Figure 36: KOPEL HSG2020 Water quality monitoring activities Jan-Feb 2021, Analysing Water Samples at Tungog Lake

Figure 37: KOPEL HSG2020 Water quality monitoring activities Jan-Feb 2021, Example Pack-Test Colorimetry Parameter Testing

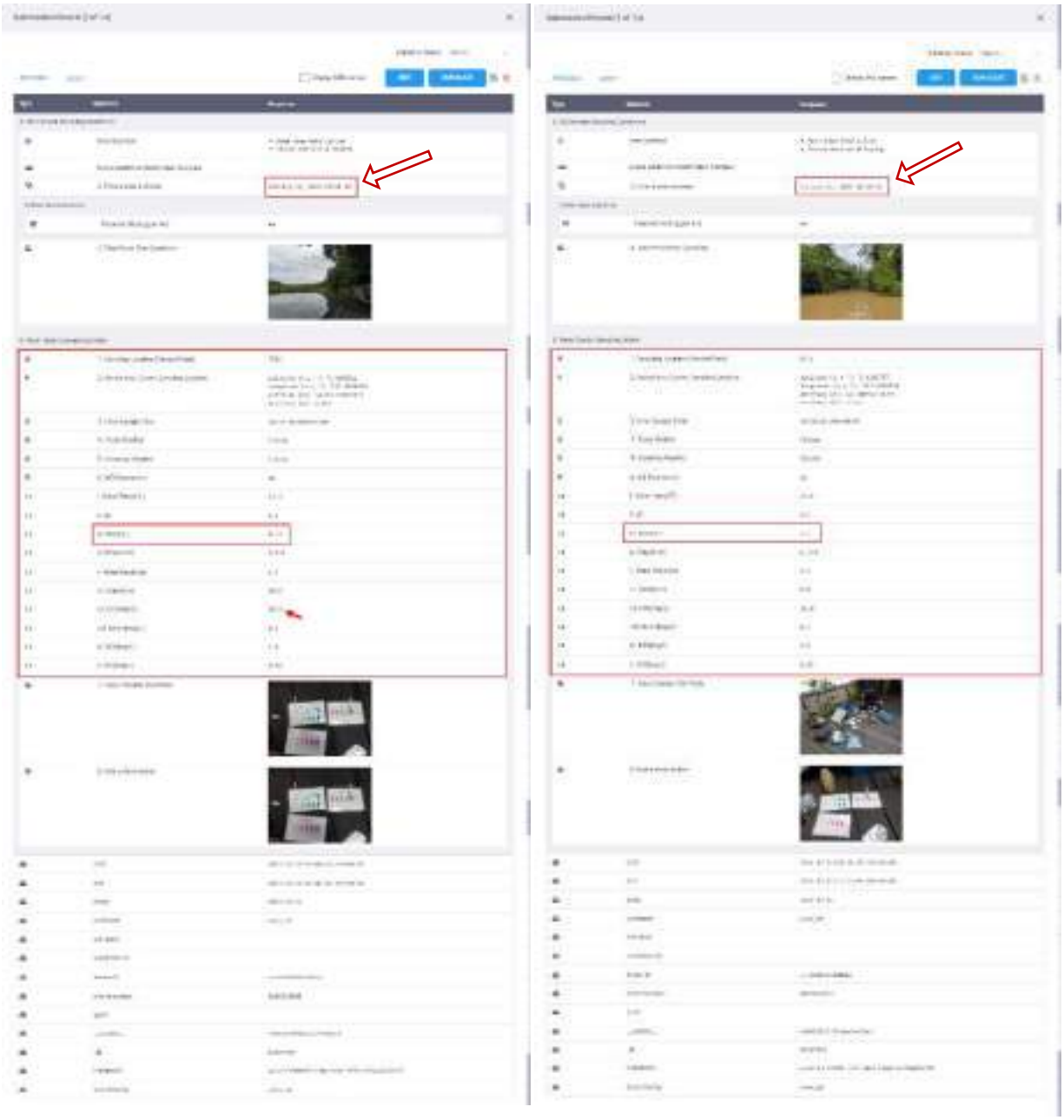

Figure 38 (above): KOPEL HSG2020 Water quality monitoring data entry outputs Jan 16 2021. Water sample form entry results for Tungog Lake and Kuala Sg Kaboi entered into KOBO Collect online form.

KOPEL initiated online form data collection using **KOBO Toolbox** and **KOBO Collect** across all projects. The online data collection utilises mobile phones as data entry devise and enables all field staff to go paperless with their field data collection. The use of KOBO Collect has improved the accuracy of data collection because all form fields have built in data validation protocols. It has also improved 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 (previous page 2) are examples of field water quality data collected during January & February 2021.

Results are shown in Fig 39-43 below.

Analysis of Data 2020

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) and TREC (Tungog Lake) – refer to figure 39. pH values ranging from 6.0 -8.0 and lie within class I of the National Water Quality Standards - refer to figure 44, 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 in regard to pH. Even so, some of the results indicate further study is warranted for example a dip in pH at TREC in November corresponds with a spike in DO in the Tungog Lake during this time. Although these changes are attributed to the influx of river water from the November high water event (floods), the relationship with pH and consequences are not well understood, hence further study is recommended.

II. **Dissolved oxygen** (DO) levels for sample points SK1, SK2, and ST2 all remain relatively consistent occupying class IIA – class III in the national water quality standards – refer to figure 40. 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 fluctuated greatly in 2020. KB1 station values range from 1.0mg/L to 5.6mg/L – refer to figure 40**,** 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 2 in January and November, consistent with post-flood release water from surrounding swamp land. 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 substantially lower again. Dissolved oxygen levels at TREC are consistently extremely low, all but one sample (5.5mg/L) range from 0.58mg/L – 3.6mg/L **– refer to figure 40**. This is mostly hypoxic (<2mg/L) and occupies class V of the MNWQS **– refer to figure 40**. This data is consistent with both 2018 and 2019 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. **Chemical Oxygen Demand** (COD): Across all sample sites in 2020, the Chemical Oxygen Demand (COD) data ranged predominantly between 10mg/L-25mg/L – refer to figure 41, fluctuating within class I, class IIA and class IIB – refer to figure 41, amongst all sample sites throughout the entirety of the year. A large spike in COD was observed during the December 2020 samples at 3 locations on the main Kinabatangan River SK1, SK2, 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. Based on this outcome further investigation into the root cause of the spikes has been recommended.

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 42 shows water clarity measurements across all sampling locations.

V. **Ammoniacal Nitrogen**: NH4-N (ammonium), alongside NO2 (nitrite) and NO3 (nitrate) concentrations were relatively stable for most of 2020 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 43.

Ammonium, Nitrites (NO2) and Nitrates (NO3) 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 43.

Conclusions and Management implications

I. Based on the current evidence from water quality monitoring in 2020 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 a more effective feedback for management of PSFR. Improvements suggested include (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.

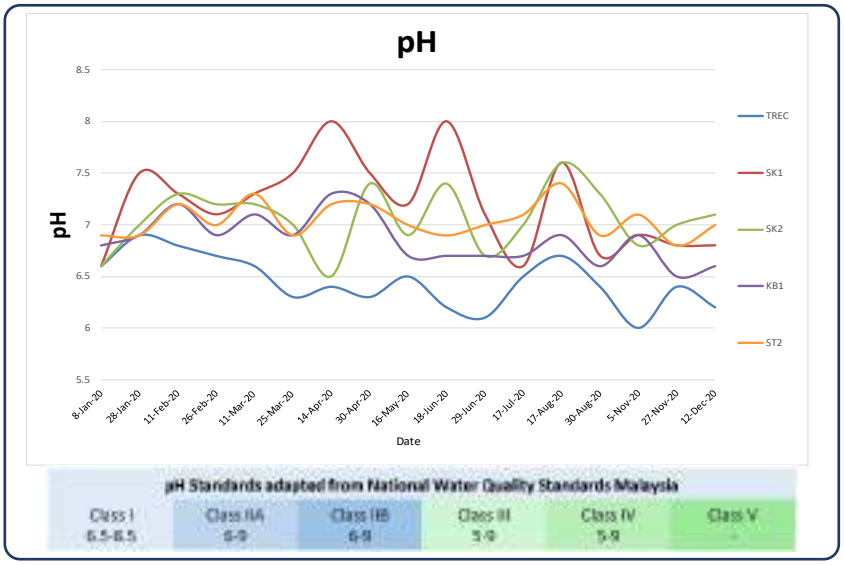

Figure 39: Water pH bimonthly analysis, 2020.

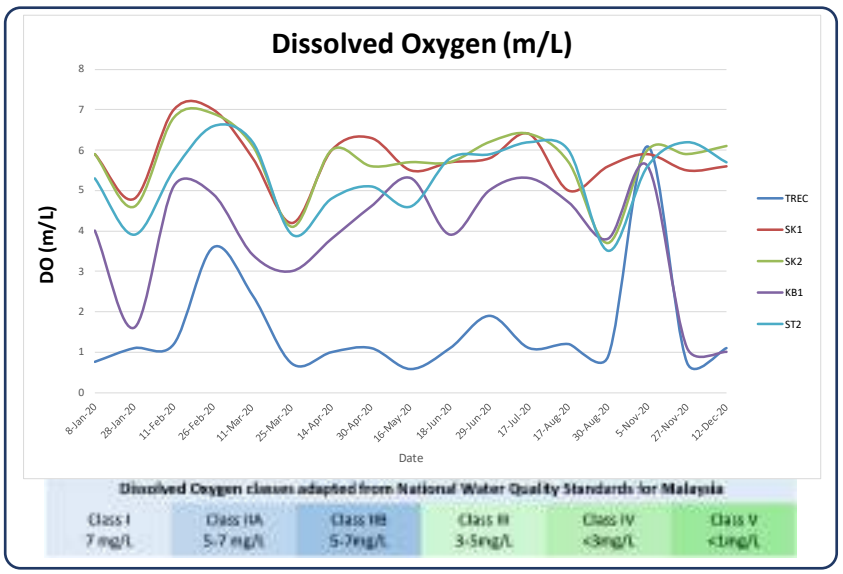

Figure 40: Dissolved Oxygen bimonthly analysis, 2020

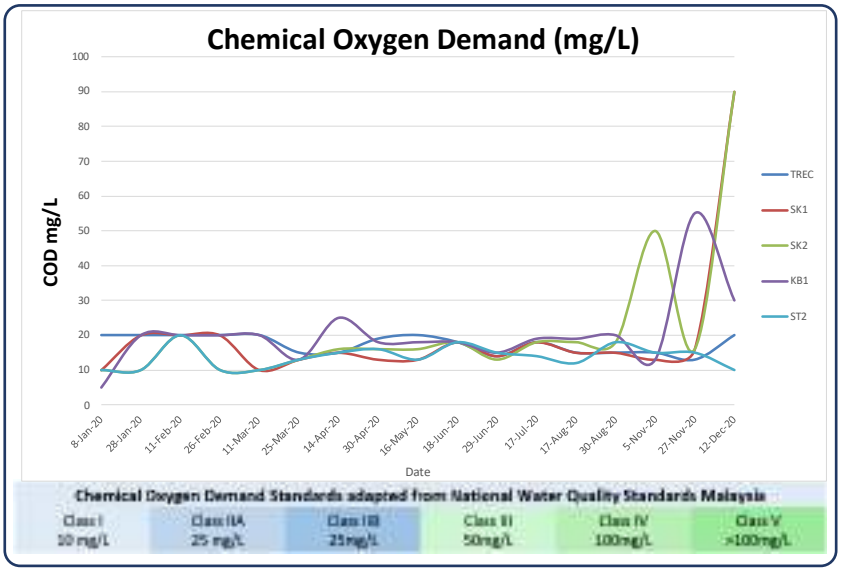

Figure 41: Chemical Oxygen Demand bimonthly analysis, 2020

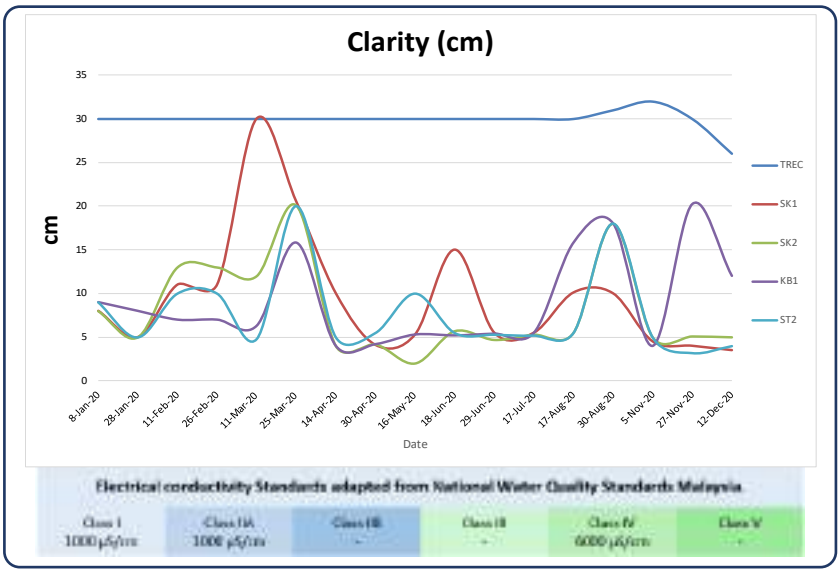

Figure 42: Water Clarity bimonthly analysis, 2020

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. Clarity decreased in the Tungog Lake after the influx of river water from the November 2020 floods.

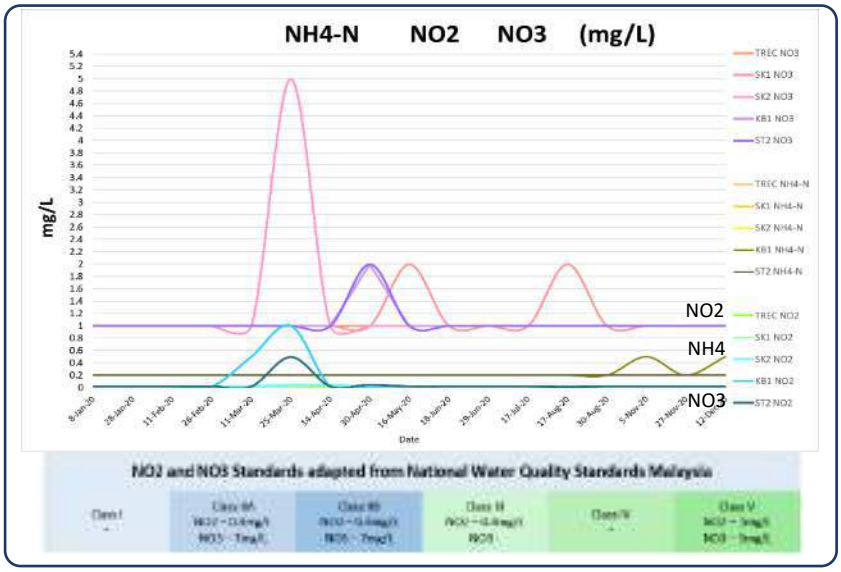

Figure 43: NH4-N, NO2 and NO3 bimonthly analysis, 2020.

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

Figure 45: Garmin base map of sample points, 2020.

TREC	Tungog Rainforest Eco Camp (Tungog Lake)
SK1	Sg. Kinabatangan confluence to Sg. Pin
SK2	Sg. Kinabatangan confluence to Jetty KOPEL
SK3	Sg. Kinabatangan confluence to Sg. Takala
KB1	Sg. Kinabatangan confluence to Kuala Kaboi

Figure 46: Sample points on the Kinabatangan River for Water Quality Analysis.

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 (Refer to page 18-24 in this document). 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

Figure 47: (left): KOPEL Guide Team working on Salvinia funded by HSG2020 December 2020

Floating grass is cut into clumps before being netted and dragged out of the lake.

Figure 48: (right): KOPEL Guide Team working on Salvinia funded by HSG2020 December 2020 (Netting process at lake edge)

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

Figure 49: Salvinia Weevil (*Cyrtobagous salviniae*) monitoring on Tungog Lake 2020

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 rapidly, outpacing KOPEL's monthly maintenance programs (manual removal). At the beginning of 2020, the Salvinia weed had covered 90% of the lake surface.

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**

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** (Refer Figure 52, Map Sample Sites, p.29)**.**

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.

Twelve (12) sample sites - refer to figure 52**,** 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 2020 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.

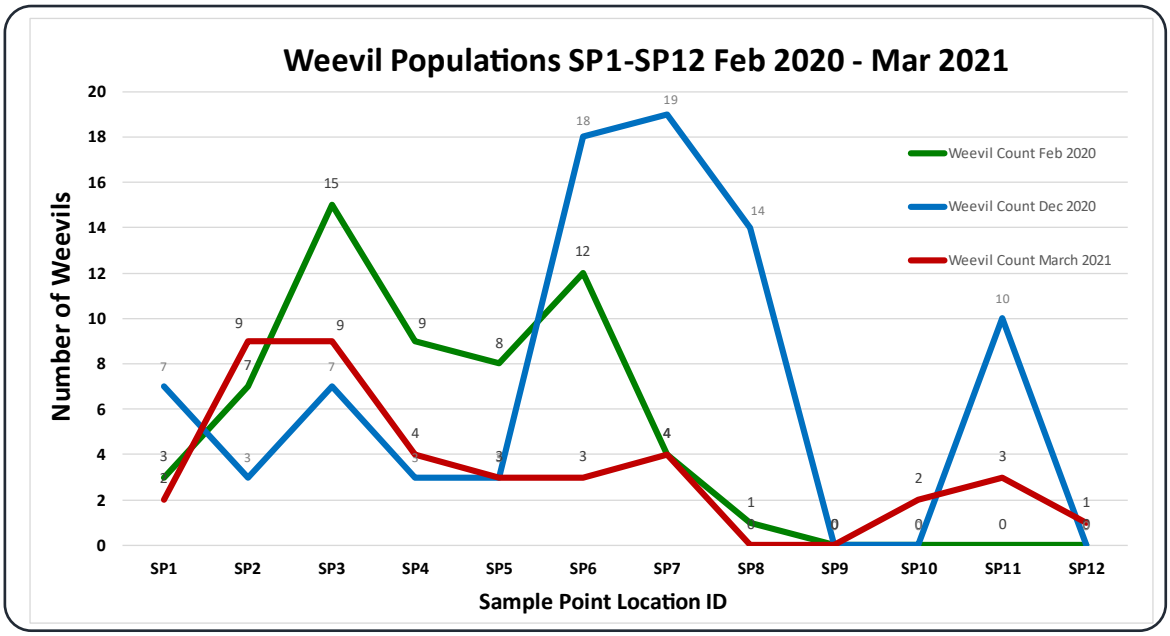

Figure 50: Weevil beetle count per 1kg Salvinia sample at each Sampling Point

sites. Sampling results are summarised as follows:

1. Sampling in February 2020 (more than one year after initial release) demonstrated a small number of Salvinia weevils were present at sample points SP1, SP2, SP3, SP4, SP5, SP6, SP7, and SP8, however, no weevil was found present in samples at sample points SP9, SP10, SP11 (at the north end of the lake) during February 2020 sampling (refer to figure 50, previous page).
2. It should be noted that, December 2020 sampling demonstrated a notable decrease in Salvinia weevil population count at the sites SP2, SP3, SP4 and SP5. This was attributed to manual Salvinia removal activities during the early months of 2020 at these sites, hence the lack of fresh Salvinia growth at these sites for weevil populations.
3. Even so, the December sampling revealed a notable increase in Salvinia weevil numbers at sampling points SP1, SP6, SP7, SP8, and SP11. All these sites had minimal disturbance during the period between February and December 2020. These results are consistent with previous records and indicate that physical disturbance (such as physical Salvinia removal) has a negative effect on the Salvinia weevil population.
4. During the December 2020 sampling only SP9, SP10 & SP12 remained with 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 2020 exhibited notable fluctuations in beetle count at several sample points, in both a positive and negative direction, over the year (refer to figure 51, below). 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.
    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.

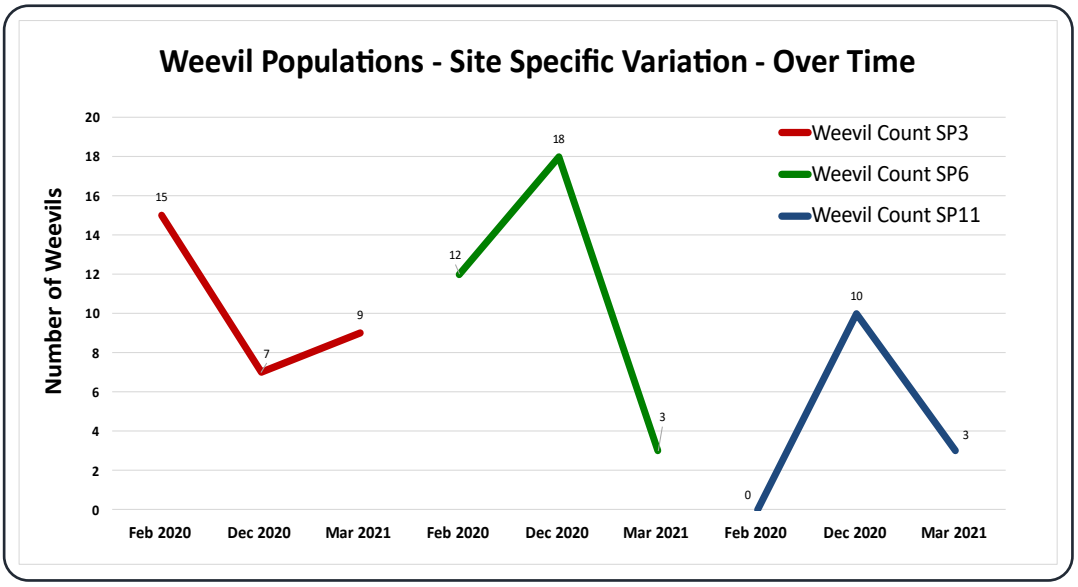

Figure 51: Weevil beetle count per 1kg Salvinia sample at SP3, SP6 and SP11 Shows site specific variation over the one year pearod Feb 2020 to Feb 2021

Salvinia Weevil Impacts:

It is worth noting that zero negative impacts of the weevil *Cyrtobagous salviniae* have been observed throughout the two-year release period. This is demonstrated in records of observations at the sampling sites, and through notes taken from parallel habitat studies and wildlife observations around the Tungog Lake. Based on the two-year observations, zero notable decline in habitat or species has been observed since the release of the weevil, and likewise there has been no notable influx of predators or other secondary or tertiary consumers, nor decline in these species on the Tungog Lake. Water quality has remained the same based on parallel water quality analysis. In this case, there has been zero changes to nutrient levels and related water quality parameters during the corresponding release period.

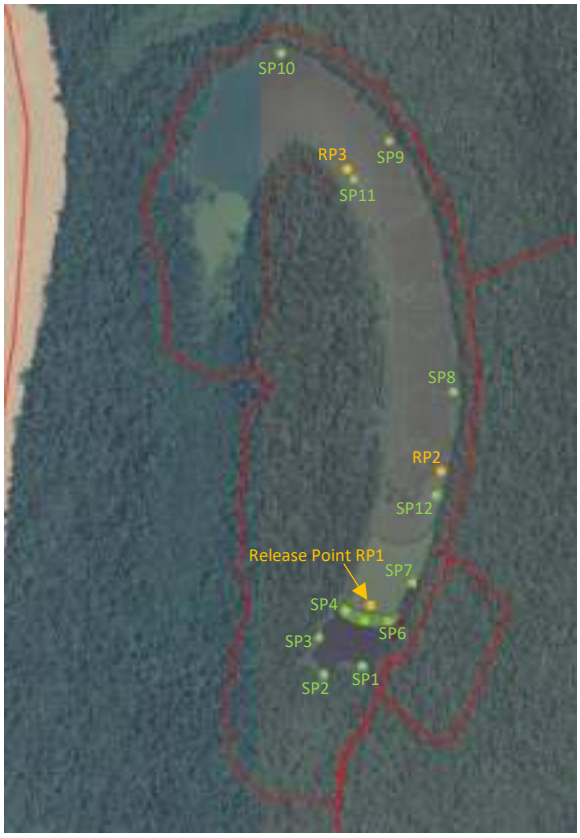

Figure 52: Location Map of 12 Sampling Points Tungog Lake

A notable outcome of the monitoring in 2020, is that the overall number of adult weevils counted across all sampling points has **increased by 42% from 59 to 84 beetles** - counted between February and December 2020. Most of the population increase was experienced in sample points SP6, SP7 and SP8. Given the very slow increase in weevil population at Tungog Lake, it is not surprising then, that there have been very little noticeable knock-on effects – either positive or negative. Based on this outcome, monitoring should remain a top priority at the Tungog Lake into the future.

What is most interesting from the recent sampling outcome is that during the same period of increase in Salvinia weevil count, the corresponding sample points SP6, SP7 and SP8 demonstrated a notable break-up of the Salvinia mats into smaller islands, alongside the development of broad open areas on the Tungog Lake at these locations. See Figure 53, below.

Figure 53: Aerial observation of Tungog Lake Salvinia mat break-up at Sampling Points SP6, SP7 and SP8.

Although this concurrence does not prove that the breakup and sinking of grass covered Salvinia mats is a direct result of the Salvinia weevil, it is worthy of note that the beetle has increased in numbers at these locations over the same period. This is a positive development for the biocontrol initiative, given the sluggish increase and spread of the Salvinia weevil over the first two years after release.

Even though the break-up of the Salvinia mats could be a direct consequence of the Salvinia weevil, the alternative scenario is also possible, that is, the increase in weevil population at these open locations is a direct result of, and not the cause of, the break-up and decline of the Salvinia mats and the subsequent opening of the lake surface at these corresponding locations.

This alternative scenario suggests that the opening of the lake surface would mark an increase in photosynthesis and Dissolved Oxygen at these locations, and likewise provide a more conducive habitat for the Salvinia weevil compared to the anoxic Salvinia grass mats. Monitoring is continuing to determine whether the eradication of the Salvinia & Grass Mats is a result of the Salvinia weevil or the cause of the weevil presence. Even so, the increase of weevils at these sites is a positive indicator for future control of Salvinia regeneration in these locations.

Figure 54: Grass Sudd (Floating grass mats) on Tungog Lake

Grass Sudds (Floating Grass Islands):

One of the major long term negative impact of the Salvinia weed on the Tungog Lake has been the development of thick grass cover on top of the Salvinia. These floating grasses are often called Floating Sudds or Grass Sudds. By early 2020 these floating Grass Sudds covered 90% of the Tungog Lake.

The problem starts when the floating Salvinia mat becomes very thick - this is known as Stage III Salvinia. The thick Stage III Salvinia produces and traps abundant decaying plant material at the underside of the thicker Salvinia mats. This creates habitat for colonising grasses, sedges and pandanus species. These grasses grow on-top-of the floating Salvinia. When the grass is combined on top of the floating Salvinia mats the floating grass mat is known as Grass Sudds. The below surface floating component of the Grass Sudds vary in thickness, from 15cm to 30cm. The grass height above the waterline varies from 15cm to 1.5m in height.

The Grass Sudds are a disaster for the lake's ecosystem, and likewise detrimental to the breeding of the Salvinia weevil (*Cyrtobagous salviniae*).

The Grass Sudds have an extremely negative impact on the water quality at the upper photic zone. The degradation of this surface layer of the water is highly detrimental to the breeding of the Salvinia weevil (*Cyrtobagous salviniae*) and undermines the effectiveness of the biological control program. The

problem arises because the roots of the grass spread rapidly in the nutrient rich decomposing stage III Salvinia (the below surface layer). The roots of the grass trap the decomposing Salvinia and bind the decaying biomass to the top 10-30cm of water. Trapping the additional decaying organic matter in this upper layer exacerbates the negative effect of the decay process on oxygen availability, and hence lowers the dissolved oxygen levels further in this upper zonation - beyond its already low levels.

This upper zone with Salvinia alone is considered hypoxic with Dissolved Oxygen <2mg/L. In effect, however, the grass sudds suffocate and suppress the floating Salvinia, degrading the situation further and worsening the negative impacts of the "overall floating weed mat" on the water body. The grasses cause the water quality to decline to an almost anoxic level (DO <0.5 mg/L), it is extremely detrimental to water quality generally, and makes conditions exceedingly difficult for the Salvinia weevil, larvae and pupa to survive in this zone.

It should also be reiterated at this point, that the **Salvinia weevil is "host specific".** This means that it has evolved to feed on, and breed in, Salvinia ONLY. Without adequate Salvinia and without suitable healthy Salvinia habitat the Salvinia weevil cannot thrive and cannot become a viable control method for the Salvinia. In the Tungog case, the grass sudds on the lake surface have degraded the aquatic conditions and have caused significant delays to the biological control program. Based on this evidence, KOPEL has been forced to take measures to remove the Grass Sudds from the Tungog Lake. Unfortunately, the Grass Sudds are not easily dealt with, and are significantly more difficult to remove than the Salvinia. Even so, both the Sabah Forestry Department and KOPEL Bhd have initiated Grass Sudds Removal Initiatives through the reporting period 2020.

Manual Salvinia Removal Efforts

Prior to COVID19 KOPEL's Salvinia Removal Program was funded by KOPEL's tourism programs, and many student groups, volunteers and voluntourists worked on Salvinia removal up to the March 18 COVID Movement Control Order and the cessation of International Tourism activities. Since November 2020, KOPEL's current Salvinia and Sudds removal program is funded by the Hasanah Foundation COVID19 Relief package HSG2020. By the end of 2020, this program had **removed approximately 1 hectare** of Salvinia and Grass Sudds from the Tungog Lake. See Figure 55 (below)

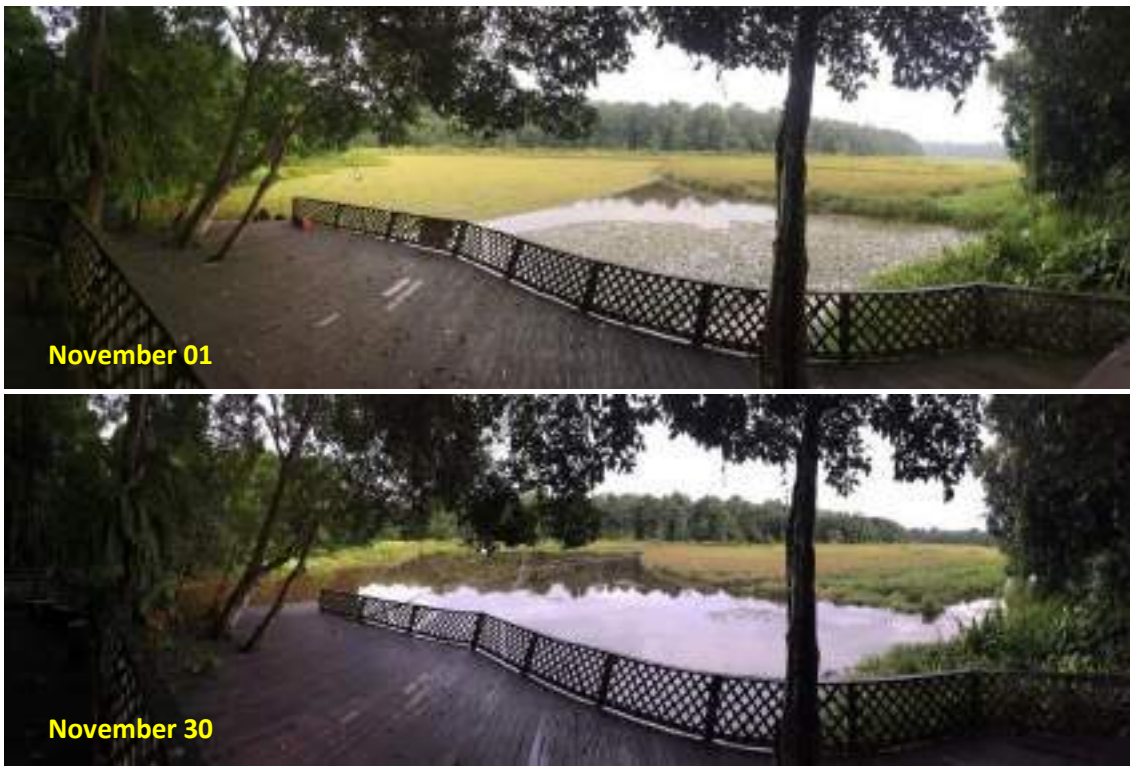

Figure 55: Before After images of Salvinia and Grass Sudd removal - Tungog Lake November 2020

In December 2020 KOPEL shifted to a semi-mechanical approach utilising boats. This approach is designed to increase the weed removal and target the removal of the thick grass sudds from the lake. The change to mechanical approach is still considered experimental because the techniques and results are still under evaluation. The current process utilises boats as the mechanical device combined with ropes, nets and pulleys as the weed haulage mechanism. In December, this approach netted approximately 0.20 hectares of Salvinia weed removed from Tungog Lake. See images 56-59 below.

Figure 56: Grass Sudds being captured in nets ready to be dragged out of the lake via rope hauling systems.

Figure 57: Rope hauling systems being readied to pull out the netted Grass Sudds

Figure 58: Rope hauling systems pulling out the netted Grass Sudds

Figure 59: Rope hauling systems releasing Grass Sudds for decomposition on the forest floor

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 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.

5. Cave Restoration & Monitoring

There are more than 11 recorded limestone caves within the Pin-Supu Forest Reserve (PSFR). Many of these caves in the Supu Complex have unique cave formations, ancient artefacts, and specialised cave fauna, all of which are significant and specialized features of HCV 3.0 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.

Since the year 2010 KOPEL has appointed four forest rangers full time, to monitor and protect the caves in the Supu Limestone Complex. The rangers are based at Supu Camp, to maintain a permanent presence at the caves and impede encroachment into the caves, whilst maintaining the facilities and trails. Prior to KOPEL's work in this site, there was no scientific monitoring of the caves. In 2018 KOPEL formed a short-term partnership with The Rufford Foundation to make scientific cave exploration under the project of, *Cave biodiversity conservation in Lower Kinabatangan, Sabah, and Malaysian Borneo*. The study detail is described below:

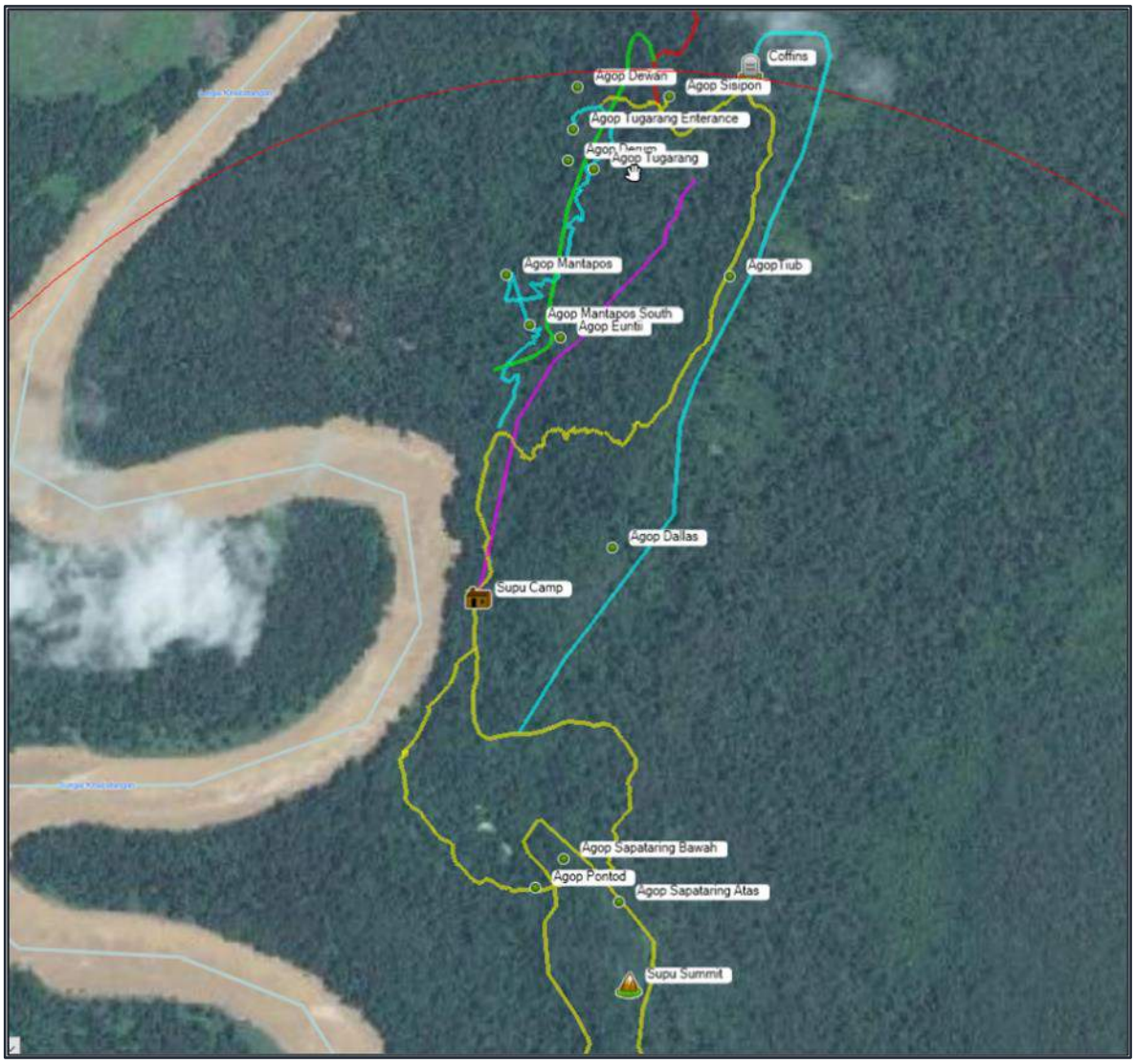

Figure 60: Location Limestone chamber in supu cave

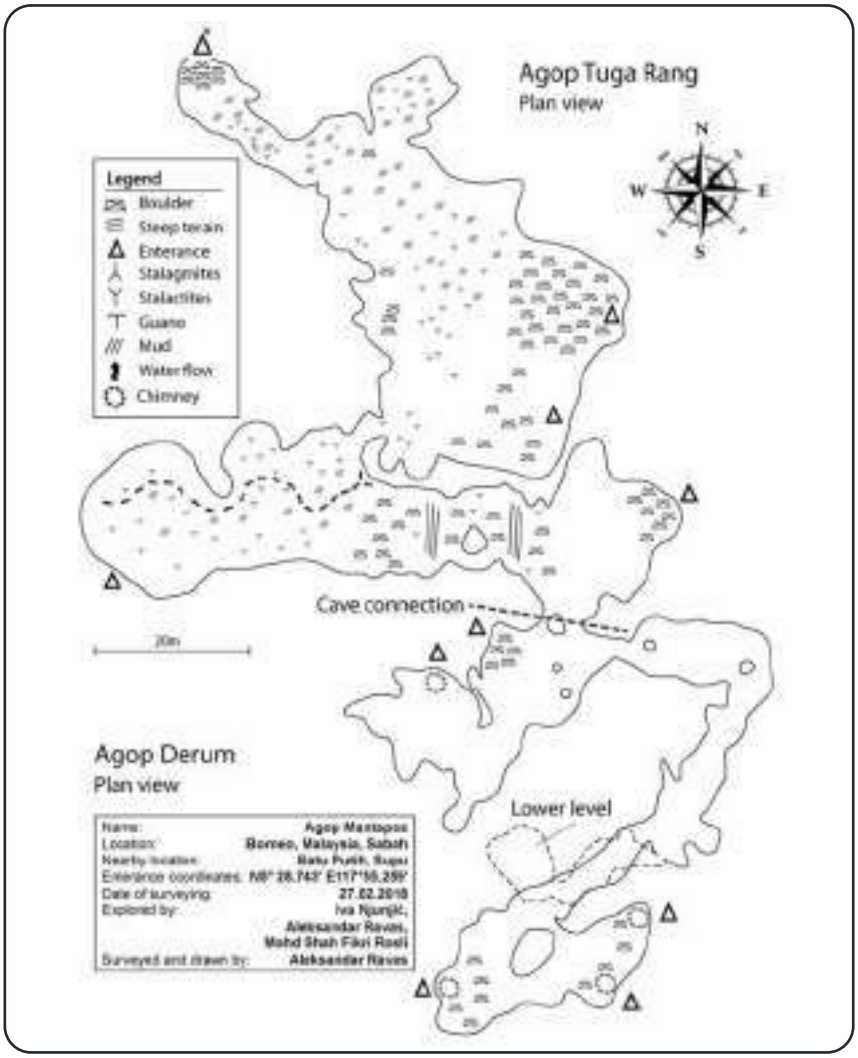

Figure 61: Cave mapping plan from The Rufford Foundation Study (Plan View)

Cave and Karst fauna conservation in Pin Supu Forest Reserve

I. The first phase of the project involved the training 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 will support the development of organized inventories for each cave, alongside measure species richness, and create maps of cave endemism. The work in this phase involved local collaborators wherever possible. The purpose of this involvement was to disseminate information 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 Batu Puteh. Also, an excursion was organised to the caves for local school students to explore hands on involvement of young school students in bio

speleological investigations. The purpose being to provoke an 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 in Supu Cave. Cave mapping within selected caves used specially modified laser rangefinder combined with and connected to mobile phone apps, the chambers of three cave were mapped out in this exploratory phase. Example cave map is shown in Figure 61 above.

Swiftlet Nest Monitoring

Swiftlet Nest surveys were not conducted from 2013 – 2018. Nest counts were started again in March 2019. The results below (figure 29, 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 62 below. The Caves Agop Tugarang, Agop Sisipon and Agop Dalas have the highest nest counts – approximately 150 nest per cave.

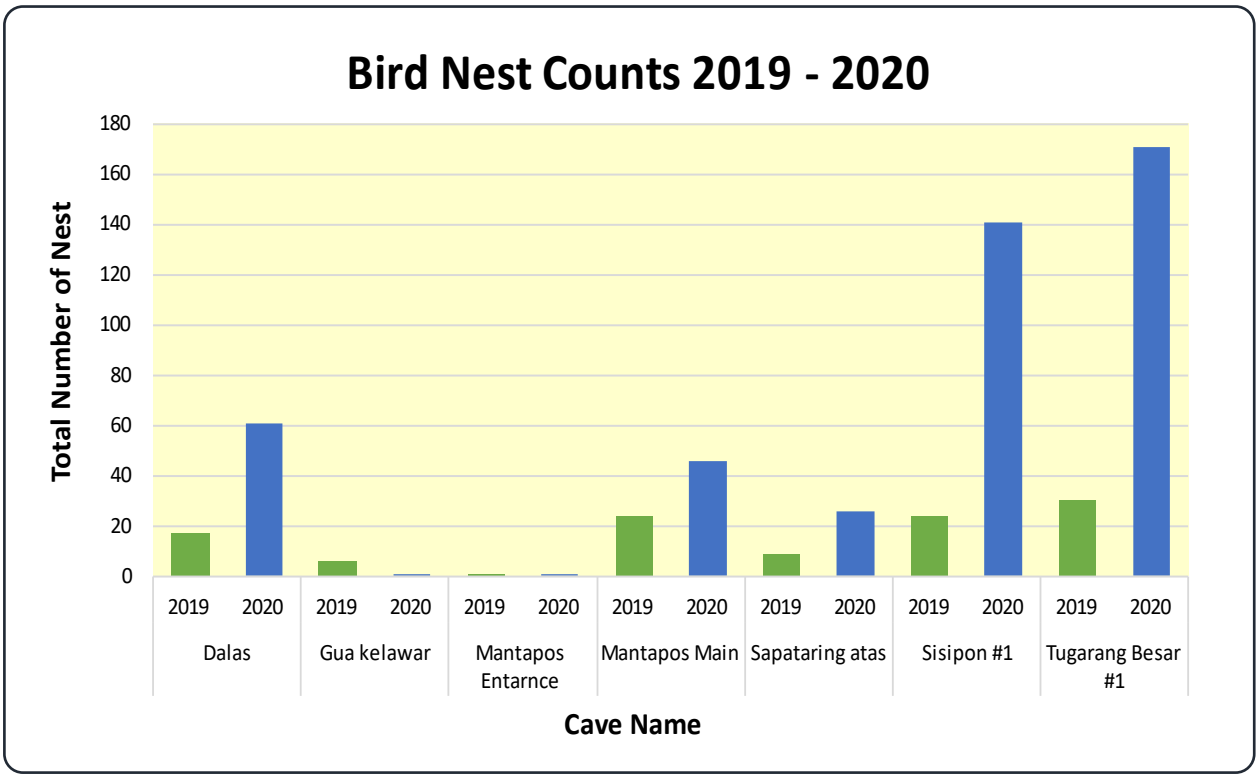

Figure 62: Birds nest counts from 6x Surveys 2019-2020

Management Implication

I. Based on the overall outcomes of the preliminary cave fauna survey, it is understood there is considerable 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. The monitoring and subsequent fluctuation of nest counts across the year demonstrated illegal intrusions were being carried out in the caves. The intrusions were reported to Sabah Forestry Department; however, lack of evidence is thwarting further action or prosecution of the offenders. Additional security interventions have been established to prevent intrusions from reoccurring.

V. The cave monitoring program involves 100% the local community hence 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. It is recommended that the cave environments and monitoring program be an ongoing part of environmental education programs in the future.

Figure 63: Birds nest survey

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 2020. 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 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.

For More Information Please Contact:

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