KOPEL FOREST ENVIRONMENT MONITORING REPORT 2021

Background & Introduction

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.

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 by.

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 reporting period 2021, conservation activities and monitoring efforts start to scale up again after the Malaysia government movement control order (MCO) because of COVID19 pandemic, and the collapse of income from tourism in 2020. The core monitoring activities were maintained by KOPEL, and KOPEL is extremely grateful for the support provided by the Sabah Forestry Department, Cardiff University, the Green Steps Group, and Yayasan Hasanah in 2020.

This report is designed to provide an overview and summary of the monitoring outcomes in 2021. 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 effort still ongoing in 2021, albeit impacted by the COVID19 pandemic and the Movement Control Restriction (MCO) in beginning mid-March 2020. Tourist arrivals are still lower in 2021, and the entry of foreign tourists is still restricted which led to cancellation of large student groups in 2021. However, the reforestation project is still being pursued by Kopel Forest Restoration team and total of tree planted in 2021 more than before.

A total of 13,510 trees were planted in 2021, combining tourism & voluntourism activities and other externally funded trees planted by the KOPEL restoration team. This year, more trees planted by KOPEL restoration team then tourist due to cancellation of large student groups. Table 1 (below) shows the overall planting totals for each site planted and a breakdown of species planted on each location. Summary of planting as follows:

A total of 17 species were planted with the bulk of the trees being Bongkol (*Nauclea sp*. = 8331), Salongapid (*Mallotus muticus* = 1753), Payung-payung (*Terminalia copelandii* = 900), Binuang (*Octomeles sumatrana* = 592), and Kayu malam (*Diospyros sp.* = 386).

	Local Name	Scientific name	Kaboi Lake 1.0	Kaboi Stumping 1.0	Laab Swamp 1.0.	Kaboi Lake 2.0	Laab Swamp 2.0	Kaboi Stumping 2.0	Ladang Kinabatangan	Total
									Tourist planting	
1	Bongkol	*Nauclea sp.*	1,582	874	947	1,384	1,717	1,788	39	8,331
2	Salongapid	*Mallotus muticus*	305				559	886	3	1,753
3	Payung2	*Terminalia copelandii*	90	210	506	35	10	24	25	900
4	Kelumpang	*Sterculia sp.*		70	30	30	5	24		159
5	Binuang	*Octomeles sumatrana*		131	56	49	100	199	57	592
6	Terosob	*Dracontomelon sp*		100		30	151	84	36	401
7	Kayu malam	*Diospyros sp.*		310	30		5	41		386
8	Kerodong	*Microcos crassifolia*		361						361
9	Keruing Paya	*Dipterocarpus sp.*		140	30	30	5	70		275
10	Mangkapon	*Colona serratifolia*	33							33
11	Sepat	*Mytrogyna spesiosa*			85		39		5	129
12	Bayur	*Pterospermum sp*		57			23	36		116
13	Pulai	*Alstonia sp*	56							56
14	Durian	*Durio sp.*		1		2	3	2		8
15	Tarap	*Artocarpus odoratissimus*		1			3			4
16	Keranji	*Dialium spp*					5			5
17	Belian	*Eusideroxylon zwageri*							1	1
		Grand Total	**2,066**	**2,255**	**1,684**	**1,560**	**2,625**	**3,154**	**166**	**13,510**

Table 1: Tree species planted at each planting site 2021

Three (4) key areas were planting in 2021, as follows:

Kaboi Lake Restoration Site (Alluvial Seasonally Flooded Forest)

Kaboi Lake Restoration Site is a seasonally flooded alluvial 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 also accessible by boat, but only during high water (flooding) events via the Kaboi River Tributary (Creek). Work on this site was funded in 2020 by the Cardiff University Regrow Borneo Initiative and is the first of five sites focusing on long-term monitoring to support KOPEL to monitor carbon sequestration and restoration ecology across a variety of floodplain forest types.

New block were open in this location which is Kaboi Lake 2.0 (1.3 ha), a total of 1560 trees from seven species were planted and the most planted tree is Bongkol (*Nauclea sp.* = 1384). Kaboi Lake 1.0 were replanted again because all the previous tree die cause of flooded, 2066 trees has been planted again in this area.

Figure 1: Location map – Kaboi Lake 1.0 & Kaboi Lake 2.0 Restoration site.

Kaboi lake is one of the problematic sites which every year will experience severe flooding over 1m in depth on this site. Following the flood, this locality saw high fatality rates. Despite the lack of a post monitoring audit (stock-check), it was estimated from visual inspection that more than 90% of the trees were lost in this single flood episode. Based on post-flood monitoring findings, many of the remaining trees had additional damage from wildlife.

Kaboi Stumping Restoration Site (Alluvial Seasonally Flooded Forest)

Kaboi stumping restoration site, is a riparian site in Pin Supu Forest reserve. In 2020, a total 453 trees were planted in both small gaps within degraded forest at this site which is riparian area. In 2021, two block were open for restoration site under Regrow Borneo project. First is Kaboi Stumping 1.0 (2.38 ha), a total 2255 trees (11 species) were planted and some of the species chosen is Bongkol (*Nauclea sp.* = 874), Kerodong (*Microcos crassifolia* = 361) and Kayu malam (*Diospyros sp.* = 310). Second is Kaboi Stumping 2.0 (2.0 ha), a total 3154 trees (10 species) were planted and the most planted is Bongkol (*Nauclea sp.* = 1788), Salungapid (*Mallotus muticus* = 886), and Binuang (*Octomeles sumatrana* = 199).

Figure 2: Location map – Kaboi Stumping 1.0 & Kaboi Stumping 2.0 Restoration site.

Ladang Kinabatangan Restoration Site (Riparian Forest)

The restoration site known as Ladang Kinabatangan is a riparian 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 encroached upon by the adjacent plantation company. This year a total 166 trees (seven species) were planted by tourist which is Binuang (*Octomeles sumatrana* = 57), Bongkol (*Nauclea sp*. = 39), and Terosob (*Dracontomelon sp*. = 36).

Figure 3: Location map – Ladang Kinabatangan Restoration site.

Laab Restoration Site (Alluvial Swamp Forest)

Laab is a permanently waterlogged swamp forest, in Pin-Supu Forest Reserve. New blocks were open in this site which is Laab 1.0 & Laab 2.0.

A total 1684 trees from seven species were planted at Laab 1.0, among the trees planted are Bongkol (Nauclea sp. = 947), Payung-payung (Terminalia copelandii = 506), and Sepat (Mitragyna speciosa = 85). Whereas a total 2625 trees from 13 species were planted at Laab 2.0, among the trees planted are Bongkol (Nauclea sp. = 1717), Salungapid (Mallotus muticus = 559), and Terosob (Dracontomelon sp. = 151).

Figure 4: Location map – Laab 1.0 & Laab 2.0 Restoration site.

Monitoring of Permanent 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 area adjacent to PSFR.

Figure 5: 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 are now nine (9) tree species, not including shrubs, vines, and grasses, within the PSP. **Plot KP02 & KP03** are the riparian corridor on the southern Kinabatangan Riverbank adjacent to

PSFR. This site was planted between 2014-2015. Both study plots 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 2021, new three plot were open which is **KP04, KP05**, and **KP06**. This permanent sample plot project was under Hasanah Foundation Grant HSG1.0 which is to support the community during the Covid19 pandemic. KP04 were located at Tungog Rainforest EcoCamp (PSFR – Block A), KP05 located at Laab which is alluvial swamp forest area (PSFR - Block B), and KP06 were located at Kaboi Lake area (PSFR – Block A).

This year, KOPEL more focus on completing each permanent sample plots (PSP) so it can be easier to find and measure than before. All the trees inside the plot were proper tagged and mapping by KOPEL staff.

Figure 6: KOPEL HSG2020 Carbon Plot Team – Preparing Tree Tags

Figure 7: KOPEL HSG2020 Carbon Plot Audit & Verification Team – Measuring DBH (girth) of Tree

Recommendations:

Based on more than 20 years of restoration efforts by KOPEL Bhd, there is still a great need for more diverse array of science to support the forest restoration efforts. KOPEL is seeking partners in both academia and industry to work in this area to support research efforts especially restoration ecology and various aspects of science that support the forest restoration efforts. KOPEL aims to upscale the forest restoration efforts over the next year and focus attention on carbon stocking alongside biodiversity conservation.

2. 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 since 2012 and has compiled a large bank of data on the wildlife within Pin Supu Forest Reserve. In 2021 a total of 12 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. In the Pin Supu Forest Reserve case, this 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. It is expected that only through the implementation of a consistent and longterm study (e.g., for a period of more than 5 years), will sufficient data be made available for the analysis of long-term trends.

The ongoing monitoring by KOPEL, has already determined the presence of several critically endangered, vulnerable, and threatened species of wildlife within this forest management unit. 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.

Further to this, the current monitoring scenario 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.

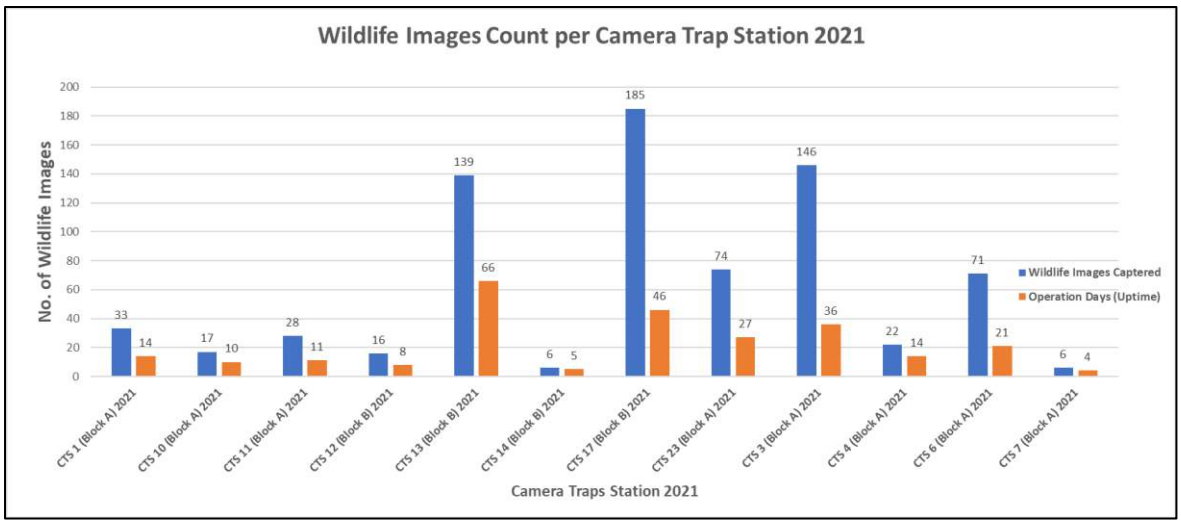

Figure 8: Number of Wildlife Pictures and Operation Days at 12 Camera Trap Stations 2021

Figure 9: Map of Camera Trap Station (2021)

Forest management planning has already taken into consideration the sensitivity of the PSFR through the establishment of HCVF values, 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, improved based on current camera technology, and expanded to meet the ongoing monitoring requirements of the forest managers of PSFR.

Camera trap monitoring in 2021

This report is a short summary of the analysis and findings for the monitoring year 2021. This report also concludes, with a list of implications for management, improvement on the analysis, and designed to provide feed-back into the annual revisions of the PSFR Forest Management Plan.

In 2021, 12 camera traps have been deployed at KOPEL camera trap station (CTS). Eight camera traps have been deployed in the southern part of the Pin Supu Forest Reserve (Block A) and these eight camera traps were set-up all in Riverine Dipterocarp Forest or Seasonally Flooded Alluvial

Swamp Forest. The other four camera traps were deployed in the northern part of the Pin Supu Forest Reserve (Block B) and these four camera traps were set up on the ridge of Supu Hill where it is located in Limestone Forest (refer figure 6).

The data that has been collected 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

Pictures from the camera traps were added manually using computer which are divided into folders and species in the picture were identified. The number of individuals were recorded and for the sex of individuals is hard to tell or identify because of the picture quality. Images of humans, unidentifiable species, or images with no animals (camera trap triggered by the movement of vegetation and the wind) were not included in the analysis. To characterise species diversity within a community, Shannon's and Simpson's index of diversity were calculated, which account for both evenness and richness. When employing Simpson's index, a higher Shannon's index value represents a more diverse community, while a value of one represents infinite diversity.

Based on the camera traps data, of all the known and previously recorded species only the clouded leopard *Neofelis nebulosi* and Asian Elephant *Elephas maximus*, was not captured in 2021. Even so, many other notable species were captured including the Critically Endangered Orang utan Pongo pygmaeus, the endangered Proboscis monkey *Nasalis larvatus,* and endangered Storm's stork *Ciconia stormi* (Table 2).

There are 733 total of individuals were recorded comprising 29 species (19 species of mammals, 9 species of birds, and one species of reptile). A total of 502 mammals, 230 of birds, and one reptile were recorded (see table 2).

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Species name	IUCN Status	Total Individuals
Long-tailed Macaque (*Macaca fascicularis*)	LC	195
Lesser Adjutant (*Leptoptilos javanicus*)	VU	134
Pig-tailed Macaque (*Macaca nemestrina*)	VU	57
Common Treeshrew (*Tupaia glis*)	LC	45
Crested Fireback (*Lophura ignita*)	NT	43
Orang Utan (*Pongo pygmaeus*)	CR	42
Storm's Stork (*Ciconia stormi*)	EN	41
Common Porcupine (*Hystrix brachyura*)	LC	38
Lesser Mouse Deer (*Tragulus javanicus*)	DD	35
Malay Civet (*Viverra tangalunga*)	LC	19
Squirrel (unknown) (Unknown)	-	16
Sambar Deer (*Rusa unicolor*)	VU	14
Common Palm Civet (*Paradoxurus hermaphroditus*)	LC	12
Malay Badger (*Mydaus javanensis*)	LC	9
Great Argus (*Argusianus argus*)	VU	6
Moon Rat (Echinosorex gymnura)	LC	4
Bearded Pig (*Sus barbatus*)	VU	4
Banded Palm Civet (Hemigalus derbyanus)	NT	3
Rat (general) (Unknown)	-	3
Malayan Sunbear (Helarctos malayanus)	VU	2
Smooth-Coated Otter (*Lutrogale perspicillata*)	VU	2
Oriental Bay-owl (*Phodilus badius*)	LC	2
Greater Coucal (*Centropus sinensis*)	LC	1
White-Crowned Shama (*Copsychus stricklandii*)	LC	1
Buffy Fish-Owl (*Ketupa ketupu*)	LC	1
Proboscis Monkey (*Nasalis larvatus*)	EN	1
Banded Linsang (*Prionodon linsang*)	LC	1
Crested Serpent Eagle (*Spilornis cheela*)	LC	1
Common Water Monitor (*Vavanus salvator*)	LC	1
Total		733
Taxonomic Class	Species Total	Individual Total
Mammal	19	502
Bird	9	230
Reptile	1	1

Table 2: Number of individual wildlife captured per species 2021 (Pin Supu Forest Reserve)

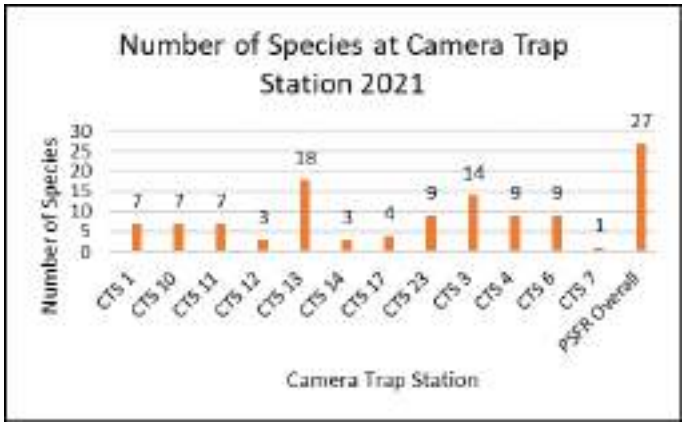


Figure 10: Total species captured per camera trap station

Figure 11: Total Species Per Camera Trap Operational Days (Updays)

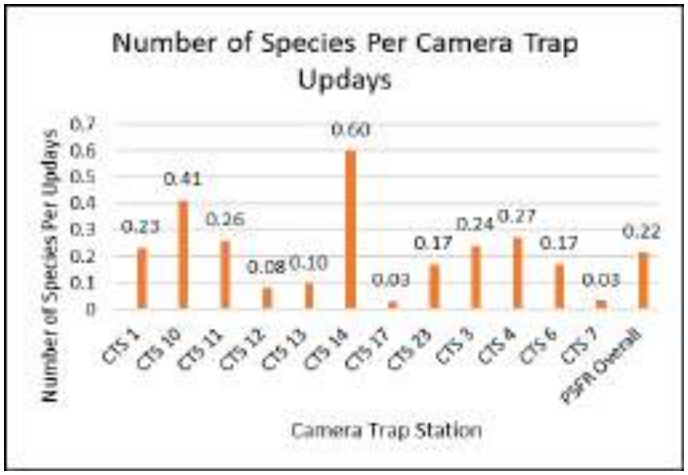


Figure 12: Camera Trap Station Updays Per Year

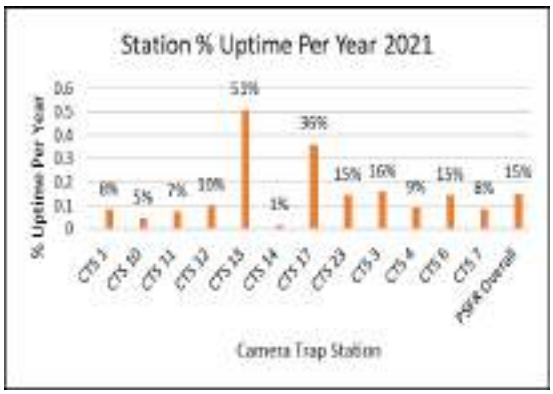
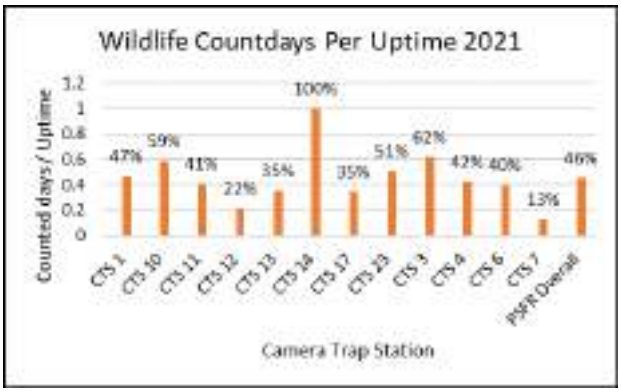


Figure 13: Camera Trap Station Wildlife Individuals Per Uptime



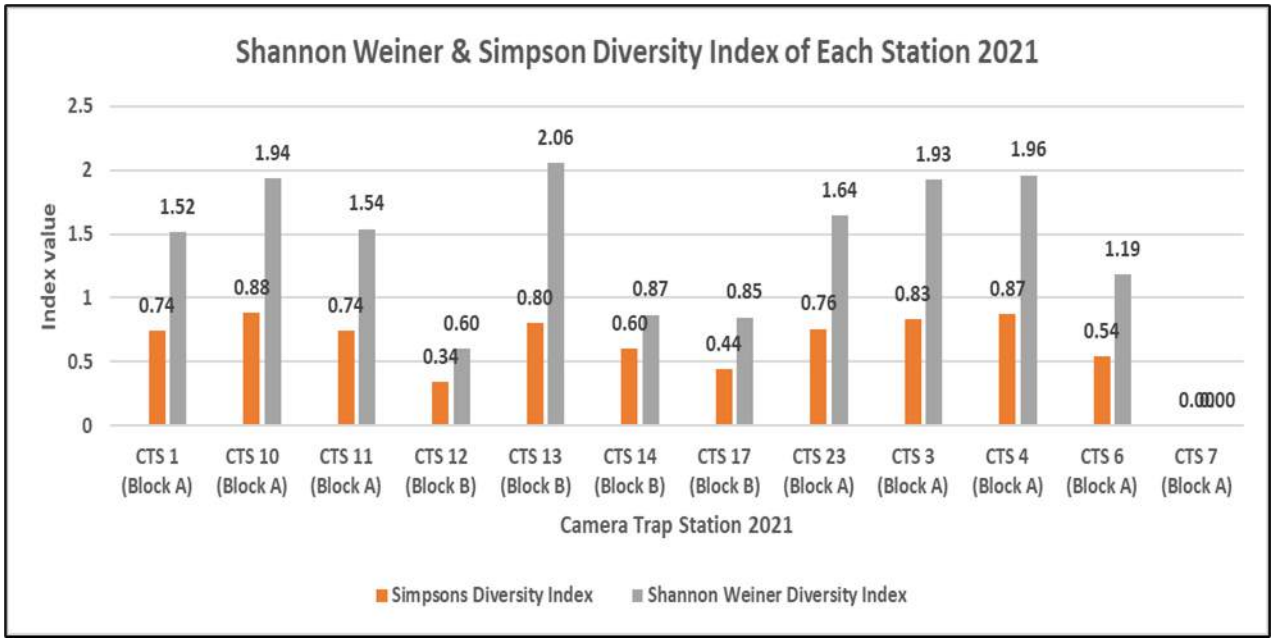


Figure 14: Simpsons and Shannon diversity index of each station in Pin Supu Forest Reserve.

Based on the graph above (Figure 14), higher value of Simpson index means the site has achieved both richness (number of species) and evenness (individual distributions in the species) in species diversity. For the Shannon index is increases as both the richness and the evenness of the community increase.

To compared between stations is too difficult, the data is not comparable due to different sampling effort. The explanation can be based on each station and what type of species that each stations obtained.

I. Camera trap station 10 (CTS 10), has the highest value of Simpson index (0.88) which is higher diversity of species then follow by CTS 4, CTS 3, CTS 13, CTS 1, CTS 12, CTS 14, CTS 6, CTS 17, CTS 12, and CTS 7. While Camera trap station 13 (CTS 13), has the highest value of Shannon index (2.06) which is higher the diversity of species in a particular then follow by CTS 4, CTS 10, CTS 3, CTS 23, CTS 11, CTS 1, CTS 6, CTS 14, CTS 17, CTS 12, and CTS 7.

II. **Block A** - CTS 10, 4, and 3 has the highest value of Simpson and Shannon index. It was located in the northern part of Tungog lake which is alluvial seasonally flooded area.

III. **Block B** - CTS 13 has the highest value of Simpson and Shannon index and located on the ridge of Supu Hill (Sepataring) which is lowland dipterocarp.

IV. Camera trap station 7 (CTS 7), both Simpson and Shannon index value is 0.00. Zero value means it has lower diversity and only present one species (Long-tailed macaque). This station is located at KOPEL old restoration site (Kaboi Lake) where it is alluvial seasonally flooded area. Due to different sampling effort, it's not impossible to get only one species due to how many cameras trap has been deployed. Only three times camera trap has been deployed in that area and only one deployment has data. It's difficult to assumed that area has lower diversity.

Conclusions & Management Implications

I. The current methodology of camera trapping is still considered one of the most appropriate mechanisms for monitoring wildlife populations within PSFR. This is because the method poses no threat to wildlife and very minimal impact on the wildlife directly and forest ecosystem more generally. But the sampling effort need to be improved.

II. Based on 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.
    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.
    c) The camera trapping needs to be upgraded, revised and improved to stay abreast of technology, and to avoid theft of the cameras (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 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. 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 establish temporal changes.

V. It is recommended that the 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.

VI. 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 same sighting of an individual being recorded multiple times in the database.

VII. 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 in the future.

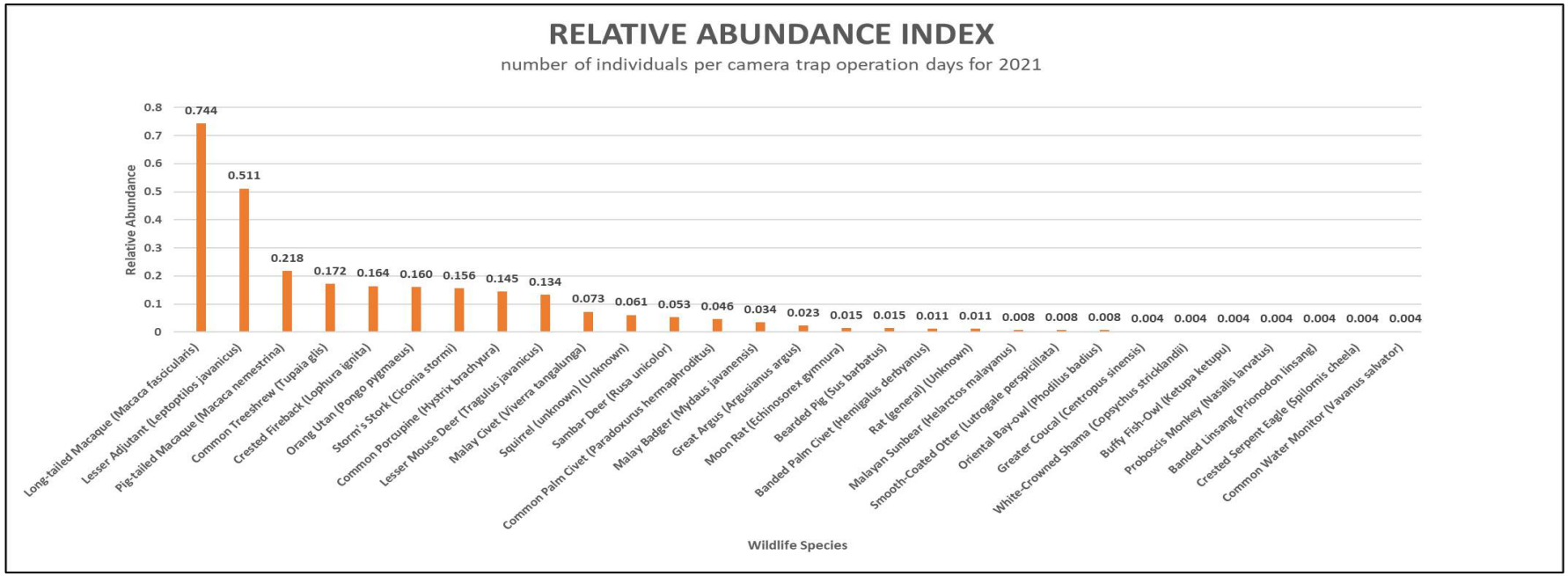


Figure 15: Relative Abundance Rate (RAI) (number of individuals per camera trap operation days)

Figure 16: Image captured of Orang Utan, *Pongo pygmaeus* primate species, listed as Critically Endangered by the IUCN. (CTS 13 12/08/2021)

Figure 17: Image captured of Smooth-Coated Otter *Lutrogale perspicillata*, listed as Vulnerable by the IUCN. (CTS 6 4/11/2021)

Figure 18: Image captured of Malayan Sunbear *Helarctos malayanus*, listed as Vulnerable by the IUCN. (CTS 13 1/07/2021)

3. Water Quality Monitoring

The Water Quality Monitoring in the vicinity of Pin Supu Forest Reserve (PSFR) was conducted by community cooperative KOPEL Bhd. This monitoring has been ongoing since 2012 and compiles water quality parameter data from a total of 6 sample points, including one at a point of discharge from the Kg Mengaris, a second at Tungog Lake, with the others at the confluence of the Kaboi River, the Takala River, Biandong River and the Pin River, with the Kinabatangan River - **refer to figure 1 and table 1**. The work is normally funded by KOPEL's ecotourism program, however in 2020 the program was funded (in the latter half of the year) until 2021 by Yayasan Hasanah.

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 44 below (National Water Quality Index).

Figure 19: KOPEL HSG2020 Water quality monitoring activities Mar-Apr 2021, Sungai Pin

Figure 20: KOPEL HSG2020 Water quality monitoring activities Mar-Apr 2021, Sungai Kinabatangan

Figure 21: KOPEL HSG2020 Water quality monitoring activities May-July 2021, Analysing Water Samples at Tungog Lake

Figure 22: KOPEL HSG2020 Water quality monitoring activities May-July 2021, Example Water at Tungog Lake

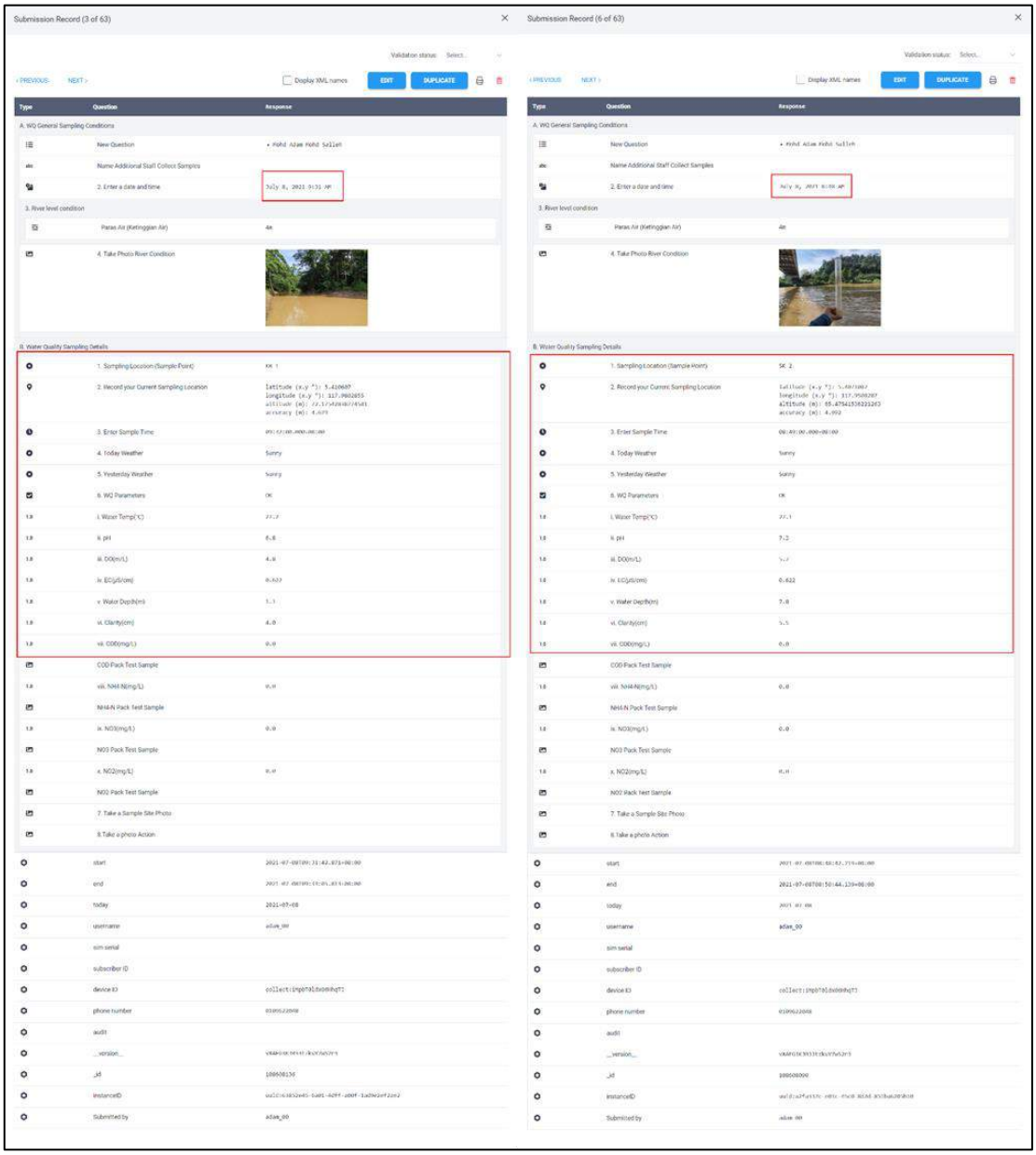


Figure 23: KOPEL HSG2020 Water quality monitoring data entry outputs July 07 2021. Water sample form entry results for Kuala Kaboi and Tungog Lake - entered to KOBO Collect online form.

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 two form outcomes above (Figure 23) are examples of field water quality data collected during July 2021.

Analysis of Data 2021

During this monitoring, the changes in water quality can be known in terms of pH level, dissolve oxygen, electrical conductivity, water depth, water temperature, and clarity for each sample sites. Data collected is compared with the National Water Quality Standards for Malaysia to determine the status of water quality in sampled area.

I. **pH** - the pH range for six sample sites is 5.5-9.0 which is lie within from Class I until Class IV of the National Water Quality Standards (**Figure 25**). Indicating no detrimental effects of the quality of both the River and the Lake. Sample site TREC occupies the lower values and get 5.6 in September. Factors such as, but not limited to, photosynthesis, respiration, fossil fuel emissions, and agricultural runoff can influence the minor fluctuations seen monthly and site wide.

II. **Dissolve oxygen (DO) -** DO levels for sample points SK1, SK2, ST2, and BI almost all remain relatively consistent occupying class IIA – class III (Figure 26). But on 25 February 2021, the level dropped below 1mg/L which are occupying class V – refer to figure 4. As these times water quality drops to class V (worst quality) based on this parameter and is considered unusable based in the National Water Quality Standards. As the sample points are located within the main channel of the Kinabatangan River, for a river of this magnitude the levels of DO are not high standard, and an area of concern, to be watched into the future. For sample point KB1, the levels fluctuated greatly in 2021 and almost same with the previous year (2020). The values range from 0.67mg/L to 5.4mg/L, mostly occupying class III. This is attributed to influences of the peat swamp upstream from this point within the Pin Supu Forest Reserve. On February and May 2021, DO at KB1 dropped below 1mg/L that occupying class V which is the worst water quality based on National Water Quality Standard.

    Dissolved oxygen levels decrease even further at TREC and were substantially lower again. As lake is not running water like river, hence, it dissolves less oxygen. Dissolve oxygen levels at TREC are consistently extremely low, the levels range from 0.5mg/L to 2mg/L – refer to figure 4. This is mostly hypoxic and occupying class V (Table 3). This data is consistent with both 2018 until 2020 sampling years. At present the situation on the lake is attributed to the vast amount of Salvinia molesta that still exists, covering around 90% of the Lakes surface, negatively affecting phytoplankton and air-water interface means of oxygenation. Although some fish are still present in Tungog lake, these levels of dissolved oxygen continue to pose a huge threat to the biodiversity and aquatic species. Based on the deteriorating conditions on Tungog Lake, it is highly recommended to continue and upscale the Salvinia removal efforts on this lake.

III. **Electrical conductivity (EC)** – EC measures the ability of water to conduct the electrical current. Based on the figure 5, sample point SK1 and BI occupying class II which is stable than the other point. Electrical conductivity at KB1 fluctuates dramatically below a Class I and above Class IIA and Class IIB but does is not enter a Class III. Based on the other parameters at present this is not of critical concern. Electrical conductivity at TREC, the range value is from 0.519µS/cm to 678µS/cm which is lower than other point. As TREC is not a moving water that

confluence to main river like other sample points, possibility for water pollution occur is low than river that has high risk for water pollution. SK1 is one of the points that near with palm oil plantation and as a moving water, that will be easier to pollute other streams.

IV. **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. 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 (0-30cm). 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 27 shows water clarity measurements across all sampling locations. Note clarity at Tungog Lake (TREC) compared to the river sampling points. SK1, SK2, KB1, ST2, and BI has a poor clarity and high turbidity than TREC. Lower clarity can affect the habitat and food supply of aquatic life, and the growth of aquatic plant.

V. **Chemical Oxygen Demand** (COD): The sample stop taken in July 2021 due to out of stock of COD packtest. The Chemical Oxygen Demand (COD) data ranged from January – June 2021 predominantly between 10mg/L-70mg/L – refer to figure 28, fluctuating within class I - class IV– refer to figure 28, amongst all sample sites. A large value in COD was observed at two locations which is TREC and KB1. Given sampling at the given locations did not show any correlation with Dissolved Oxygen (DO), or other parameters at these times, the results did not raise major concerns for water quality at these sampling points. Even so, these anomalies have been noted for ongoing investigation, and likewise have raised several unanswered questions. Subsequently checks on equipment, sampling methods were also completed.

VI. **Ammoniacal Nitrogen**: The sampling was stop in July 2021 due to out of stock of NH4-N (ammonium) packtest concentrations were relatively stable from January – June 2021 at all sampling sites, except ST2, KB1, and B1 which are 0.5mg/L on February 2021.– refer to figure 29.

Conclusions and Management implications

I. Based on the current evidence from water quality monitoring in 2021 there is insufficient evidence to suggest major pollution occurrence at the sampling points, or the need for immediate corrective action in 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.* This aquatic fern shades out any submerged plant life and blocks oxygen exchanged to suitable animals and fish. The aquatic life is threatened by the low oxygen conditions and imbalance in the ecology of the lake. A long-term integrated pest management approach involving the Salvinia weevil (*Cyrtobagous salviniae*) alongside physical removal is highly 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. Even so, 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, i.e., recommended further training. (b) the establishment of a laboratory at KOPEL, (c) upgrading of sampling equipment, (d) installing auto logging monitoring stations, (e) installing hydrological station and automatic weather station to corelate results, and the expansion of these efforts to include other closely related monitoring such as hydrology monitoring.

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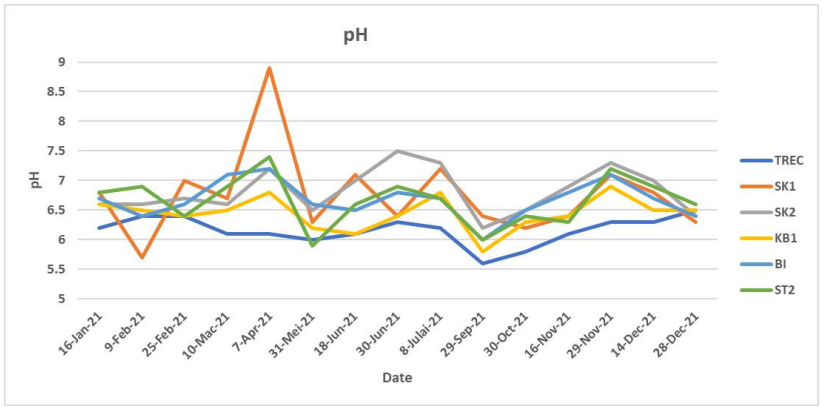


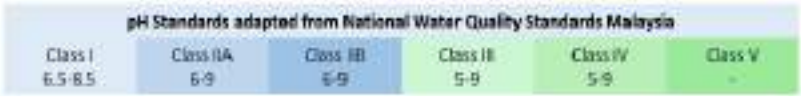
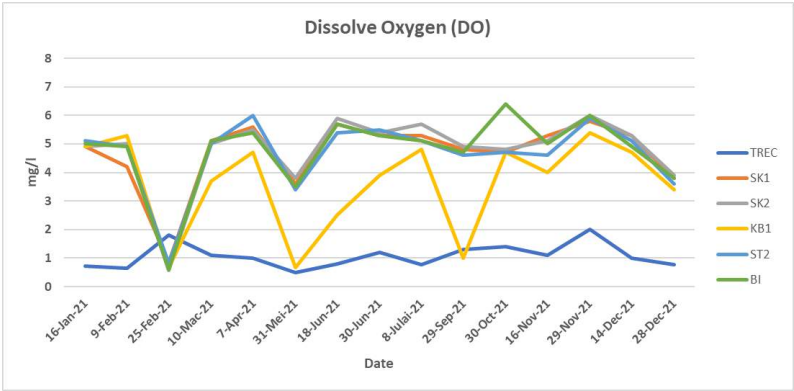


Figure 24: Water pH bimonthly analysis, 2021.



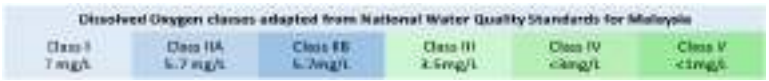


Figure 25: Dissolved Oxygen bimonthly analysis, 2021

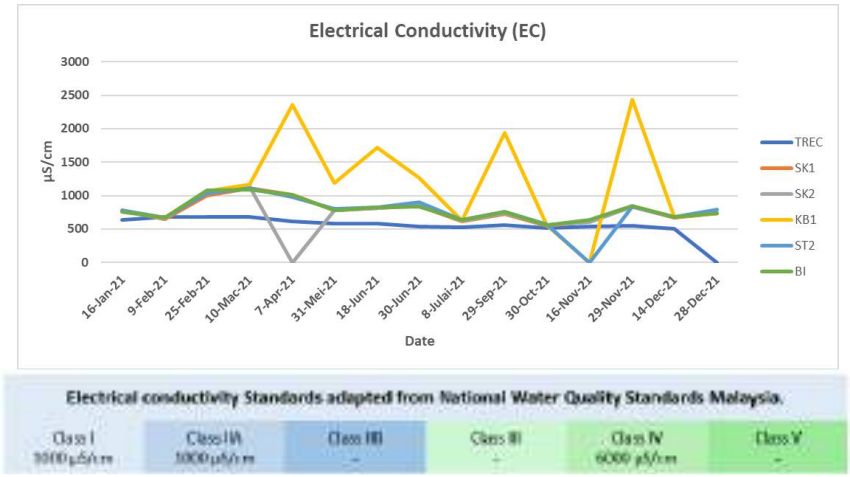


Figure 26: Electrical Conductivity (EC) bimonthly analysis, 2022

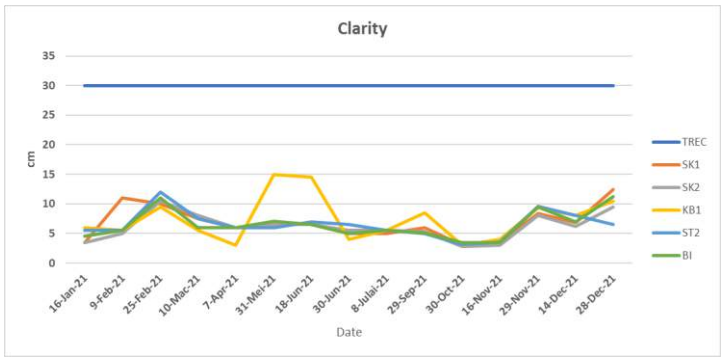


Figure 27: Clarity bimonthly analysis, 2021

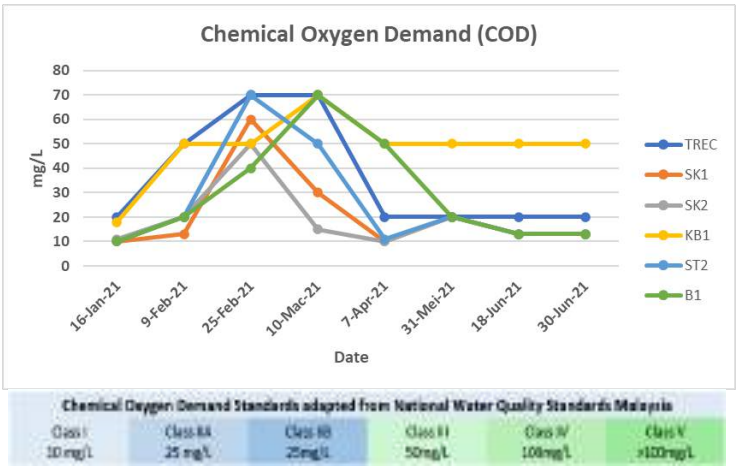


Figure 28: Chemical Oxygen Demand bimonthly analysis, 2021

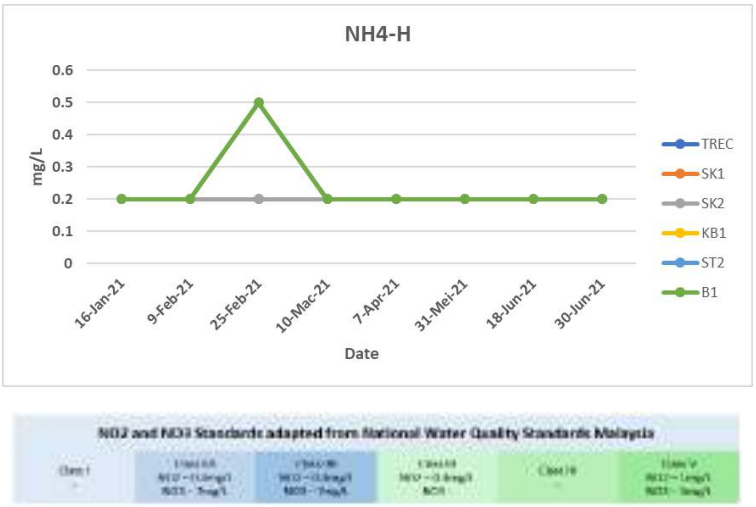


Figure 29: NH4-N bimonthly analysis, 2021

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.

Table 3: Water classes and uses adapted from National Water Quality Standards for Malaysia.

Figure 30: Garmin BaseCamp Map of Water Quality Sample Points, 2021

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

Table 4: Water quality monitoring sample points in Kinabatangan River.

4. Lake Tungog Salvinia Removal Project

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. In the Tungog Lake the Salvinia is a disaster for local fisheries and likewise the food abundance for many wildlife species.

Since 2005, there have been attempts to have the Salvinia removed. Up until 2013, KOPEL maintained an intensive monthly maintenance programme after totally clearing the lake of Salvinia weed in 2007. KOPEL was given a Sabah Environmental Award in 2009 for their achievement. Several of the natural wildlife species, including otters (*Lutrogale perspicillata* and *Aonyx cinereus*), Oriental darters (*Anhinga melanogaster*), and Buffy Fish Owls (*Ketupa ketupu*), returned and were present at Tungog Lake during this time when it was entirely open and free of Salvinia. Unfortunately, the Tanduo Crisis caused maintenance to stop for five months in 2013. Unintentionally, the Tanduo problem led to the suspension of KOPEL operations at this time. The Salvinia weed quickly spread throughout the five-month closure, covering almost 25% of the lake. Salvinia weed continued to spread quickly despite KOPEL restarting the human eradication actions, outperforming KOPEL's monthly maintenance routines (manual removal).

Albeit the MCO, the Salvinia removal work continued by utilising the mixed-mechanical-approach or ropes through a pulley-block, which acts like a winch, combined with the pulling power of a boat and 40hp engine to provide the lifting power (Figure 31).

Figure 31: KOPEL Guide Team working on Salvinia funded by HSG2020 July 2021 Floating grass is cut into clumps before being netted and dragged out of the lake using ropes system and boats.

The floating grass and Salvinia is cut into blocks. This is done manually from a boat using a long-handled farm sickle (scythe). The small islands of grass and Salvinia are floated to the docking area, using the small boats, where they are netted and hauled out using the ropes and pulley-block technique. The work is heavy, slow and gruelling. Each Salvinia weed bundle dragged out of the lake can weigh up to 300kg (Figure 32-34).

Figure 32: KOPEL HSG2020 Salvinia Team – starting back after MCO mid-June 2021 **(BEFORE)**

Figure 33: KOPEL HSG2020 Salvinia Team – Tungog Lake south on July 31 2021 **(AFTER)**

Figure 34: KOPEL HSG2020 Salvinia Team – Cutting floating grass sudds into small and using boats to push the small floating islands to the rope-hauling point.

Salvinia Weevil Monitoring

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.

Following the monitoring standards specified by the Sabah Agriculture Department, post-release monitoring was promptly commenced. KOPEL is continuing to monitor the Tungog Lake's general aquatic ecosystem and any larger ecological repercussions in parallel with the weevil release monitoring.

Twelve (12) sampling sites were constructed around the lake to track the weevil's progress and its effects on the Salvinia weed and the surrounding ecosystem (Figure 1). For Salvinia weevil population sampling, the Water Float Trap (WFT) methodology is utilised. This entails taking 1kg of Salvinia weed samples and submerging them for 24-48 hours to force adult weevils to surface for oxygen. Adult beetles can be trapped after they emerge and counted to establish the presence or absence of weevil adults in the Salvinia sample. Plant damage caused by the weevil's presence was also analysed in the Salvinia samples. Because there is a direct correlation between the amount of bud damage and the presence of adults, damaged buds are one indicator of weevil activity.

The sampling was started again on March 2021 due to Malaysian Movement Control Order (MCO) on January 2021 and February 2021. The results of the ongoing monitoring activities in 2021 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.

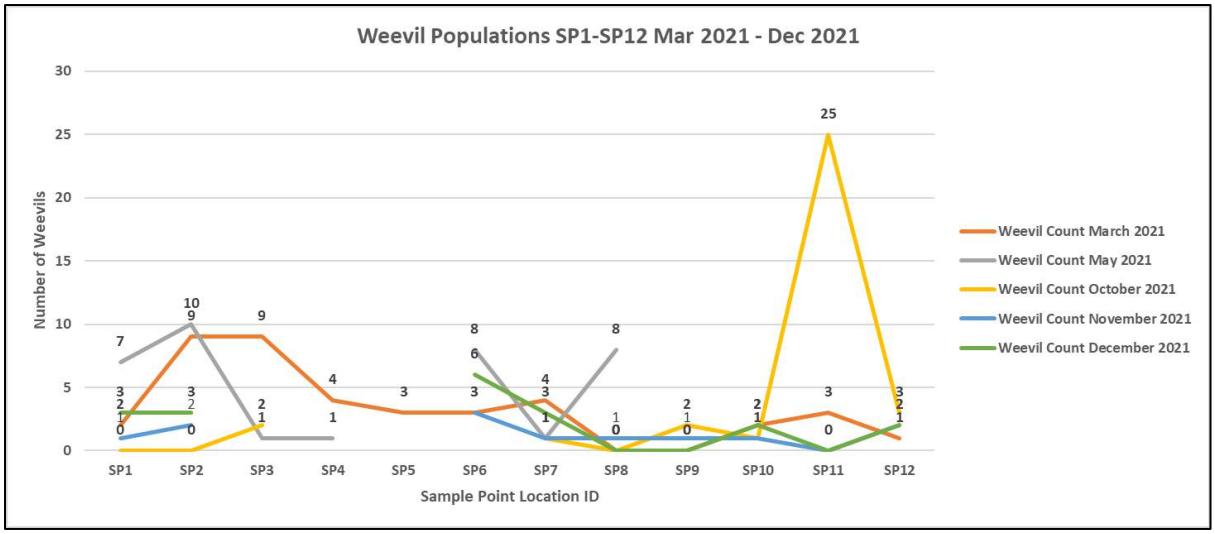


Figure 35: Weevil beetle count per 1kg Salvinia sample at each Sampling Point

Sampling results are summarised as follows:

1. Sampling on March 2021 demonstrated a small value of Salvinia weevil present at sample point SP1, SP2, SP3, SP4, SP5, SP6. SP7, SP10, SP11, and SP12, however, no salvinia weevil found at sample point SP8 and SP9 during sampling on March 2021.
2. On May, October, November and December 2021, no sample was taken in some sample point, especially, SP5 and SP4. This is due to the manual Salvinia removal activities that has remove the salvinia weed caused lack of fresh Salvinia growth at the sites for weevil populations.
3. It should be noted that, November 2021 sampling demonstrated a notable decrease in Salvinia weevil population count at almost all of the sampling sites. This was attributed to manual Salvinia removal activities and the thick grass suds that grow on the salvinia weed, hence the lack of fresh Salvinia growth at these sites for weevil populations.
4. However, October 2021 sampling shows an increase in Salvinia weevil numbers at sampling points SP11. These sites had minimal disturbance of Salvinia manual removal work, but only that month. On November and December, the site remained zero weevil count. This is attributed to the thick grass covering the Salvinia mats at these sampling points, and the lack of primary Salvinia weevil habitat at these locations.
5. Sampling over the reporting period of 2021 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. 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.
    a. 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 HCV 3.0 and is of critical importance 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. Based on the monitoring of Salvinia and biocontrol on Tungog Lake it is becoming increasingly apparent that reliance on one specific method, albeit biocontrol OR manual removal alone, will be insufficient to remove the threat and moreover unsustainable in the long-term. Based on the current analysis it is recommended that the Salvinia removal efforts be further integrated to involve both biological control and manual, physical, or mechanical methods on the Tungog Lake. In the short-term mechanical methods will be imperative given the Salvinia weevil (*Cyrtobagous salviniae*) is not suitable to overcome the Grass Sudds impacting the lake. Hence, funding or investment in mechanical approaches should be sought in the short to medium term.

III. It has taken more than two years after the release of the Salvinia weevil (*Cyrtobagous salviniae*) to show any signs of weevil population growth or the spread of the Salvinia weevil on Tungog Lake. Even so, within the last six months the Salvinia weevil is showing some small signs of spreading to new parts of the lake without human intervention. Numbers are increasing in areas of open water and fresh Salvinia growth, this is consistent with the literature and experience in other sites globally – stage II Salvinia being optimal habitat for *Cyrtobagous salviniae*. Decline in dissolved oxygen (DO) and the presence of the Grass Sudds is described as the major impediment to the success of this 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.

IV. 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 including: (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.

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 2021. 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.