The presence of blue panchax (*Aplocheilus panchax*) in the waters, contaminated by heavy metals, of the abandoned tin mining pits of different age

[1]Diah Mustikasari, [2]Agus Nuryanto, [2]Suhestri Suryaningsih

[1] Doctoral Student of Doctoral Program, Faculty of Biology, University of Jenderal Soedirman, Purwokerto, Indonesia; [2] Faculty of Biology, University of Jenderal Soedirman. Corresponding author: A. Nuryanto, agus.nuryanto@unsoed.ac.id

Abstract. The characteristics of abandoned tin mining pits are an interesting environment for study, being quite extreme, with acidic pH indicators, and heavy metals. This research aimed to elaborate on blue panchax (*Aplocheilus panchax*) in waters of abandoned tin mining pits of different ages and contaminated with heavy metals, located in Bangka Island, Indonesia. The results showed that the *A. panchax* was found in pits with ages between 1 and 5 years, which had a pH value of 3.81-3.84, and dissolved oxygen (DO) ranging from 5.33 up to 5.63. *A. panchax* was also found in pits with ages between 5 and 15 years (pH of 3.86-3.91 and DO of 5.63-5.97), in pits with ages between 15 and 25 years (pH of 7.25-7.46 and DO of 6.3-7.07), and pits with ages between 25 and 50 years. *A. panchax* was not found in pits with ages between 50 and 100 years (pH of 6.88 and DO of 7.20) and pits with ages >100 years (pH of 5.45-5.67 and DO of 6.33-6.43). Ecosystems of abandoned tin mining pits where *A. panchax* was found were generally polluted by heavy metals such as Sn, Fe, Hf, and Cu. The heavy metal concentrations found in the pits tend to decrease over time, reaching a minimum in the pits with an age between 25 and 50 years although the heavy metal contamination trend reverses, showing a growth pattern in the pits with an age >50 years, higher than in the pits with an age between 15 and 50 years. PCA analysis described that *A. panchax* abundance in the abandoned tin mining pits was positively correlated with the pH. Moreover, the pH itself was strongly correlated with the DO and the presence of Cl, Mg, Al and mineral elements, such as Si, S, Ca and P.

Key Words: killifish, chronosequences, conductivity, minerals, contamination.

Introduction. Bangka Island is one of the islands in Indonesia located in Southeast Asia of the tin belt (Sudiyani et al 2011), known as a tin producer. It makes Indonesia the second-largest tin producer in the world after China (Syarbaini et al 2014). Tin mining carried out since 1668 (Irawan et al 2014) has the consequence of the formation of dug basins in the form of lakes or ponds (Kurniawan & Kurniawan 2012; Kurniawan et al 2018). The post-mining ecosystem condition has high acidity characteristics, low oxygen value, and heavy metal contamination (Kurniawan et al 2019). The tin mining process does not use hazardous chemicals. Still, elements found in nature can undergo oxidation and other chemical reactions due to land opening or the presence of standing water. The chemical reaction exposes heavy metals, causing water quality changes and potential contamination residues (Kurniawan & Mustikasari 2019). Many contaminants that have been identified in land and post-mining waters, including As, Co, Cu, Cr, Fe, Ga, Hf, Sn, Ta, Te, Th, Mn, Ni, Pb, Zn, and V (Gyang & Ashano 2010; Ashraf et al 2011a; Ashraf et al 2012; Rosidah & Henny 2012; Kurniawan 2017; Kurniawan et al 2019).

The presence of heavy metals in ex-tin mining pits waters can affect aquatic organisms such as fish. Some fish are unable to live in these extreme conditions, and some others are considered as pioneer fish that occupy pits waters at the when pits are left behind the mining activities. Blue panchax (*Aplocheilus panchax*) was found to live under the conditions of ex-tin mining waters (Kurniawan 2019). The research has not yet explained the post tin mining consequences on the *A. panchax* life, in particular the heavy metals impact. Therefore, this study aimed to elaborate descriptively the presence of the *A. panchax* found in abandoned tin mining pits with different ages In Bangka Island, which were contaminated with heavy metals.

Material and Method

Description of the study sites. The research station was conducted in Pangkalpinang City and Bangka Regency, Bangka Belitung Archipelago Province, Indonesia. The research took place in abandoned tin mining pits located at six clusters with chronosequences. The coordinates and maps of the research stations were presented in Table 1 and Figure 1.

Table 1

The coordinate of research stations

Research stations	*Coordinates*	
Station A	1°58'8.80"S	106°6'24.10"T
Station B	1°58'12.27"S	106°6'24.97"T
Station C	1°53'54.70"S	106°3'15.13"T
Station D	1°53'51.80"S	106°3'12.42"T
Station E	2°0'46.62"S	106°9'0.96"T
Station F	2°0'36.91"S	106°8'53.61"T
Station G	1°55'58.68"S	106°9'22.86"T
Station H	2°9'36.17"S	106°9'33.33"T
Station I	1°39'34.51"S	105°48'28.70"T
Station J	1°44'7.39"S	105°48'8.80"T

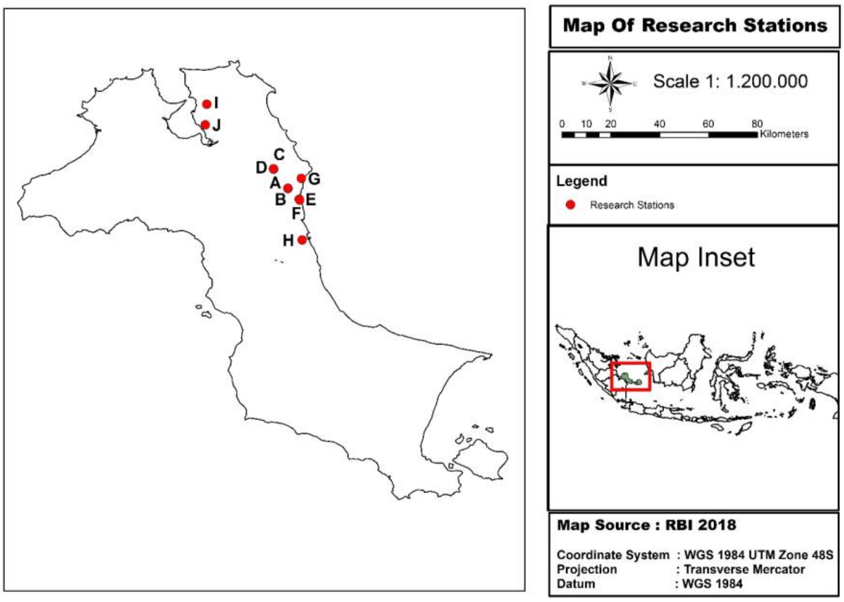

Figure 1. Map of research stations in abandoned tin mining pit with different ages in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, and Station I and Station J were >100 years.

Instrumentations. The analyzed parameters of pits water quality were the pH value measured by the pH meter (PH-009 (I)-A Sun Care) and the dissolved oxygen (DO) measured with the DO meter Lutron DO-5510. The Lutron WA-2017SD device was used to measure the temperature, oxidation-reduction potential (ORP) or Eh, total dissolved solids (TDS), and conductivity. The speciation and concentration of elements in the form of heavy metals and non-heavy metals were measured by X-Ray fluorescence (Rigaku), which has three light spreader metals, namely copper (Cu), molybdenum (Mo), and aluminum (Al). Data on the presence of *A. panchax* and on the water quality in the pit were analyzed descriptively. The analysis was performed in an excel program. Correspondence between the presence of *A. panchax* and the condition of the abandoned tin mining pits waters was analyzed through PCA (principal component analysis) using the program of Statistica 6.0.

Results

The power of hydrogen (pH) and electrical potential (Eh). The measured water quality parameters under the post-mining tin were pH and Eh values. The pH and Eh values obtained under tin mining pits with different ages are shown in Figure 2.

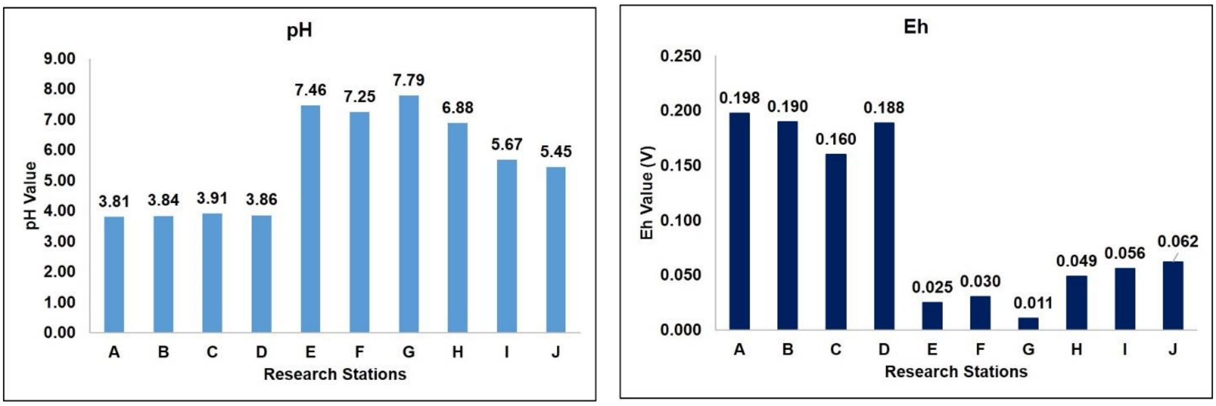

Figure 2. Value of pH (left) and Eh (right) in abandoned tin mining pit with different ages in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, and Station I and Station J were >100 years.

The pH value indicates that acidic water conditions at age <15 years, with pH values ranging from 3.81 to 3.91, and does not change significantly. The changes in pH value occurred in pits with age between 15 and 50 years, which results in water with neutral pH. Anomalous pH values occurred in pits with age >50 years, which indicated a tendency to be still acidic. Water acidity conditions can also be observed from the Eh value, which showed oxidation process at a high Eh value and reduction process at a low Eh value. The Eh in pits with age <15 years showed the highest value, describing oxidative activity and higher acidity conditions. The pits with age >15-50 years showed a process of metal reduction at increased pH values, although pits with age > 50 years showed a higher Eh those of an age between e15 and 50 years.

Water temperature and dissolved oxygen (DO). The pits water temperature measured at the time of the study were around 31°C. Oxygen solubility in the pits tended to be low in the age <15 years, namely 5.33-3.97, compared to the age >15 years, at 6.33-7.20. The values indicated that the DO values tended to increase with the age of abandoned tin mining pits. The highest DO rate was recorded in a pit with the age between 50 and 100 years, and the lowest was in pits with the age between 1 and 5 years. Higher temperature values contributed to the increase of DO value and conversely, lower temperature lowered the DO value (Figure 3).

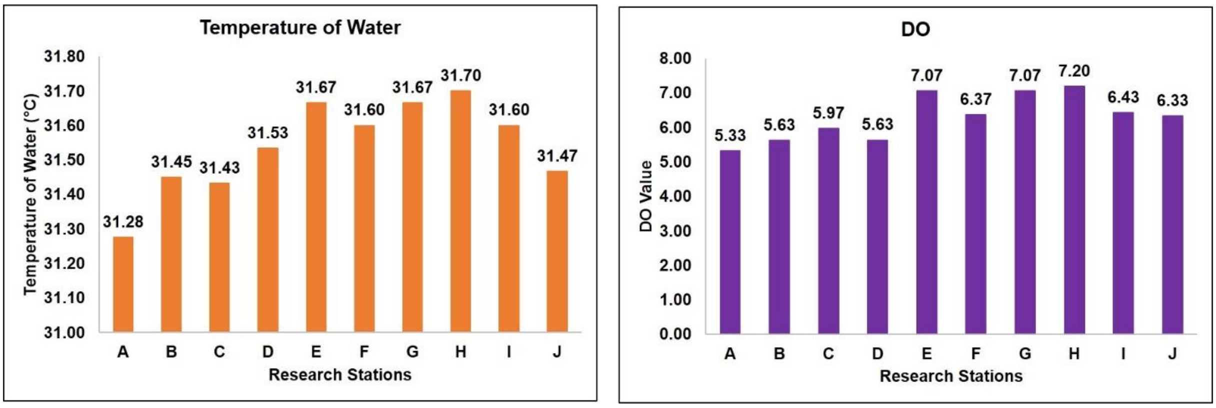

Figure 3. Water temperature (left) and DO (right) in abandoned tin mining pits with different ages, located in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, and Station I and Station J were >100 years.

Total dissolved solid (TDS) and conductivity. Other water quality parameters measured were the TDS value and conductivity. The total dissolved solids and conductivity found in abandoned tin mining pits with different ages fluctuated and did not show a pattern related to the pits chronosequence. TDS and conductivity values showed the same pattern: the lower the TDS value, the lower the conductivity. The highest TDS and conductivity values were found in pits with an age between 15 and 25 years, and the lowest value was found in pits with an age between 5 and 15 years (Figure 4).

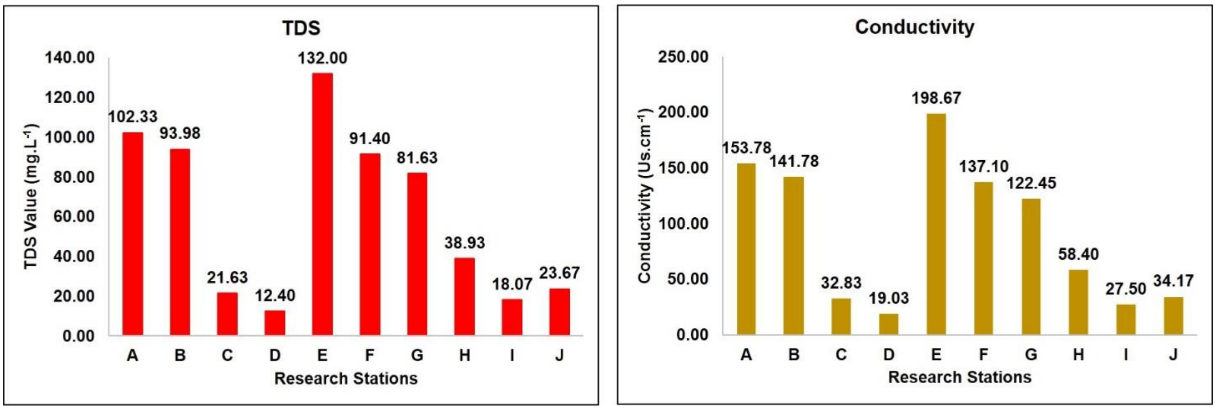

Figure 4. Value of TDS (left) and conductivity (right) in abandoned tin mining pit with different ages in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, and Station I and Station J were >100 years.

Trace elements. Many trace elements were found during the study in abandoned tin pits mining. The elements were classified into two different groups: heavy metals and non-heavy metals. The XRF analysis showed that four type heavy metals were dominant (>1 ppm): Sn, Fe, Hf and Cu, which were found in all pits, no matter the age (Figure 5). Accumulations of higher heavy metal residues were found in pits with an age between 1 and 5 years, compared to pits of another age. The concentration of Sn tended to decrease from pits with an age between 1 and 5 years to pits with an age between 25 and 50 years. However, the Sn's concentrations were quite high in the pits with an age >50 years. The values indicated that the concentration of metals, mainly Sn, was influenced by not only the pits chronosequence, but also the reservoir of Sn in the pit.

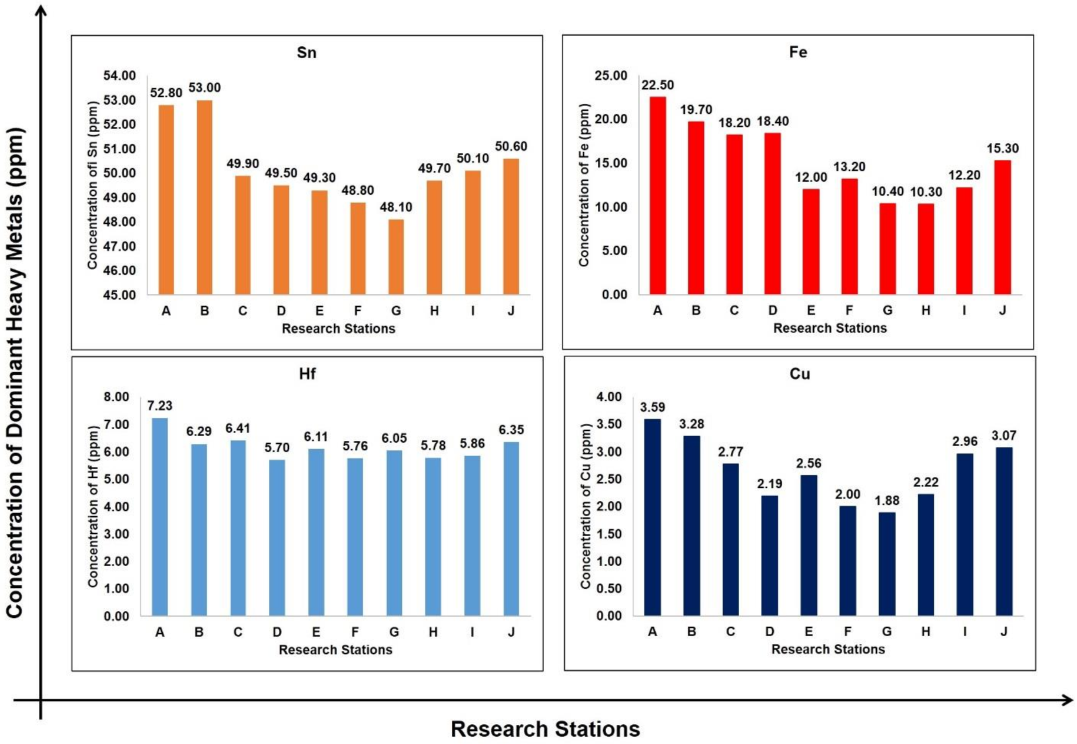

Figure 5. Heavy metals distributions in abandoned tin mining pits in Bangka Island, Indonesia: Sn (orange), Fe (red), Hf (light blue), and Cu (dark blue). Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, and Station I and Station J were >100 years.

Non-heavy metals elements were also identified in abandoned tin mining pits, namely Mg, Al, Si, Cl, S, Ca, P, Ta, and Ti (Table 2). These elements can be attributed to water quality changes in abandoned tin mining pits, with a particular time sequence. Many elements in the form of non-heavy metals found in pits with different ages showed a pattern of increasing concentration value in pits with age <5 years and in pits with an age between 5 and 25 years. Concentrations of non-heavy metal in pits with age >50 years were found to show lower values than pits with an age between 25 and 50 years.

Table 2

Non-heavy metals distribution in abandoned tin mining pits

Non-heavy metals□	*Research stations and concentration of elements (ppm)*									
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
Mg	731	795	815	856	932	919	936	868	858	857
Al	291	285	174	215	489	422	849	643	256	242
Si	174	148	148	156	445	321	589	419	216	321
Cl	21.2	15.7	20.5	22.4	57.5	60.03	68.9	56.6	27.89	28.8
S	6.03	8.55	14.5	21.6	28.8	32.3	51.2	14.5	18.5	14.5
Ca	13.1	9.99	11.7	13.3	20.5	20.4	45.3	28.7	37.8	35.9
P	8.42	9.43	9.93	8.95	11.7	11.7	10.1	8.72	7.29	12.9
Ta	6.07	4.73	5.44	6.08	5.73	6.04	5.43	5.84	4.05	3.69
Ti	5.25	3.21	3.17	2.88	3.1	3.31	4.25	3.25	3.24	5.29

Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, and Station I and Station J were >100 years.

The presence of A. panchax. *A. panchax* was one of the fish species found in abandoned tin mining pits. Remarkably, it was able to live in pits with an age <1 year, but also in some of the older pits, suggesting that *A. panchax* presence could be considered as a bioindicator for the quality of the waters. Its early presence (in pits with age <1 year) justifies considering it as a pioneering fish, although its presence was still influenced by water quality. The morphology of *A. panchax* was shown in Figure 6, and its presence in the abandoned tin mining pits with different ages was presented in Table 3.

Figure 6. Morphology of *Aplocheilus panchax* with a silver dot (red circle) (original).

Table 3

The presence and abundance of *Aplocheilus panchax* in abandoned tin mining pits

Presence and abundance of Aplocheilus panchax (Research stations) (ind m^{-2})									
A	B	C	D	E	F	G	H	I	J
+	+	+	+	+	+	+	-	-	-
3	5	26	13	23	28	31	0	0	0

Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, and Station I and Station J were >100 years. (+) = available, (-) = not available.

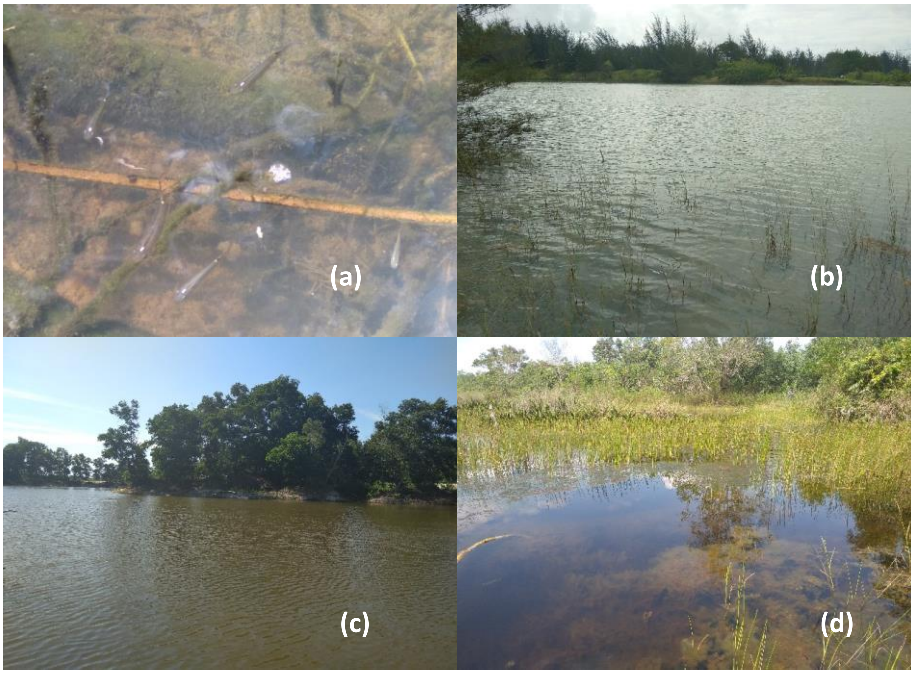

Figure 7. Characteristics of abandoned tin mining pits with *Aplocheilus panchax*. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100 years, Station I and Station J were >100 years (original).

A. panchax was also found in the pit with an age between 25 and 50 years, although in the pit with an age >50, which had better water quality than the pits of an age <15 years, it could not be found alive. The data proved that *A. panchax* could live in a wide range of water quality, but other factors can still determine its presence, such as: medium density grasses and wood or dead and weathered plants sheltering fish activities and foraging groups (Figures 7a, 7b). In pits with an age between 50 and 100 years, no aquatic plants were found (Figure 7c), while in pits with an age >100-year water, plants were found, but of a high density, probably not suitable for *A. panchax* (Figure 7d).

Relationship between A. panchax's presence and environmental conditions. The results of the PCA analysis provided information related to the relationship between *A. panchax*'s presence and the status of its ecosystem (Figure 8). The correlation values of the research parameters (Table 4) showed the strength of the relationship between these parameters.

Table 4

A correlation value of PCA analysis

	pH	*Temp.*	*TDS*	*Cond.*	*DO*	*Eh*	*Abund.*	*Sn*	*Fe*	*Hf*	Cu	Mg	Al	Si	Cl	S	Ca	P	Ta	Ti
pH	1.0	0.8	0.3	0.3	0.9	-1.0	0.4	-0.7	-0.9	-0.5	-0.7	0.9	0.8	0.9	1.0	0.8	0.7	0.4	0.1	-0.1
Temp.	0.8	1.0	0.0	0.0	0.9	-0.8	0.3	-0.8	-0.9	-0.8	-0.8	0.9	0.7	0.7	0.8	0.7	0.6	0.1	0.1	-0.5
TDS	0.3	0.0	1.0	1.0	0.1	-0.1	0.3	0.2	0.0	0.3	0.1	0.1	0.4	0.3	0.4	0.2	-0.2	0.3	0.4	0.1
Cond.	0.3	0.0	1.0	1.0	0.1	-0.1	0.3	0.2	0.0	0.3	0.1	0.1	0.4	0.3	0.4	0.2	-0.2	0.3	0.4	0.1
DO	0.9	0.9	0.1	0.1	1.0	-0.9	0.3	-0.7	-1.0	-0.5	-0.6	0.8	0.8	0.9	0.9	0.6	0.7	0.3	0.0	-0.2
Eh	-1.0	-0.8	-0.1	-0.1	-0.9	1.0	-0.3	0.7	0.9	0.5	0.6	-0.9	-0.7	-0.8	-0.9	-0.7	-0.8	-0.4	0.2	0.0
Abund.	0.4	0.3	0.3	0.3	0.3	-0.3	1.0	-0.6	-0.2	-0.2	-0.6	0.6	0.4	0.4	0.5	0.7	0.0	0.4	0.5	-0.3
Sn	-0.7	-0.8	0.2	0.2	-0.7	0.7	-0.6	1.0	0.8	0.7	0.9	-0.9	-0.5	-0.6	-0.7	-0.8	-0.5	-0.3	-0.2	0.3
Fe	-0.9	-0.9	0.0	0.0	-1.0	0.9	-0.2	0.8	1.0	0.7	0.7	-0.9	-0.7	-0.8	-0.8	-0.7	-0.8	-0.2	0.1	0.3
Hf	-0.5	-0.8	0.3	0.3	-0.5	0.5	-0.2	0.7	0.7	1.0	0.8	-0.7	-0.3	-0.3	-0.4	-0.5	-0.3	0.0	0.0	0.7
Cu	-0.7	-0.8	0.1	0.1	-0.6	0.6	-0.6	0.9	0.7	0.8	1.0	-0.8	-0.6	-0.6	-0.8	-0.8	-0.3	-0.2	-0.4	0.4
Mg	0.9	0.9	0.1	0.1	0.8	-0.9	0.6	-0.9	-0.9	-0.7	-0.8	1.0	0.6	0.8	0.8	0.8	0.6	0.5	0.0	-0.3
Al	0.8	0.7	0.4	0.4	0.8	-0.7	0.4	-0.5	-0.7	-0.3	-0.6	0.6	1.0	0.9	0.9	0.7	0.6	0.1	0.3	0.0
Si	0.9	0.7	0.3	0.3	0.9	-0.8	0.4	-0.6	-0.8	-0.3	-0.6	0.8	0.9	1.0	0.9	0.8	0.7	0.4	0.1	0.1
Cl	1.0	0.8	0.4	0.4	0.9	-0.9	0.5	-0.7	-0.8	-0.4	-0.8	0.8	0.9	0.9	1.0	0.8	0.5	0.3	0.3	-0.1
S	0.8	0.7	0.2	0.2	0.6	-0.7	0.7	-0.8	-0.7	-0.5	-0.8	0.8	0.7	0.8	0.8	1.0	0.6	0.3	0.2	-0.1
Ca	0.7	0.6	-0.2	-0.2	0.7	-0.8	0.0	-0.5	-0.8	-0.3	-0.3	0.6	0.6	0.7	0.5	0.6	1.0	0.1	-0.5	0.3
P	0.4	0.1	0.3	0.3	0.3	-0.4	0.4	-0.3	-0.2	0.0	-0.2	0.5	0.1	0.4	0.3	0.3	0.1	1.0	-0.1	0.3
Ta	0.1	0.1	0.4	0.4	0.0	0.2	0.5	-0.2	0.1	0.0	-0.4	0.0	0.3	0.1	0.3	0.2	-0.5	-0.1	1.0	-0.3
Ti	-0.1	-0.5	0.1	0.1	-0.2	0.0	-0.3	0.3	0.3	0.7	0.4	-0.3	0.0	0.1	-0.1	-0.1	0.3	0.3	-0.3	1.0

Temp.-temperature; Cond.-conductivity; Abund.-abundance.

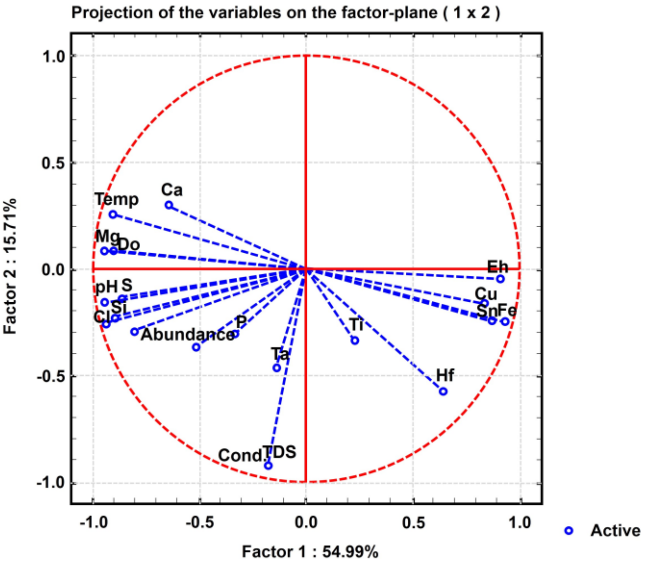

Figure 8. PCA analysis between the abundance of *Aplocheilus panchax* and the ecosystem parameters.

The correlation analysis showed that *A. panchax*'s presence was more strongly correlated with the pH value factor. The analysis also showed that pH value was strongly associated with the presence of elements such as Al, Si, Cl, S, Ca, and P. Those elements are trace-minerals essential for the growth of phytoplankton. In turn, phytoplankton abundance affects organic materials cycle in the pits. Therefore, up to certain level, pH values contributed to water fertility. As consequences, those processes affect *A. panchax*'s presence in abandoned tin mining pits waters. Therefore, it was shown in Figure 8 and Table 4 that pH value is the principal ecological component which determines the presence of *A. panchax*.

Discussion. The vital indicator in post-mining ecosystems is the pH value. The main characteristic of a post-mining location is low (acidic) pH conditions. Acidic mine drainage (AMD) waters are highly acid with a pH value of less than 4 (Kolmert & Johnson 2001; Ashraf et al 2011b). Low pH value in pit mining is a result of the oxidation process of sulfide minerals (Tan et al 2007), which are categorized as potentially acidic forming (PAF) or materials that can cause acid pH conditions (Celebi & Oncel 2016). These materials undergo oxidation and hydrolysis processes that occur with elements such as S, Fe, Cu, Zn, Ni, Cr, and Pb into cations such as Cu^{2+}, Zn^{2+}, Ni^{2+}, Cr^{3+}, Pb^{2+}, and other elements increasing the amount of H^+ ions which contribute to the increase of the environmental acidity. H^+ ions present in an ecosystem can cause acidic pH conditions (Gonzalez-Toril et al 2006; Gaikwad & Gupta 2008; Mejia et al 2009; Heidel & Tichomirowa 2011; Dopson & Johnson 2012; Hatar et al 2013).

Acid mine drainage can also be affected by metals such as Al, As, Cd, Co, Cr, Mn, Pb, and Zn, which are formed from mining activity waste associated with soil or rock layers and with weather conditions (Campaner et al 2014). The presence of these elements can directly or indirectly affect the pH value (De Saedeleer et al 2010; Zhao et al 2010; Fernandes et al 2011; Strom et al 2011; Huang et al 2012; Sadeghi et al 2012; Zhang et al 2014). This acidic condition is seen in abandoned tin mining pits with an age between 1 and 5 years and between 5 and 15 years (Figure 2).

Acidic conditions that occur under tin mining post are supported by metals such as Sn, Fe, and Cu, which are heavy metals found mostly in pits with an age between 1 and 5 years and between 5 and 15 years (Figure 5). As the chronosequence was found in pits with an age between 15 and 25 years and between 25 and 50 years, the heavy metal concentrations tend to decrease or lower with a pH increase to neutral. The chronosequence data in tin post-mining waters shows that a decrease in the level of heavy metals acts as PAF and indirectly causes an increase of the pH values (Kurniawan et al 2019).

The oxidation process of the elements contained in the pits can also be indicated that pits with the acidic pH had a higher Eh value than the neutral pits (Figure 2). The Eh value indicated a reduction-oxidation potential based on the standard hydrogen potential and the pH value, which shows the activity of hydrogen ions (H^+) or protons (Huang 2016). A high Eh value indicates an oxidation activity or condition, while a low Eh value represents a reduction condition (Naudet et al 2004).

The high Eh value in the pits with age >50years, compared to the pits with the age between 25 and 50 years, showed that the chronosequence in a relatively long time did not always correlate linearly with the pH increase from acid to neutral values. Acidic conditions in the environment can be influenced by several factors, including the high availability of oxidative minerals, the fertility of the waters, the substrate or other conditions that occur in the ecosystem, such as Eh, DO, BOD, COD, TSS, TDS, nitrogen, and phosphate (Kurniawan 2019). Changes in pH can also be influenced by non-heavy minerals such as Mg and Ca. The presence of these elements and their associations form carbonation minerals such as $MgHCO_3$, CaOH, and $CaCO_3$, which cause pH values to increase from acidic conditions to neutral (Bruni et al 2002; Sanderman 2012).

Changing the pH to neutral conditions can stimulate the presence of aquatic organisms. Some organisms can live optimally at neutral pH but do not survive at acidic pH. Neutral pH value can cause higher oxygen solubility than acidic pH. In that case, neutral pH is triggered by aquatic organisms that live optimally and carry out aerobic photosynthesis that produces oxygen through the reaction of $H_2O + CO_2 \rightarrow CH_2O + O_2$ (Johnson 2016). The presence of organisms can also cause more and more organic matter to be present in these waters. The organic matter can produce CO_2 and water and also organic carbon (Gibert et al 2002; Khatoon et al 2017). The CO_2 is reused for photosynthesis that produces O_2.

The decomposition of organic material in a long time sequence can cause an increase in CO_2. Increased CO_2 that interacts with H_2O can also form carbonic acid (H_2CO_3) in a reaction of $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$ (Loerting & Bernard 2010; Ghoshal & Hazra 2015). H_2CO_3 dissociates into carbonate ions (HCO_3^-), which can bind and neutralize hydrogen ions (H^+), causing the decrease of the H^+ ions concentration in water and pH to become neutral (Andersen 2002). Organic acids, formed from the decomposition of organic materials that have the functional group R-COOH as organic anions, dissociate and use H^+ cations so that the concentration of H^+ in the environment decreases, causing the pH to rise towards neutral (Rukshana et al 2011).

The presence of heavy metals, the pH, Eh, and many other variables are interrelated in the environment. An ecological approach can be carried out to modify the quality of the waters under the post-mining tin. Changes occur also naturally, through a process of succession, lasting for an extended period. The presence of aquatic organisms can also speed up restoring water quality, and one of them is *A. panchax*. *A. panchax* found in acidic conditions in pits with an age between 1 and 5 years and between 5 and 15 years indicated that these fish could live in extreme conditions such as acidic pH.

A. panchax is part of the killifishes group, which has an annual life cycle and can live in marginal aquatic environments. The fish can adapt to seasonal ephemeral waters, and are often found on the edge of open (flowing) or stagnant (closed) freshwaters and in surrounding areas (Furness 2015). Fish from the Aplocheilidae family can live in aquatic environments with neutral pH conditions, from very low to very high DO content, as well as in a wide range of water hardness conductivity, as shown in Table 5 (Prasad et al 2009; Raja et al 2015; Karuppaiah & Ramesh 2016).

Table 5

Characteristics of water for the Aplocheiloidei family

Characteristics of waters	*Value*						
	(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*
Temperature (^{o}C)	21-25	25-28	26-30	28-30	25-32	30-32	19-32
pH	6.8-7.5	7.1-7.8	7.5-7.9	7.3-7.9	7.3-8.1	7.5-8.1	7.0-9.23
DO (mg L^{-1})	4.8-11.6	4.1-6.4	3.0-3.8	2.0-3.8	0.2-0.3	0.2-0.3	0.02-14.4
COD (mg L^{-1})	9-13	12-62	110-150	100-150	160-250	173-299	12.6-71.2
BOD (mg L^{-1})	3.5-12.2	9.5-16.8	96-338	110-338	53-300	45-300	0.01-10.16
Hardness (mg L^{-1})	33-98	-	-	-	-	-	34-356
Alkalinity (mg L^{-1})	18-77	-	-	-	-	-	120-360
Conductivity (mhos cm^{-1})	42-88	108-270	250-329	280-2,000	850-2,900	950-2,900	240-1,560
Turbidity (NTU)	-	14-22	16-25	21-30	26-32	29-32	-
TDS (ppm)	-	-	-	-	-	-	135-1,451.6

(a) Reservoir Bhavanisagar, Tamil Nadu, India (Raja et al 2015); (b) Dam Viagai, (c) Anaipatti River, (d) Solavandhan River, (e) Arapalaiyam River, (f) Anna Nagar River, India (Karuppaiah & Ramesh 2016); (g) Mysore Wet land, India (Prasad et al 2009).

The species of the Cyprinodontiformes order generally can live in intertidal areas (waters affected by water flow or tides) or ephemeral habitat (waters that appear as influenced by rain or have seasonal fluctuations of volume) (Turko & Wright 2015). Ephemeral waters periodically or regularly experience drought. Ephemeral environments are usually found as water reservoirs or isolated inundations in savannahs or grasslands. They are formed during the rainy season, either around small and temporary streams in forest areas, swamps or stagnant ponds, or around puddle adjacent to permanent water bodies. Those ecosystems recede during the dry season (Furness 2015).

Conclusions. This study has successfully documented the presence of *A. panchax* in abandoned tin mining pits, especially in pits with age <1 year, which suggests that *A. panchax* could be used as a pioneering fish in the ecosystem. *A. panchax* can survive conditions of acidic waters, low DO and high exposure to many heavy metals, such as: Sn, Fe, Hf, and Cu. *A. panchax*'s presence was also supported by the presence of aquatic plants that had not a high density and wood or dead plants, which became the substrate for the life of this species of fish, favoring in particular their protection, activities, groups forming and foraging.

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Authors:
Diah Mustikasari, University of Jenderal Soedirman, Faculty of Biology, Doctoral Student of Doctoral Program, Jl. Dr. Soeparno, Karangwangkal, 53122 Purwokerto, Central Jawa, Indonesia, e-mail: diah.mustikasari83@gmail.com
Agus Nuryanto, University of Jenderal Soedirman, Faculty of Biology, Jl. Dr. Soeparno, Karangwangkal, 53122 Purwokerto, Central Jawa, Indonesia, e-mail: agus.nuryanto@unsoed.ac.id
Suhestri Suryaningsih, University of Jenderal Soedirman, Faculty of Biology, Jl. Dr. Soeparno, Karangwangkal, 53122 Purwokerto, Central Jawa, Indonesia, e-mail: suhestri.suryaningsih@unsoed.ac.id

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