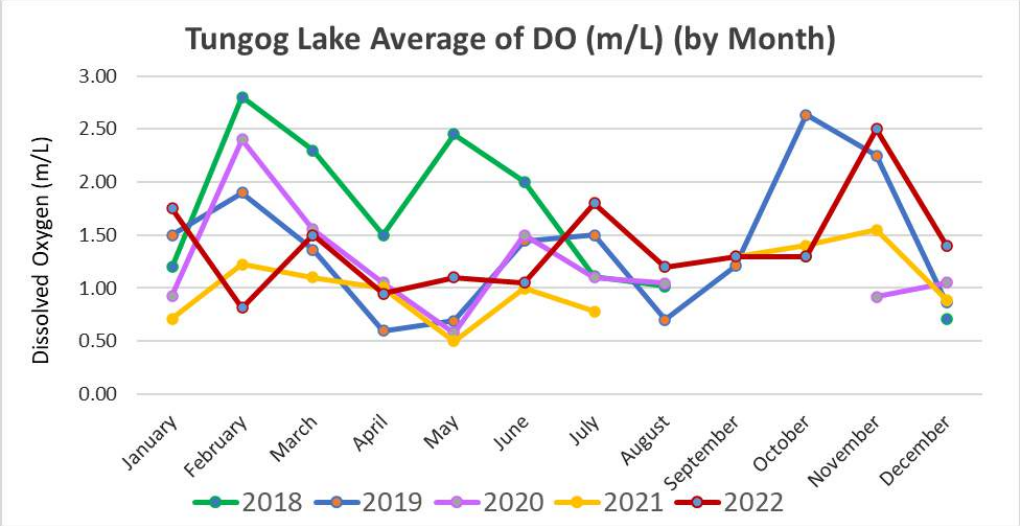


Figure 52: Tungog Lake comparison of monthly Dissolved Oxygen (DO) measurements 2018 - 2022.

Salvinia Weevil Monitoring

Post release monitoring was immediately initiated following the monitoring protocols established by the Sabah Agriculture Department. In parallel with the weevil release monitoring, KOPEL is continuing to monitor the overall aquatic ecosystem of the Tungog Lake and any broader ecological impacts (refer to previous section).

Twelve (12) sample sites were established around the lake to monitor the progress of the weevil and its impacts on the Salvinia weed and surrounding habitat. The Water Float Trap (WFT) methodology is used for Salvinia weevil population sampling. This involves collecting 1kg samples of Salvinia weed and drowning the samples for 24-48hours to force the adult weevils to surface for oxygen. After the adult beetles surface, they can be captured for counting, and hence determine the presence or absence of the weevil adults within the Salvinia sample. The Salvinia samples were also assessed for plant damage as a result of the weevil's presence. Damaged buds are one indicator of weevil activity due to a direct relationship between the amount of bud damage and adults present.

The results of the ongoing monitoring activities in 2022 confirm the weevil is still present around the very first release site and have spread in small numbers to various sites within 100-200m of the initial release.

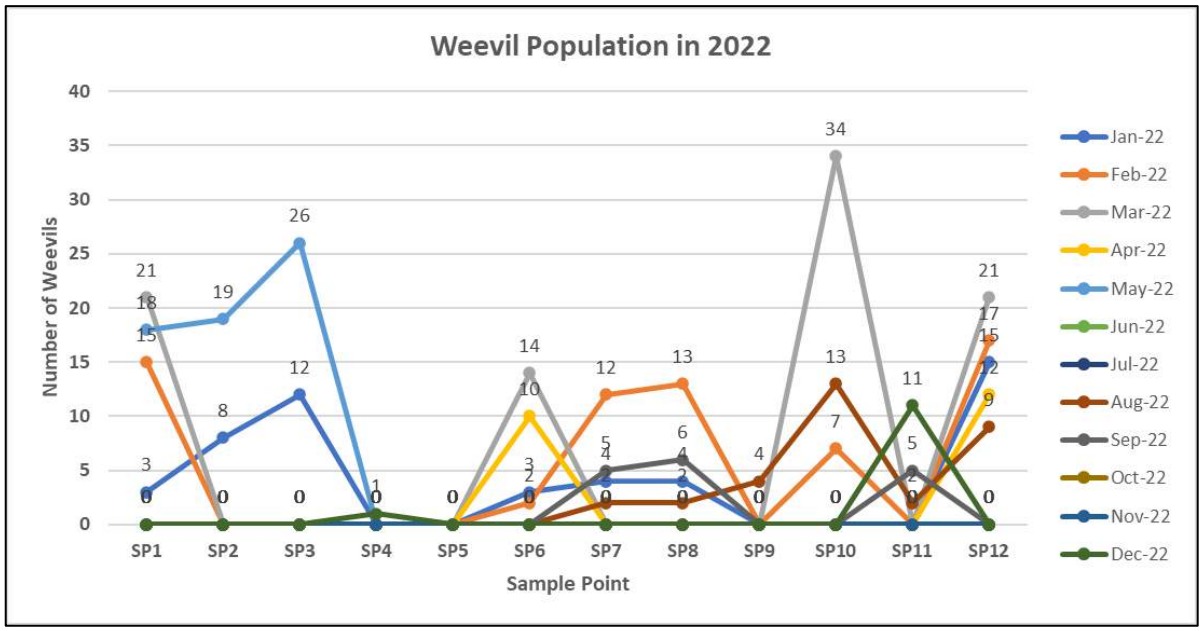


Figure 53: Weevil beetle count per 1kg Salvinia sample at each Sampling Point.

Sampling results for the year 2022 are summarised as follows:

I. Sampling in 2022 demonstrated a significant number of Salvinia weevils were present at almost all sample points. The two sample points SP4 and SP5 with zero Salvinia weevils counted is because of no fresh salvinia was found at these sites for testing the presence of of the biocontrol beetle/weevil *Cyrtobagous salviniae*.

II. It should be noted that, no sampling activities in June, July, October, and November 2022, and no sample were taken at some sampling sites (especially SP4, SP5, and SP9). This is due to manual Salvinia removal activities during at these sites, and the lack of fresh Salvinia growth at these sites for weevil population testing.

III. Sampling over the reporting period of 2022 exhibited notable fluctuations in beetle count at several sample points, in both a positive and negative direction, over the year. This indicates that

the beetle is extremely sensitive to external environmental factors, such as the ongoing Salvinia removal work.

IV. At the end of this monitoring period, it is uncertain precisely what factors are causing the rise and subsequent decline in population at the sampling sites, but several factors are still being investigated such as:
    a. The physical disturbance to the beetle habitat caused by the ongoing removal Salvinia during manual removal efforts by KOPEL and volunteers at these locations.
    b. The thickening of the Salvinia into Stage III Salvinia mats, causing a degradation of optimal Salvinia habitat for the weevil.
    c. The incursion/invasion of grasses on top of the Salvinia, causing a degradation of optimal Salvinia habitat for the weevil.
    d. Corresponding decline in Dissolved Oxygen in the primary weevil habitat in the very upper photic (epilimnion) zonation (surface 20cm). Severe decline in DO in this zonation is caused by the decomposition of Salvinia mats and grass roots holding the decomposing Salvinia from dropping to the bottom of the lake.

Management Implications

I. Based on the monitoring of Salvinia weed, Grass Sudds and water quality on the Tungog Lake, the Salvinia weed and subsequent Grass Sudds covering Tungog Lake remains an immediate and major threat to Tungog Lake and the freshwater aquatic ecosystem. Tungog Lake is already identified as HCV3.0 and is of critical importance to Malaysia at the site specific, ecosystem and landscape levels. Ongoing Water Quality monitoring at the lake has highlighted the decline in dissolved oxygen to chronic hypoxic levels, this is the direct impact of the Salvinia and Grass Sudds covering the lake. Therefore, continuing the removal of the Salvinia and Grass Sudds from Tungog Lake is of critical importance for the survival of this special place and its unique aquatic ecosystem.

II. Decline in dissolved oxygen (DO) and the presence of the Grass Sudds is described in as the major impediment to the success of the biocontrol program, hence designing solutions to physically remove the Grass Sudds and increase the dissolved oxygen levels in the upper photic zone will be critical moving forward. More work should be done to overcome these key related issues. In parallel with this, continuing to monitor the impacts of the Salvinia weevil will be of the upmost importance in management approaches to controlling the Salvinia on Tungog lake in the future.

III. Based on the monitoring of Salvinia and biocontrol on Tungog Lake it is apparent that reliance on one specific method, albeit biocontrol OR manual removal alone, will remain insufficient to remove the threat of the Salvinia, especially the later stages where Grass Sudds have developed on top of the Salvinia.

IV. In this regard, it is recommended that Salvinia removal efforts continue to be integrated and continue to involve both biological control and manual, physical, or mechanical methods on the Tungog Lake, until the lake is fully restored.

V. In the short-term mechanical methods will remain imperative and must be continued given the Salvinia weevil (*Cyrtobagous salviniae*) is a not suitable mechanism to overcome the Grass Sudds impacting the lake. Hence, funding or investment in mechanical approaches should be sought in the short to medium-term.

VI. The efforts on the Tungog Lake could be expanded to help the 10 other oxbow lakes covered by Salvinia in the Lower Kinabatangan. The Tungog Lake could be viewed as a testing ground for best

practices, whereby lessons learned, or techniques developed, can be transferred to other sites in the region.

VII. November 2022 marked four years since the release of the Salvinia weevil (*Cyrtobagous salviniae*). At the end of 2022, there are **positive signs that the weevil population growth is combatting the regrowth of Salvinia on Tungog Lake**. For example, numbers of weevils are increasing in areas of fresh Salvinia growth, this is consistent with the literature and experience in other sites globally – stage II Salvinia being optimal habitat for *Cyrtobagous salviniae*. This observation will remain one of the critical factors to monitor moving into the future.

VIII. Based on the outcomes of measurable effectiveness indicators it is recommended that the monitoring efforts on Tungog Lake be expanded to improve feedback into the management of the PSFR and likewise to help improve conservation and restoration efforts on the Tungog Lake. Improvements suggested include: (a) establishing a detailed and in-depth profiling of Tungog Lake to monitor more facets of this unique aquatic ecosystem, (b) expanding the collaboration and partnerships to local universities and research partners to support building local capacity to continue monitoring of Tungog Lake, and (c) expanding the collaboration and partnerships with volunteer organisations to support the manual removal of the Salvinia water weed.

IX. Any final note should include that KOPEL will continue to source funding and continue its efforts to remove the remaining Grass Sudds on Tungog Lake. KOPEL is also committed to maintaining the water quality monitoring on the Tungog Lake alongside looking for new and innovative ways to restore and improve the water quality on the Tungog Lake.

Figure 53 (above): Drone Shot by KOPEL Team working on Salvinia funded by Hasanah Foundation January 2023

KOPEL acknowledges the support of many individuals, including KOPEL staff members, and partners in support of conservation efforts on the Tungog Lake and expresses sincere gratitude for funding support provided by the Hasanah Foundation for the duration of the COVID19 pandemic and the proceeding period of normalisation for the year 2022.

5. Cave Restoration & Monitoring

KOPEL has identified more than 11 limestone cave systems within the Supu Hills Limestone Complex located at the northwest side of the Pin-Supu Forest Reserve (PSFR)(see Figure 54 below). The caves in this area have high conservation value with distinctive limestone formations, antiquity-related artefacts, and specialised cave fauna, all of which are significant aspects of HCV3.0 for PSFR. KOPEL began active conservation and restoration efforts in the Supu Limestone Caves in 2010 after receiving support from Sabah Wildlife Department to manage and restore the swiftlet population within the caves.

Figure 54: Map of main Cave Chambers in Supu Limestone Complex

Three full-time forest rangers have been employed by KOPEL in 2022 to safeguard the caves within the Supu Limestone Complex. The work of the ranger team is designed to maintain a constant presence at the caves and prevent intrusion into the caves, whilst maintaining the facilities and trails. The rangers are based permanently on rotation at the Supu Adventure Camp adjacent to the Supu limestone complex.

Prior to KOPEL's management of this area there has been very little in the way of scientific study of the caves systems in this area. In 2018 KOPEL formed a short-term partnership with The Rufford Foundation to conduct preliminary scientific exploration of the caves under the Cave Biodiversity Conservation Project in Lower Kinabatangan, Sabah, and Malaysian Borneo. The study detail is described below:

Cave and Karst fauna conservation in Pin Supu Forest Reserve

I. The first phase of the project involved the training of local conservation staff regarding basic cave survey techniques, including cave mapping & sampling of cave fauna. Phase 1 involved, exploring Supu limestone hills, mapping a selection of caves and compiling information on the history of cave-use via interviews with local people. This field work also involved specimen collection to establish baseline data on species richness and endemism of cave-adapted beetles and Micromollusks in the area.

II. The second phase of the project was the identification of the material and data collected and the analysis of the data collected during the first phase of the project. Combining the data collected

in the field with existing materials at University Malaysia Sabah is designed to support the development of organized inventories for each cave, alongside measure species richness, and also help determine cave endemism. The work in this phase involved KOPEL staff wherever possible. The purpose of the local involvement was to help disseminate information locally and build local skills in analysis techniques alongside the creation of promotional materials to be used for educational activities and public presentations.

III. The last phase of the project focused on education and raising environmental awareness. Two sessions were organised to share information on the process and findings about cave life were delivered to local primary school students from the Batu Puteh community. An excursion was also organised to the caves for local school students to explore hands on involvement of young school students in bio speleological investigations. This program was designed to provoke interest in disciplines associated with cave explorations. Towards the end of the project, findings were presented to staff and students at KOPEL, Danau Girang Field Centre, and University Malaysia Sabah. Other invitees were conservation officers from the Sabah Wildlife Department, Sabah Forestry Department, and the Minerals & Geosciences Department at UMS.

Important caves access trails were mapped out to prepare for the scientific exploration at the Supu Caves. Cave mapping within selected caves used specially modified laser rangefinders combined with and connected to mobile phone apps, the chambers of three cave were mapped out in this exploratory phase. An example of the cave maps developed during the study is shown below – see Figure 55 below

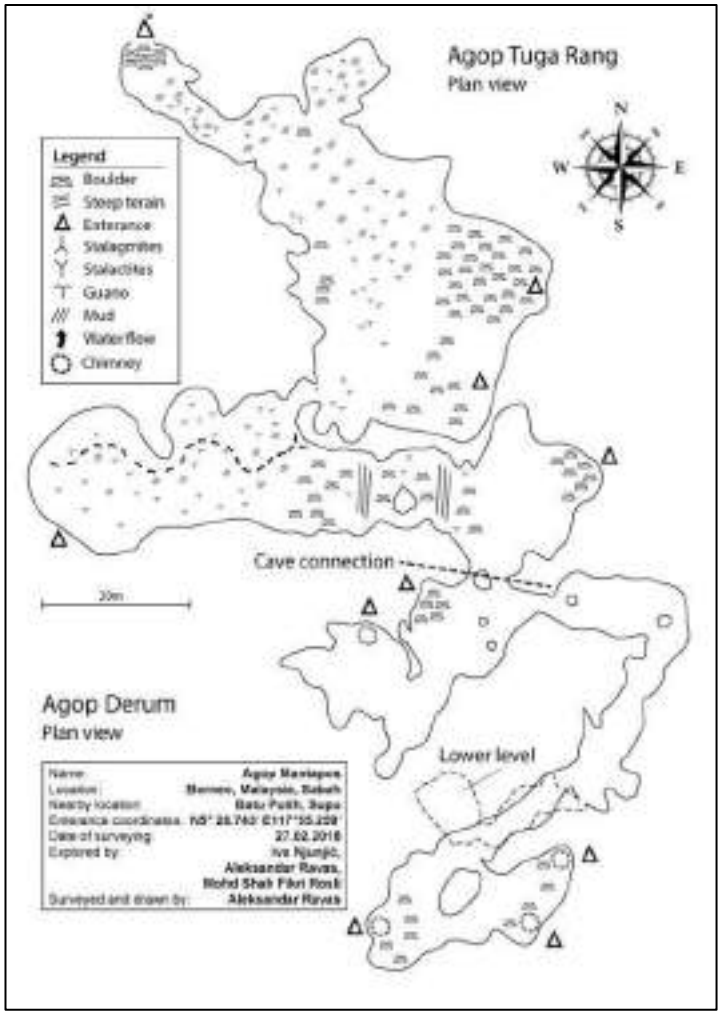


Figure 55: Cave mapping plan from The Rufford Foundation Study (Plan)

Swiftlet Nest Monitoring

In 2022, nest counts were carried out in January 2022 (see Figure 57 below). The results below are a summary of the nest counting work. The methodology of the nest surveys involves (a) counting all nest within the caves, (b) counting nest with eggs or young swiftlet (these are left undisturbed and untouched), and (c) collection of abandoned nests. The outcomes of the nest counting survey is shown in Figure 56 below.

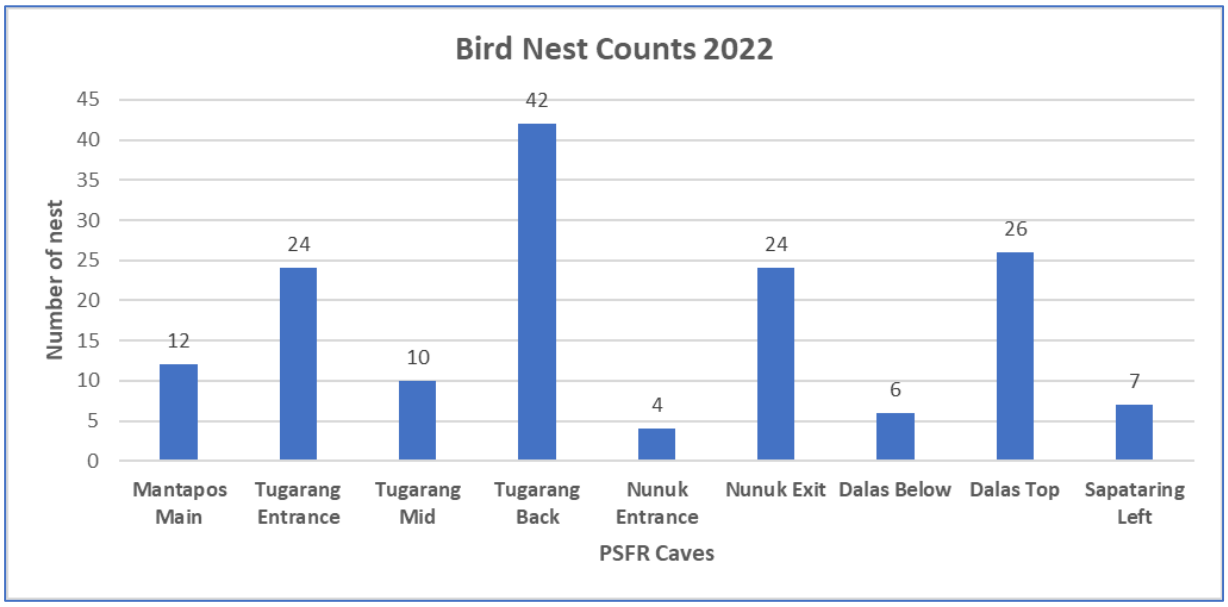


Figure 56: Birds nest counts from survey in January 2022

Management Implications:

I. Based on the overall outcomes of the preliminary cave fauna survey, it is understood there remains a lack of knowledge and research into unique habitats such as the limestone caves, hence it is recommended that the monitoring be expanded to cover all aspects of cave fauna and cave conservation in the future. The data and results can be used to improve the practice in management and monitoring the caves into the future.

II. Results of nest count monitoring shows a notable increase in the population of nesting swiftlets in the caves of the Supu Limestone Complex. This is considered a positive indicator for conservation efforts within Pin Supu Forest Reserve.

III. From a management perspective the increase in nest count is also a positive indicator of the health of the forest ecosystem within PSFR and is likewise considered a positive indicator of forest protection efforts across the reserve.

IV. It is recommended that the State Government strengthen the management and conservation of the caves by strengthening their legal and administrative arrangements with KOPEL Bhd, e.g., via a Memorandum of Understanding (MOU) that will incorporate the protective and conservation functions of the work, whilst permitting the utilization of swiftlet nests harvested during the nest counting activities.

V. The proposed MOU has already been forwarded to SWD and SFD and is designed to provide an avenue to generate revenue for KOPEL to support the protection activities and reinvest in the management and infrastructure of the sites. These steps should also remove swiftlet nests in a timely manner to deter poaching within the caves and encroachment in the reserve more generally.

Figure 57: Bird nest survey 2022

Closing Remarks:

In summary ongoing monitoring work has been effective and continues to have consistent outcomes, no other major changes are suggested apart from what has already been outlined in this document. It is important that this work continues into the long-term hence ensuring reliable and consistent income into this program is paramount to its success. Income generation mechanisms are also hoped to be expanded to benefit expanded monitoring activities in the future.

KOPEL Bhd continues to work closely with numerous partners both in the preparation and analysis of data collected for the monitoring in 2022. KOPEL Bhd acknowledges and is extremely grateful for the efforts of students, volunteers, KOPEL staff, and the staff of Sabah Forestry Department and Sabah Agriculture Department. Special thanks is extended to Yayasan Hasanah for financial support to keep the monitoring activities going through the COVID19 movement control orders in 2020 and cessation of tourism activities. It is hoped that future partnerships can be established with Sabah Wildlife Department and other research institutions (such as UMS and Danau Girang Field Centre) to further build local capacity within KOPEL Bhd to strengthen monitoring and protection activities.

It is also hoped that the monitoring work can be expanded and improved to support better management of the forests and ecosystems around the Community of Batu Puteh and in the process further the knowledge and skills transfer to the community, the education of students, and economic benefits to the community, alongside improved conservation of the HCVF values into the future.