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Total suspended solids (TSS) adverse effect level to malaysian mahseer (tor tambra)

***[1]Ahmad A.K**
[1] Department of Earth Science and Environment,
Faculty of Science and Technology,
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

[2]A. H. Siti-Munirah
[1] Department of Earth Science and Environment,
Faculty of Science and Technology,
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

[3]H. R. E. Dyari
[1] Department of Earth Science and Environment,
Faculty of Science and Technology,
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

[4]B. Haslawati
[2] Glami-Lemi Fisheries Research Institute, Titi, Negeri Sembilan

[5]W. M. W. Maisarah
[1] Department of Earth Science and Environment,
Faculty of Science and Technology,
Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor

**Corresponding Author: Ahmad.A.K*
Email: abas@ukm.edu.my

Abstract:

Total suspended solids (TSS) as other contaminants could cause adverse effects to fish if present at an excessive level. To date, Malaysia does not have any specific standard on TSS limits for freshwater community protection, especially fish. This study was conducted to determine the non-adverse effects level of TSS to the Malaysian mahseer (Tor tambra). The stress test was undertaken using the Multispecies Freshwater Biomonitor (MFB™) (eight test chambers) for 24 hours exposure with ten-minute intervals. The stress signal was observed on behavioural responses that were ventilation and locomotion. Fifty juveniles ranging from 5cm to 7cm standard length were collected from natural ecosystems and exposed to thirteen series of TSS concentrations (50 mg/L, 100mg/L, 150 mg/L, 200 mg/L, 250 mg/L, 300 mg/L, 400 mg/L, 500 mg/L, 600 mg/L, 700 mg/L, 800 mg/L, 900 mg/L and 1000 mg/L) in closed circulated system in the laboratory. A total of 13,104 observations were recorded during continuous 24-hour experiments. The same species from similar locations where test species were collected were caught for quality of growth assessments using length-weight analysis. Laboratory result indicates more time was used for locomotion from ventilation, however, ventilation has a more significant coefficient of variation when exposed to a stressor. One-sample t-test indicates insignificant different time used for locomotion and ventilation compared to control (p = 0.987 and 0.974 respectively, = 0.05) for 50 mg/L to 500 mg/L. However, the time used for behaviour was significantly changed at? 600 mg/L TSS concentration, where low-frequency (locomotion activity) was reduced but high-frequency activity (ventilation) increase was increased significantly. Gill flaring or coughing activity was observed at? 600 mg/L for TSS removal from their gill membrane and was more frequent at higher TSS concentrations. The TSS concentration in the studied river (where the fish were caught) was found to fluctuate ranging from 7.3 mg/L during no rain to 957 mg/L during or after rain. Length-weight analysis of field captured Tor tambra shows negative allometric growth patterns ($b<3.0$), which indicates inconvenience growth conditions. Since almost similar TSS range of concentration was tested in the laboratory, inconvenience growth could be displayed by a significant ventilation change. Gill flaring proves the species experience inconvenience conditions due to excessive TSS and the result from this study is very useful for Tor tambra protection. This study reveals the lowest TSS cause adverse effects Tor tambra grow is 600 mg/L. This value is useful as a benchmark for the maximum TSS allowable in the river that receives impact from any development. Therefore, the government may enforce this limit in EIA approval conditions to protect Malaysian endangered Mahseer (Tor tambra).

Keywords:

Freshwater biomonitoring, biological indicator, length-weight analysis, fish stress signal

1. Introduction:

In every development, land clearance is a crucial activity and potential to cause soil surface erosion and total suspended solids (TSS) in aquatic systems (Rocha-Santos et al 2016; Moges Kidane et al., 2019). Soil erosion, which can be considered as a diffuse source can occur throughout the catchment of a watercourse. Activities such as vegetation clearance and unsustainable land use management would accelerate soil erosion which causes TSS contamination to streams and rivers (Rocha-Santos et al 2016). As a result, TSS contamination has become a critical problem for aquatic ecosystems. Excessive loads of TSS could disturb and harm aquatic communities, especially fish because intolerant species are vulnerable to environmental stressors (Cumming & Herbert, 2016). Deforestation, in the name of development, consisting of land clearing as well as timber harvesting activities, has deteriorated this valuable species' habitat (Seet, 2010).

According to Zhang et al. (2011), fluctuation of river water quality influenced fish weight, survival rate, sustainable growth rate and yield. Since fish is sensitive to stress conditions, which can be induced by changes in environmental conditions, their behaviour can be used as a signal for water quality assessment and monitoring (Cumming & Herbert, 2016). Therefore, monitoring and quantifying behavioural responses has become an important tool for assessing fish stress and disease in aquaculture farms due to water contamination (McFarlane et al., 2004). The behavioural aspects of the fish that were used included their physical activities such as locomotion, positive rheotaxis and escaping behaviour, while the physiological parameters include respiration rate, gill ventilation frequency, heartbeat, pumping rate, bio-electric potential, photosynthetic activity, growth and bioluminescence.

Fish behaviour was previously assessed by several techniques such as the electrical impedance conversion technique (Craig and Laming, 2004), video monitoring (Petrell et al., 1997; Magalhães et al., 2007; Nimkerdphol and Nakagawa, 2008; Krag et al., 2009), hydroacoustics (Tao et al., 2010), acoustic reverberation (Conti et al., 2006), acoustic Doppler velocimetry (Masaló et al., 2008) and acoustic telemetry (Bégout Anras and Lagardère, 2004). The multi-freshwater biomonitor (MFB) has several advantages over other in situ online biomonitors as it requires no filtration or pre-treatment of water samples. Additionally, since it is a non-optical system, measurements can be monitored under turbid water.

High TSS concentrations in water bodies are reported to cause particles to clog on gills and reduce gas exchange, leading to oxygen deprivation (Hess et al., 2015). This condition greatly affects fish especially juveniles as they higher oxygen demands (Wenger et al. (2014). For instance, in a study of snapper juveniles (Pagrus auratus), it was shown that an increment of epithelial hyperplasia/fusion of the fish lamella was positively correlated with suspended sediment loads, which caused coughing and gulping in turbid conditions (Lowe 2013). Berry et al. (2003) found that high levels of suspended sediment for a short time may be less of a problem than chronic exposure to suspended solids. High turbidity for short periods causes fish to avoid the sediment plume. Exposure for long durations causes sublethal physiological effects such as increased respiration rates in response to oxygen depletion due to clogged gills, and reduced feeding rates leading to slower growth. A study by Lake and Hinch (1999) on North American freshwater fish demonstrated the concentrations of suspended solids that could kill fish over short periods typically ranged from 100 to 100 000 mg/L, whereas concentrations that cause sublethal effects are often in the range of 10 to 100 mg/L.

Few studies were undertaken to evaluate water quality effects on fish communities in Malaysia's river systems such as Zulkafli et al. (2018) and Nyanti et al. (2018), but their studies were focused on other water quality effects rather than TSS specifically. The TSS effects on fish are of serious concern. This study aimed to determine TSS levels that would impair Malaysian mahseer (Tor tambra). This species has been classified under the protected and endangered category by the International Union for Conservation of Nature red checklist (IUCN) for many reasons. Naturally, this species living at most upstream where anthropogenic activities such as logging, mining and large-scale plantations are taking place and causing excessive sediment yield into the river system and affecting intolerant fish species like Malaysian mahseer. Since Malaysia does not have specific guidelines for safe TSS levels for fish surveillance except general river classification for water usage. This study aims to determine the maximum TSS tolerable level for Tor tambra surveillance. The result from this study is very useful to apply in Malaysian environmental legislation such as environmental impact environment (EIA), integrated river basin management (IRBM) implementation in Malaysia.

2. Materials and methods:

2.1. Test species and sampling:

Tor tambra (Family: Cyprinidae), which is locally known as the 'kelah' or 'empurau', is an economically valuable, recreational and ornamental fish due to its character and attractive colouration (Saufinas et al., 2012). This species is a relatively expensive freshwater fish, costing up to USD 100 (approximately RM430) per kilogram. The fish is an active swimmer and usually inhabitant in rapid waters. They feed on a variety of foodstuffs including smaller fish (they are omnivorous) and occupy the topmost rank of the complex riverine community (Chee, 2004; Kunlapapuk and Kulabtong, 2011). This species generally has an elongated body and is moderately laterally compressed. According to Haryono and Tjakrawidjaja, (2006), this species has a noticeable snout with inferior or sub-inferior mouth looks like horseshoe-shaped, while its upper jaw is strongly protractile.

In this study, juvenile Tor tambra were collected from the upstream of Nenggiri River, which is in the Gua Musang District, State of Kelantan, on the East Coast of Peninsular Malaysia. The upstream site of this river is seriously affected by sediment yield due to logging and mining activities. Fish were caught using a cylindrical trap and collected samples were quarantined for four days in 4' x 2' x 2.5' tank for acclimation and were fed with commercial food once a day before being kept in a permanent stock container. The tank was aerated by an electrical air pump to provide sufficient dissolved oxygen (5 mg/L to 7 mg/L). The collected fishes size ranges were from 7.3 to 10.3 cm standard length. For validation purposes, twenty-seven individuals from similar sites where tested species were collected were caught and measured for their length-weight for the growth condition analysis.

2.2. Multispecies freshwater biomonitor (MFB™):

In this study, locomotion, and ventilation activities of Tor tambra at different concentrations of TSS were examined. Fourteen different concentrations (including the control) of TSS: 0 mg/L (control), 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, 300 mg/L, 400 mg/L, 500 mg/L, 600 mg/L, 700 mg/L, 800 mg/L, 900 mg/L and 1000 mg/L were used. The range of concentration selected for laboratory testing was based on the pre-determined actual TSS range of concentration in the studied river. Sediment for the same river was used for TSS solution preparation. The collected sediment was oven-dried, sieved through 63µm pore size and was mix 1000ml of tab water for stock preparations. The stock mixture was then measured for serial of TSS concentrations using the dilution factor formula $M1V1 = M2V2$.

A Multispecies Freshwater Biomonitor unit (MFB™; LimCo International, German) with eight measurement chambers were used for locomotion and ventilation signals detection at different TSS concentrations (Figure 1). A quadrupole impedance conversion technique was applied.

Inside each chamber are two sets of stainless-steel plate electrodes, located at the chamber wall. The first pair creates a high-frequency signal of alternating current of up to 50 Hz resulting electric field inside the chamber. Any movement is registered as an impedance signal and is picked up by the second electrode pair. The impedance signals are then sent to the recording device and continue onto computer data analysis (Gerhardt et al., 2006). A modification was made by putting the digital camera at one end of the chamber opening to capture test species activities during 24-hour test period.

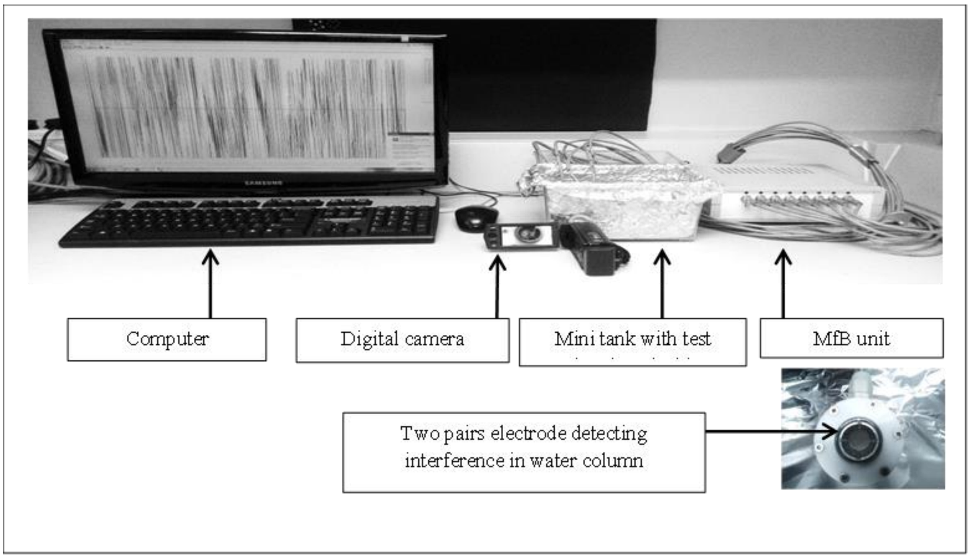


Figure. 1: The MFB unit with accessories for fish stress detections

The MFB™ allows behaviour investigation of which closely related to physiological changes due to alterations in water quality (Craig and Laming 2004). Major advantages of this systems include greater sensitivity relative to chemical indicators, their non-destructive nature, ecological relevance and ability to perform long-term biomonitoring. In this study, all procedures were carried out following Gerhardt et al. (1994). The MFB™ chambers were placed inside 30cm x 15cm x 10cm aluminium foil-coated aquarium. Preliminary tests indicate aluminium foil used is able to reduce interference during testing period. The camera recorded fish activities and the data obtained were compared with recorded time series peaks (impedance). This aid in determining actual activity that produces the signal correctly.

Test species were placed into the chamber inside a plastic aquarium containing 1.5L of water. A closed circulation system was applied, which dissolved oxygen (DO) and pH were set as constant parameters. Water was continuously circulated to maintain the TSS saturation as well as the DO concentrations. The water temperature was maintained between 26 and 28 °C and dissolved oxygen was at 5.80 - 7.50 mg/L using an aqua speed A3004BIO air pump.

The behavioural patterns were recorded continuously for a period of 24 hours after 10 minutes of acclimation time, with 4 minutes of recording time and 6 minutes interval time. This test was undertaken at room temperature (27 °C). The signal measured was then transmitted to the computer amplifier where the data are registered with the MFB™ software. The MFB™ then translated the behavioural activities of the fish into amplitude graph mode and fish movements were plotted in the graph as the activity (V) over time (s). This amplitude graph was then transformed to a discrete fast Fourier transformation (FFT) histogram graph that includes the relative amounts of the low-frequency behaviours (e.g. 0-2 Hz of locomotion) and high frequency behaviours (e.g. 2.5-8 Hz of ventilation) (Figure 2). This FFT mode transcribed fish activity data as a percentage for every activity that was recorded during the observation. Fifty individuals of the species were tested, and 13104 observations were recorded. Locomotion data were separated from ventilation data and comparisons with the control were tested using a paired t-test with a 95% significant level (? = 0.025).

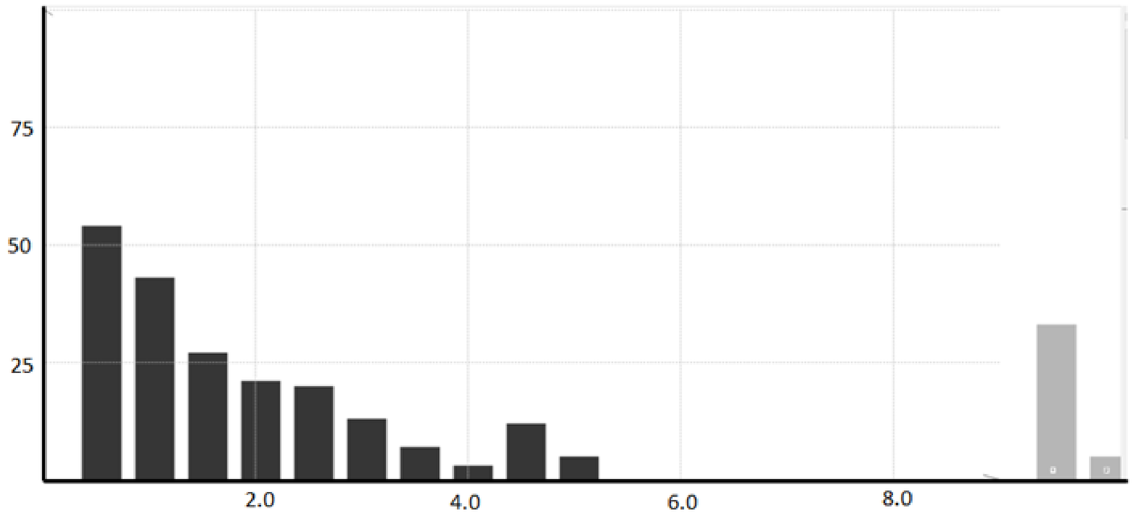


Figure. 2: Types of fish response detection in MFB chamber histogram FFT (% Hz) mode. (L1 = average locomotion and L2 = average ventilation)

2.3. Fish growth estimation:

Wild species from the same river were caught for length-weight analysis. Due to the difficulty to have this endangered species, only twenty-seven individuals were caught, measured for standard length (cm) and weight (g) and immediately released into the river. The length-weight relationship is determined from the expression W = alb and log-transformed to W = log a + b*log L, where W is the total weight, L is the total length, a is the intercept, and b is the slope. The result estimates whether species in the river somatic growth is isometric (b = 3), allometric (b > 3) or negative allometric (b < 3) growth pattern (Santos et al., 2002). The degree of association between the variables was measured for determination of the coefficient, r2 at 95% significant level of the parameters a and b in length-weight analysis.

2.4. The TSS in the river:

The TSS concentration in the studied river was analysed. River water was collected at four different occasions to represent dry and wet period. One litre of river water was manually collected since the river is shallow and analysed for TSS concentration following APHA standard method. The TSS was measured using the gravimetric method and triplicates were made for each occasion.

2.5. QA and QC:

Water temperature and dissolved oxygen were maintained during the experiment. Circulated water temperature was constant between 24.0°C to 26.0°C and dissolved oxygen was between 5.8mg/L to 7.5mg/L. A constant flow rate in the aquarium was created using a water pump to ensure homogenous TSS in all test chambers throughout the test period.

3. Results and discussions:

Fish reacts in many ways to adapt to sublethal stress from TSS. Three overarching trends reported are physiological, adjustment and avoidance (Kjelland et al., 2015). Llyod, (1987) summarised various response studies on TSS impact at different fish species and life stages.

3.1. Control test:

In the control treatment, test species showed continuous and regular locomotion movements without pause, which were exhibited by regular and repeated peaks in movement patterns over time. The locomotion signal was separated from ventilation based on the frequency range produced (Figure 3). Observations on the control indicate locomotion was produced at low frequencies in five different ranges (1.0Hz, 1.5Hz, 2.0Hz and 2.5Hz), whereby ventilation at higher frequencies in six different ranges (3.0Hz, 3.5Hz, 4.0Hz, 4.5Hz, 5.0Hz and 5.5Hz).

An average of seven replicate treatments on control species indicate that the species used 95.9 ± 3.27% of the time for locomotion and only 3.37 ± 1.42% time for ventilation (Table 1). Only one replicate exhibited a very high time used for ventilation compared to others and was significantly different from other observations (one-way ANOVA, $p < 0.05$, ? = 0.05). The mean obtained was significantly away from the calculated mean confident interval (CI), thus this replicate was excluded from the descriptive statistics to avoid bias due to extreme data.

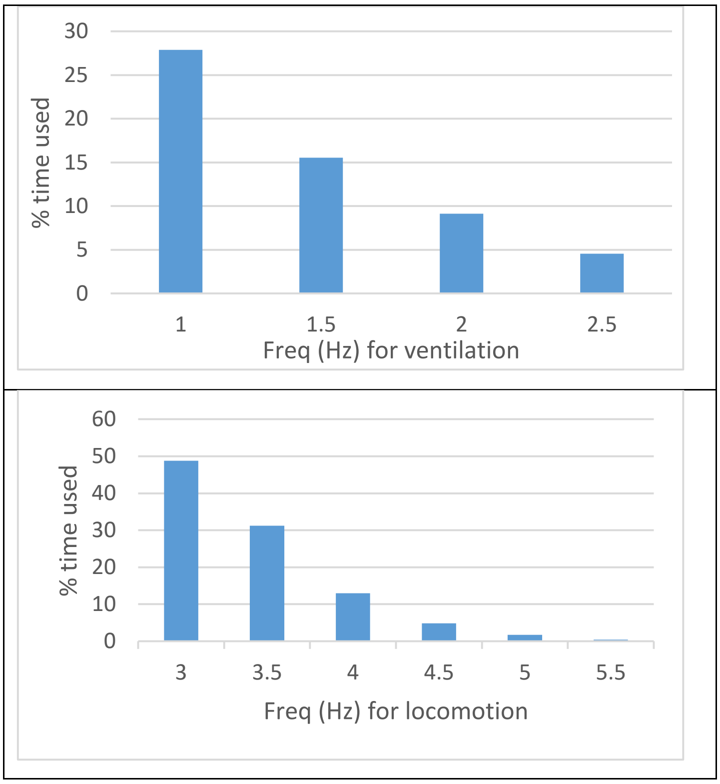


Figure. 3: Time used for each ventilation and locomotion frequency produced during 24-hour control testing

Table. 1: Mean locomotion and ventilation time used comparison for control

Replicates	Behaviours (%)	
	Locomotion	Ventilation
	Mean ± SD	Mean ± SD
1	89.26 ± 7.51	10.91 ± 7.75
2	97.84 ± 3.19	2.58 ± 4.33
3	94.81 ± 4.83	5.19 ± 4.83
4	98.09 ± 1.50	2.14 ± 2.41
5	98.04 ± 1.29	2.97 ± 4.06
6	98.12 ± 1.73	2.22 ± 2.66
7	94.87 ± 5.46	5.13 ± 5.45
Mean ± S.D.	95.86 ± 3.276	3.37 ± 1.42
Confidence intervals $_{mean}$	92.08 – 99.64	2.29 – 4.45
Coefficient of Var.	3.42%	42.14%

Based on the student t-distribution model, the mean confidence interval for ventilation exhibited larger variability compared to locomotion. To make a fair comparison, the coefficients of variation for both were transformed to percentage and result showed that ventilation represented about 42% of the data variance compared to only 3.42% for locomotion. This explains in natural habitat, test species produce more regular locomotion to stabilise their position in the habitat to minimise oxygen required (ventilation).

For both activities, test species exhibited normal conditions by producing more lower frequency (repeated activity/second) than high frequency (Figure 4) and therefore information gathered from the control test was used as a benchmark to evaluate fish response to TSS exposure and to determine acceptable TSS levels by local Tor tambra.

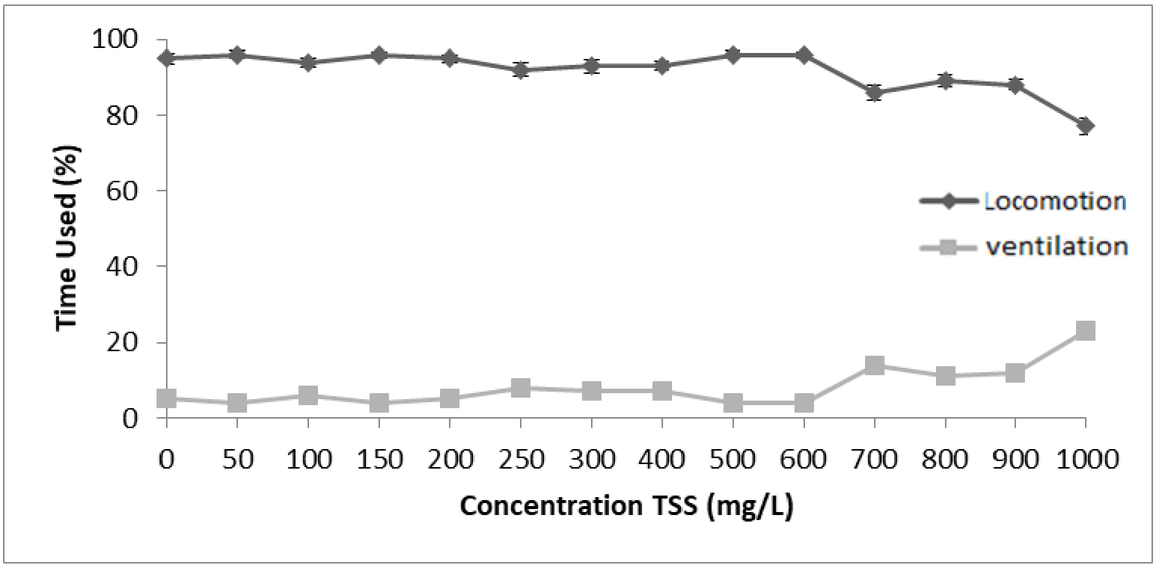


Figure. 4: Locomotion and ventilation signals in FFT mode for 24-hour exposure

3.2. Test species response:

This study attempts to establish Tor tambra acceptable level for TSS contaminations and the information gathered is useful for species conservation management in Malaysia. This species has a site-specific preference, which only inhabits at the upstream side of riverine system. This kind of ecosystem is mostly located within catchment forest that naturally has very good water quality. However, in Malaysia, these areas recently progressively declined due to logging, mining, and forest conversion activities. The main adverse effects of those activities are excessive surface soil erosion that resulted in high sediment yield to the river. To date, Malaysia does not have a specific guideline of TSS concentration for fish protection, therefore, this behaviour response study was initiated to reveal tolerable TSS concentrations for Tor tambra populations. This species is known as intolerant to any contamination, and therefore protecting this species would protect other species in the community.

The result from 13,104 observations for 24-hour exposure shows that even ventilation time used is lesser than the locomotion, but it changes rapidly, which explains respiratory impairment is a more sensitive indicator of stress impacts than locomotion. A stress assessment study provides an early and quick response compared to a mortality test. Fish's respiratory very sensitive to TSS contaminations because it could reduce respiratory performance by clogging the gill lamellae or damaging gill tissues. Determining TSS direct effects on fish is challenging and there is limited information available on the acceptable limit. Even though available, information is difficult to be compared due to the different effects examined, methods used, unit used and different test species. Some studies used turbidity instead of TSS for effect determinations.

Both activities were recorded to produce insignificant different times used from control at 50, 100, 150, 200, 250, 300, 400 and 500 mg/L TSS exposure. For each TSS concentration, the percentage of time used for locomotion and ventilation only vary with small variation from control and one sample t-test result indicates insignificant differences of both activities at each exposed concentration compared to control ($p > 0.01$, ? = 0.05). This indicates that TSS at this range of concentrations does not cause significant disruption to the test species. Cavanagh, (2014) reported that severe gill damage occurs at a high level of suspended sediments (>500 mg/L) even though varies by species, life stages and period of exposure. Greer et at (2015) also reported that brown trout oxygen consumption was not affected by 600 mg/L. Tor tambra increases breathing efficiency even at low TSS concentrations and the best-fit of the line for all frequencies produced was strongly deviated from zero as TSS was increased, except for the lowest frequency was vice versa. The species gradually reduce large movement as TSS was increased and produced higher frequency locomotion rates such as more pectoral fin and caudal fin movements. Test species started to produce a significant variance behaviour when exposed to 600 mg/L and above. During 24-hour of 600 mg/L exposure, test species lessened locomotion and gradually increase ventilation activity time used and produced more perceptible ventilation and locomotion variation from the control test (Figure 4).

3.3. Ventilation activity-ventilation band variation (band 2: 3.0. 3.5, 4.0, 4.5, 5.0 and 5.5 Hz):

From 2,016 observations made, test species were recorded to produce more low-frequency ventilation at most of the exposed concentrations. The first three lowest frequencies (3.0, 3.5, 4.0Hz) were mostly produced during the exposure and represent 85% of the total time used for ventilation. As TSS concentration was gradually increased, test species increase their ventilation time used. The lowest frequency (3.0Hz) was gradually declined but significantly drop after 600mg/L TSS exposure and onward (Figure 5). This indicates tested species increase their ventilation as exposed concentration was increased and the one-way ANOVA test showed a significant difference in ventilation time use between frequencies ($p<0.05$, ?=0.05) and the Tukey test indicates a significant difference between the three highest frequencies (4.5Hz, 5.0Hz and 5.5Hz) compared to the control but were insignificant between them (higher frequencies). This indicates rapid breathing activity during high TSS concentrations exposure. This study was made for 48-hour exposure to observe quick significant responses from tested species. In natural habitats, avoidance is a critical response to any anthropogenic threats especially moving to unimpacted stream reaches. As this option was impossible in test chamber, Tor tambra responds to the stressor by reducing activities that require more dissolved oxygen especially large movement (low-frequency signal). Berli et al (2014) in their study on trout juveniles found that high turbidity reduces swimming performance. Other research has shown that fish avoided areas with high levels of turbidity and suspended solids (Wenger et al., 2014). Richardson et al. (2001) showed that the upstream migration of banded k?kopu (Galaxias fasciatus) was reduced when turbidity exceeded 25 NTU, resulting in recruitment limitation. This study proves that, reducing large locomotion and increasing respiration are significant when avoidance is not possible. Based on video recording, the test species stabilised its position in the test chamber in most of the exposure time when exposed to 600 mg/L and above. A similar result was obtained by Satpathy & Parida (2020), where fish were found to reduce locomotion gradually, irregular swimming and react abnormally at higher TSS exposure. Ahmad et al., (2015) in their study on Tor tambroides using MFB found that ventilation behaviour changed significantly at 300 mg/L exposure, but not for locomotion. They also found that locomotion change was not significant with elevated TSS. A direct comparison with other studies that used different species is not appropriate because each species may exhibit different tolerant behaviour even similar species but different life stages.

Linear regression was used to determine the TSS influence on time used for ventilation at different frequencies and the results are presented in (Figure 6). Only 3Hz was exhibits a significant depletion in time used as TSS concentration increased, while others fluctuated irregularly with different variances.

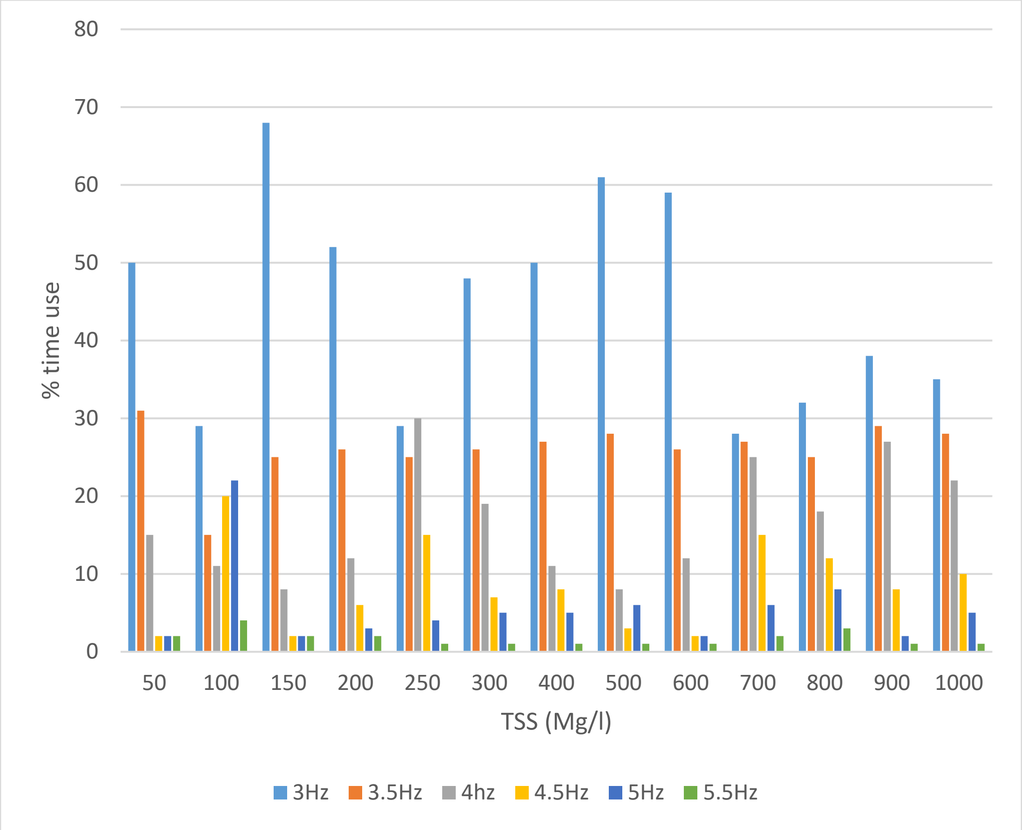


Figure. 5: Variation of time consumed for ventilation when exposed to gradient TSS concentrations

Data obtained demonstrate R2 value for all tests was varied. The higher R2 denote a fraction of the variance that is explained by the best-fit line. Despite the low value, the best-fit line still differs significantly from zero due to the large sample size. However, the regression equation produced shows that TSS significantly affects ventilation, especially at lower frequencies (Figure 6). Due to high data variance, the median time used was adopted to predict TSS influence on ventilation, and the result indicates breathing rate was determined by 14.4% TSS change with the best-fit line was $y = 0.4767x + 8.656$.

3.4. Locomotion variation (band 1: 0.5, 1.0, 1.5, 2.0 and 2.5Hz):

Test species exhibits decrement in time used for low frequencies of locomotion as TSS increased and vice versa for higher frequencies (1.5Hz, 2Hz and 2.5Hz) (Figure 7). Tested species exhibited more aggressive smaller locomotion at higher TSS exposure, and therefore significant effects were observed at lower frequencies (Figure 7). The best-fit line was denoted by higher R2 values located between 15% to 45%.

One-way ANOVA tests indicated that each frequency was significantly different in time used at different TSS concentrations ($p < 0.05$, = 0.05). The test species consumed the highest time for locomotion at the lowest frequency (0.5 Hz, 39.31%).

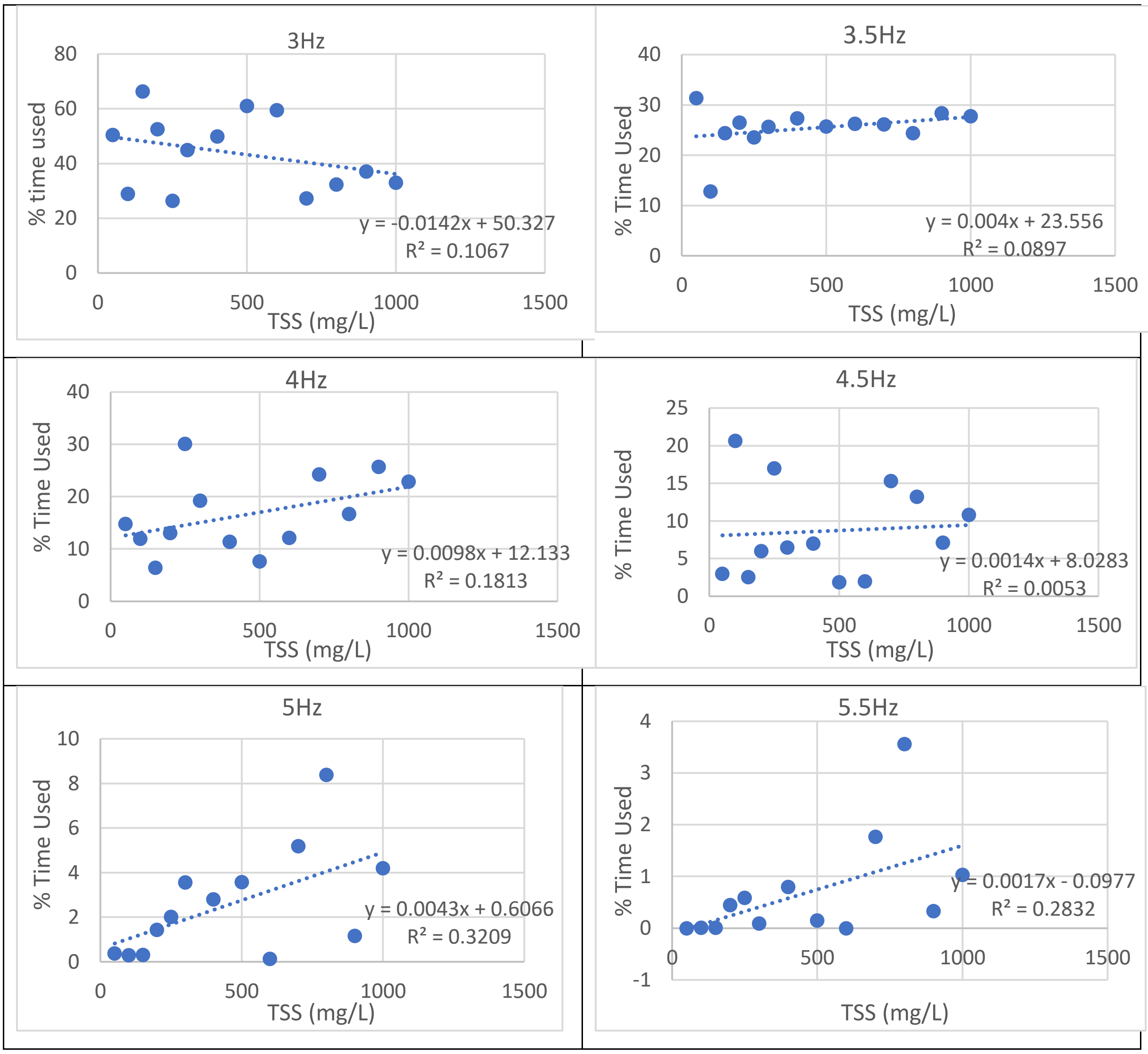


Figure. 6: The TSS influence on ventilation activity at different frequencies

When TSS concentrations were gradually increased, the fish started to minimise large movements that demand high dissolved oxygen, and therefore low frequencies (0.5 and 1.0 Hz) were reduced to minimise dissolved oxygen used. Many studies do not focus on locomotion specifically, but more on fish avoidance behaviour, foraging efficiency and pray-predator reaction (Sullivan and Watzin, 2010). Kemp et al., (2011) reported majority of species have had similar pray-predator interaction effects.

3.5. Coughing activity:

Moving to better places and increasing ventilation activity are two common fish responses to avoid excessive TSS. However, within the restricted area as in the testing chamber, fish must react to the stressor and coughing is one of the observed responses. Instead of providing evidence for ventilation and locomotion signals in amplitude and FFT modes, video capture provides evidence for coughing activity.

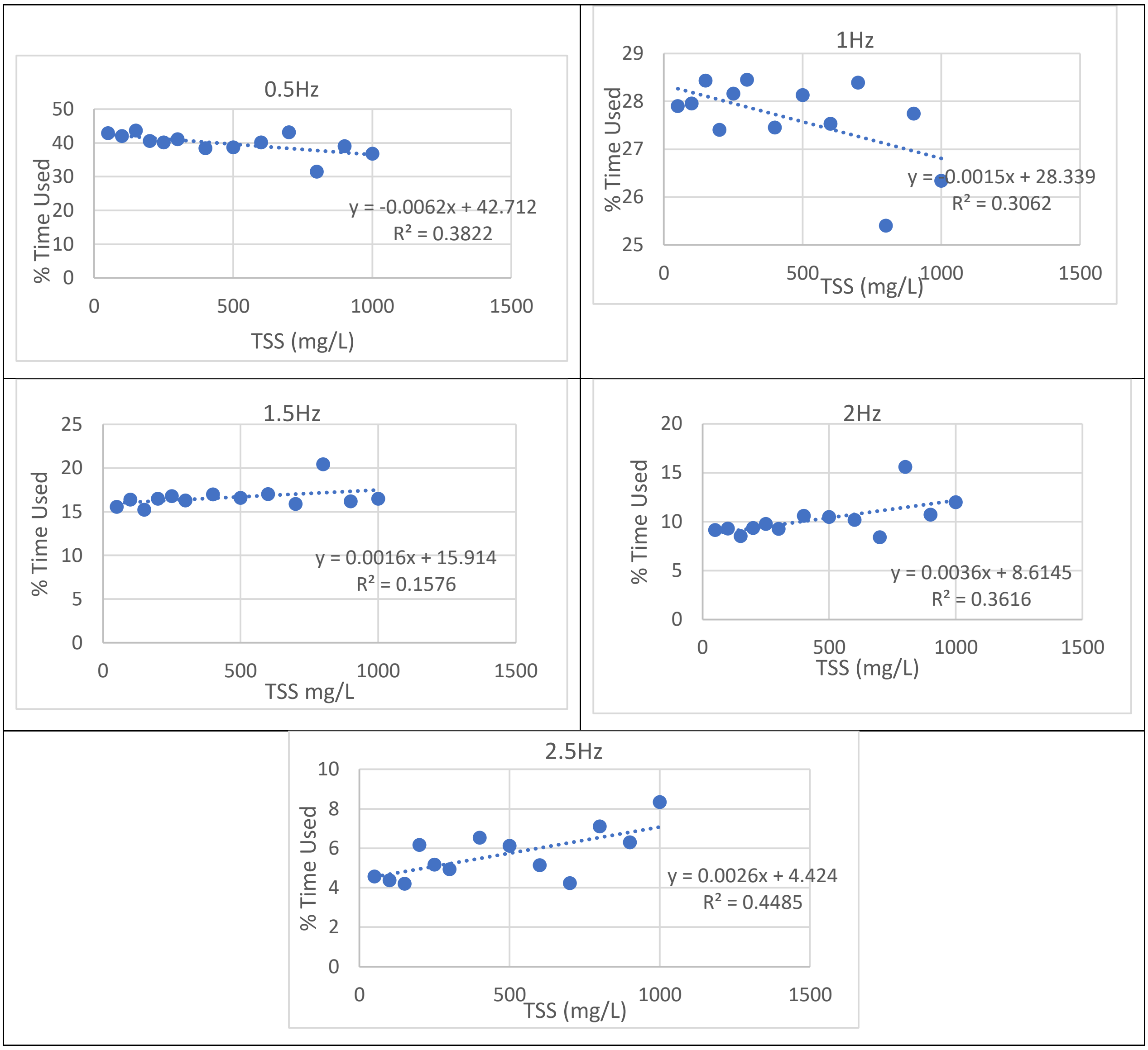
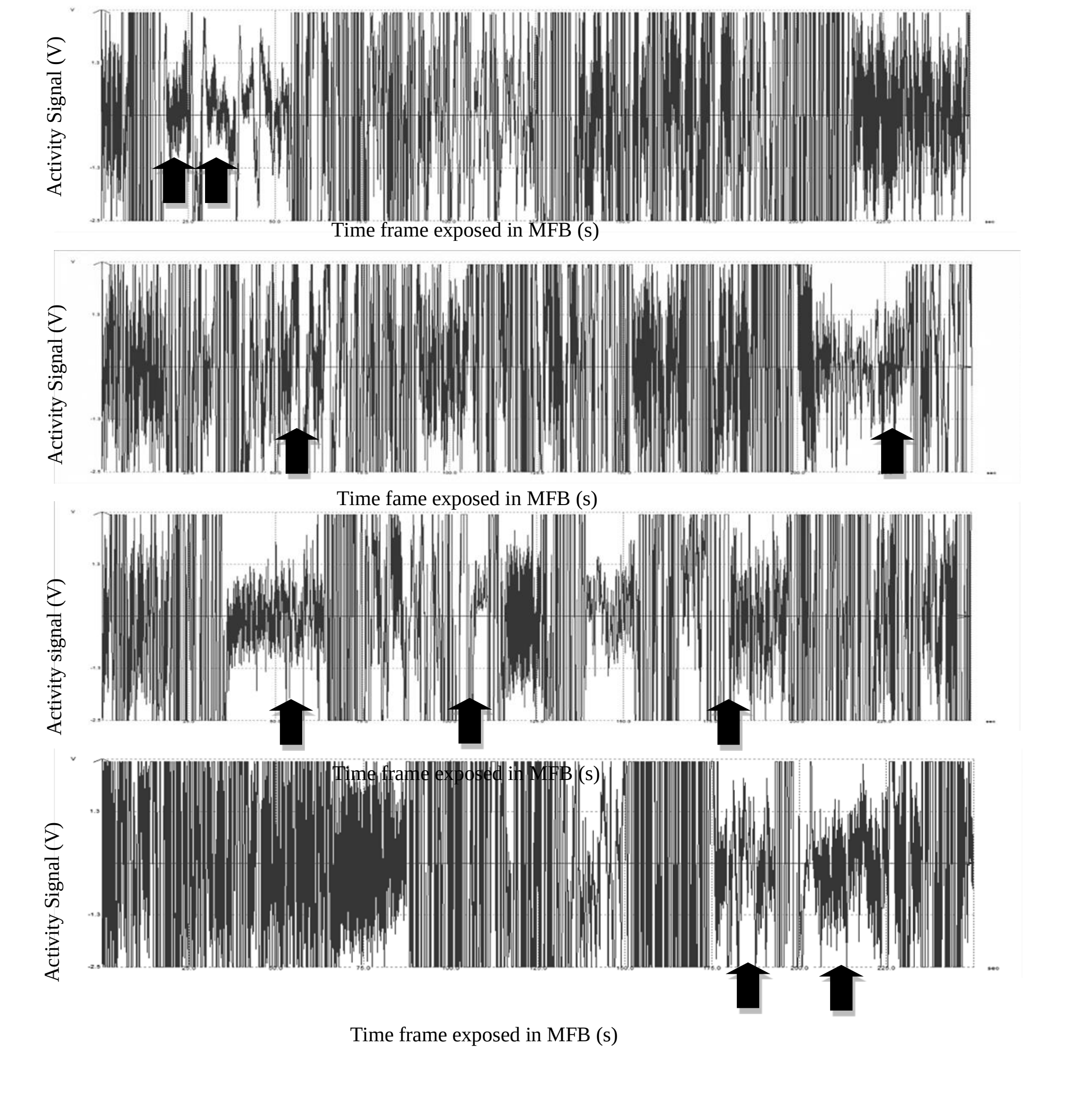


Figure. 7: The TSS influence on locomotion activity at different frequencies

Fig. 8 demonstrates the coughing signal in amplitude mode produced by test species and actual activity was captured by an attached video camera. A significant coughing activity was initiated at 600 mg/L of TSS exposure with unequal intervals. Excessive TSS particles trap on lamella surface and reduce breathing efficiency. Fish makes coughing activity to remove particles that clog their gill membranes and reduce oxygen absorption (Servizi and Martens 1991). Newcombe et al., (1991) reported increasing coughing rate as first response exhibited by fish to survive in turbid water.

Bouaoud et al, (2021) reported that gill bloated is significant at 500 mg/L with the presence of mucus coating the lamellae, and this phenomenon is called hyperplasia. Excessive TSS clogs would create gill trauma, which could kill the fish (Curry & MacNeill, 2004). Without considering other factors such as temporal, rate and maximum frequency, cough activity appears to have high potential for stress signal, as indicating maximum tolerable level for fish.



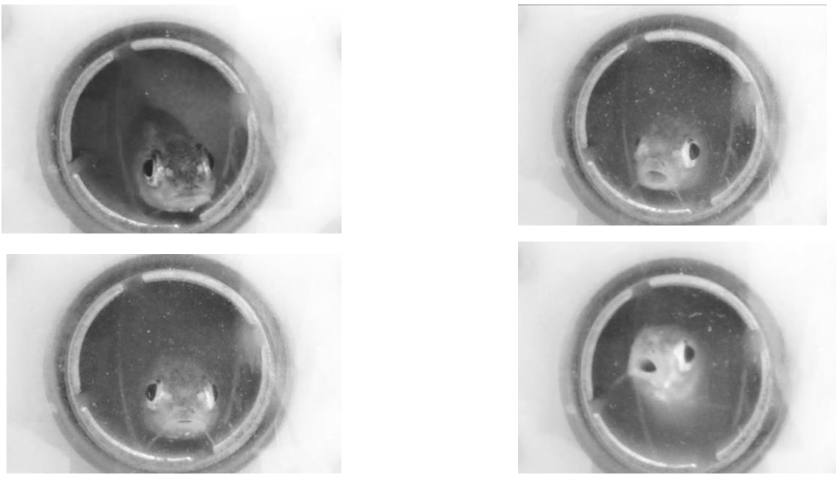


Figure. 8: Amplitude signal detected during coughing activity (above) and test species captured during coughing (below, left) and normal breathing (below, right)

This study shows that cough activity is another good stress indication signal that is useful for fish persistence.

3.6. Length-weight analysis:

The length-weight analysis examines fish somatic growth. The length-weight relationship is one of the standard methods that yield authentic biological information and is of great importance in fishery assessments. To make this study more credible, similar species from their natural habitat were analysed for their growth condition. Fish from the same study area where the tested species were collected was caught for length-weight analysis to validate the TSS interference on their growth pattern. Besides that, the TSS in the river was evaluated for dry and wet periods and the result shows that the TSS concentration during the no-rain period ranged from 7.3 mg/L to 29.3 mg/L but increase to 540 mg/L to 957 mg/L after rain. This shows enormous fluctuation and could affect species growth as this laboratory test indicates a significant ventilation and locomotion change were detected at 600mg/l TSS. From twenty-seven fish caught (5.0 to 19.0 cm length and 2.0 to 130 g weight), data showed that the fish are in negative allometric growth as the b value is 2.853 (b equal to 3.0 for isometric growth) (Figure 9). The best-fit line in regression analysis showed that length induces very large fish growth variation, which is approximately 96% (Table 2).

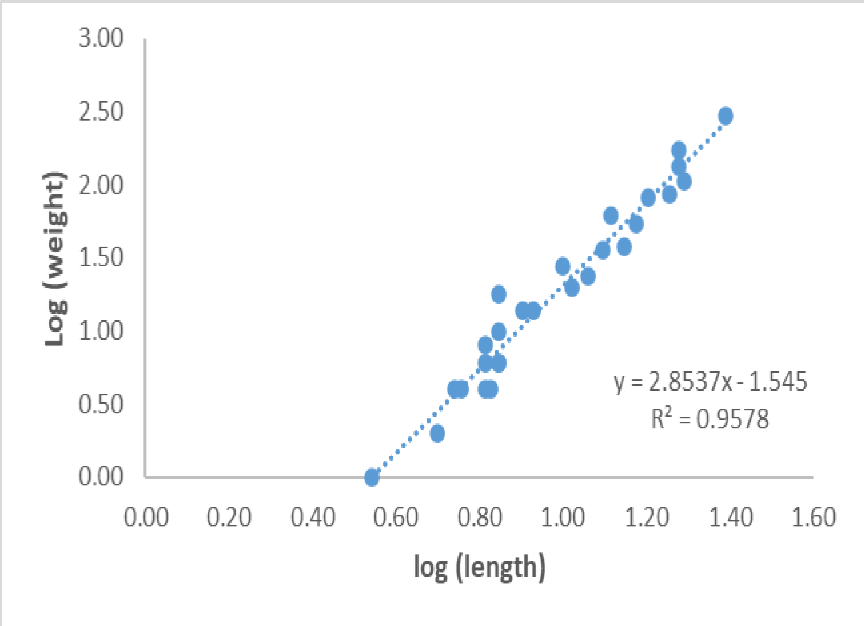


Figure. 9: Length-weight analysis for Tor tambra growth pattern.

Table. 2: Species growth pattern estimation using length-weight analysis.

Species	n	a	b	R^2	Growth conditions	$W=aL^b$
Tor tambra	27	-1.545	2.853	0.957	NA	$W=-1.545L^{2.8537}$

Note: NA = negative allometric

4. Conclusion:

Many studies confirm that excessive TSS potentially cause fish hyperplasia or fish dead, but subject to species, age, locality and other environmental factors. Information on allowable or safe levels of TSS in riverine systems is crucial for river management to protect this endangered species. This study reveals 600 mg/L TSS potentially cause chronic effects to Malaysia Tor tambra. This species is known as a very intolerant species and protecting this species would benefit other more resistant species. The related authorities such Department of Environment (DOE) and the Department of Fisheries (DoF) may use this finding as guidance for the maximum TSS allowable to be released into the Tor tambra habitat. By using 600 mg/L as the maximum total TSS allowable in the river, the developers must estimate the appropriate sediment yield amount to be discharged into the affected river. The Malaysian environmental impact assessment (EIA) practitioner may use this finding as part of mitigating measures for water quality and fish protection.

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The authors declare that they have no financial or non-financial competing interests.

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