

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

by Agus Nuryanto

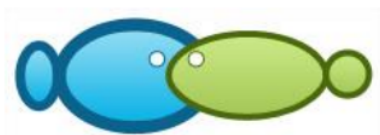
Submission date: 20-Mar-2023 04:23PM (UTC+0700)

Submission ID: 2041555925

File name: 32_Diah_Mustikasari-Bioflux.pdf (1.53M)

Word count: 6971

Character count: 31770



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

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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 (*Aplocheilichthys 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 (*Aplocheilichthys 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.

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

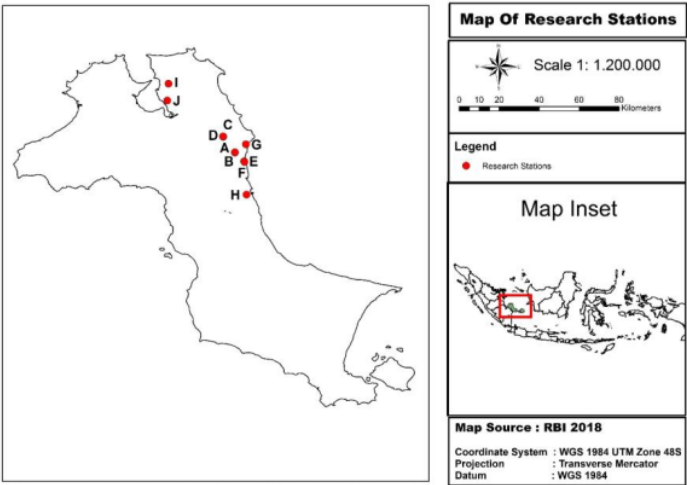


Figure 1. Map of research stations in abandoned tin mining pit with different ages in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station 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 (11-ron 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.

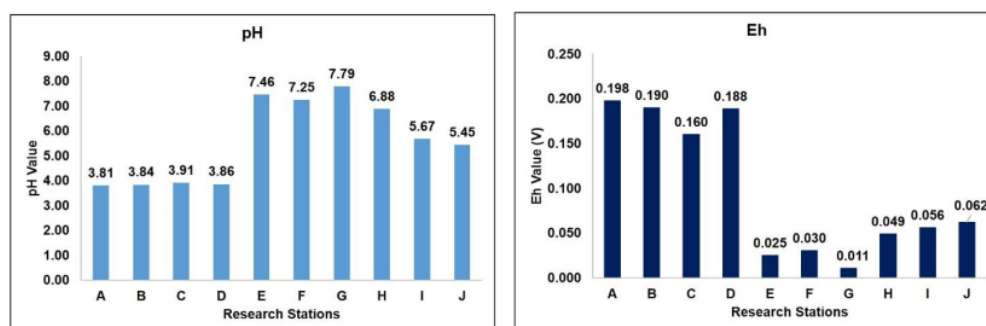


Figure 2. Value of pH (left) and Eh (right) in abandoned tin mining pit with different ages in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years,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

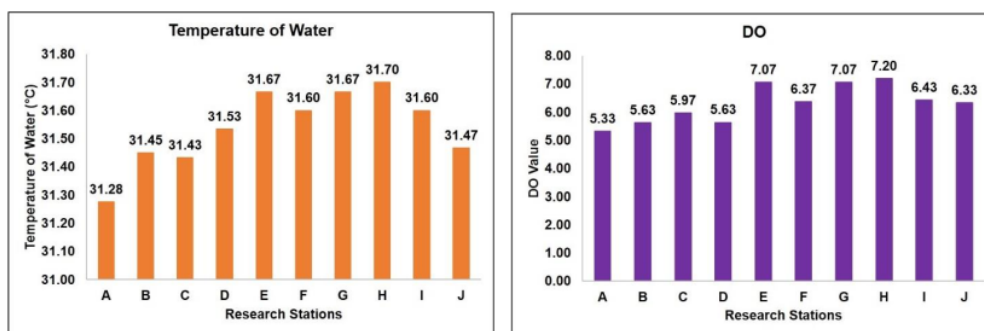


Figure 3. Water temperature (left) and DO (right) in abandoned tin mining pits with different ages, located in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between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

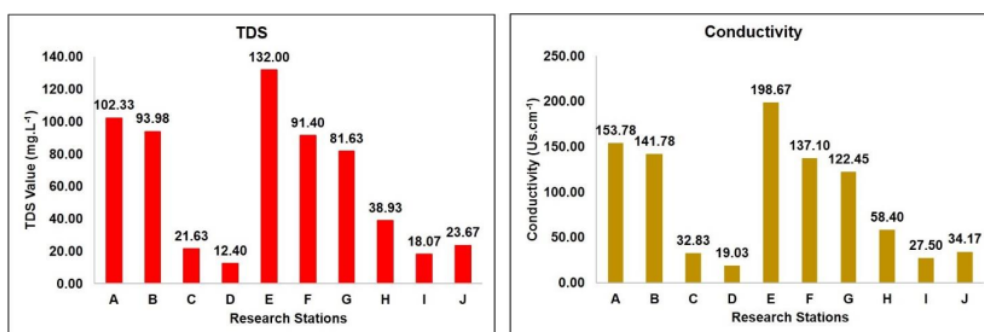


Figure 4. Value of TDS (left) and conductivity (right) in abandoned tin mining pit with different ages in Bangka Island, Indonesia. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25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

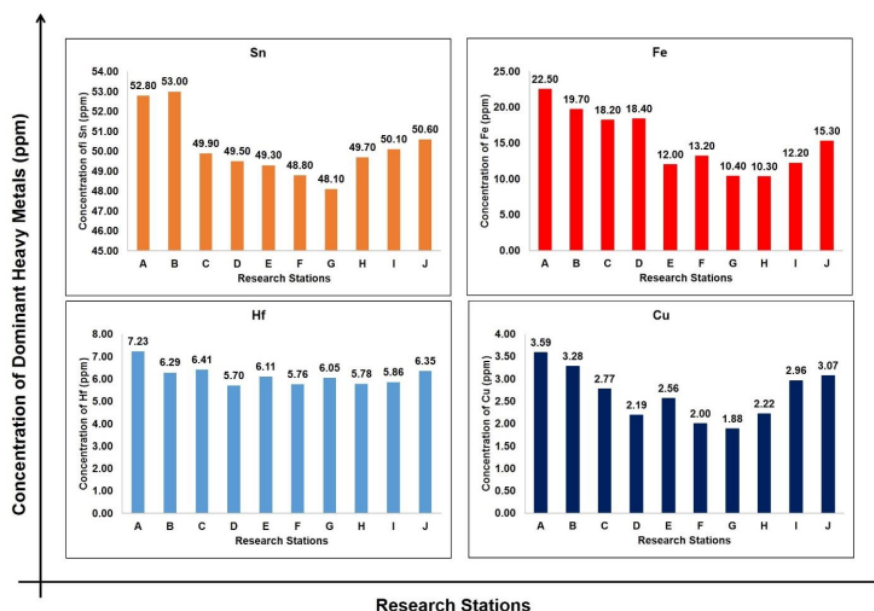


Figure 5. Heavy metals distributions in abandoned tin mining pits in Bangka Island, Indonesia: Sn (orange), Fe (red), Hf (light blue), and Cu (dark blue). Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years,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

2 Presence and abundance of <i>Aplocheilus panchax</i> (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.

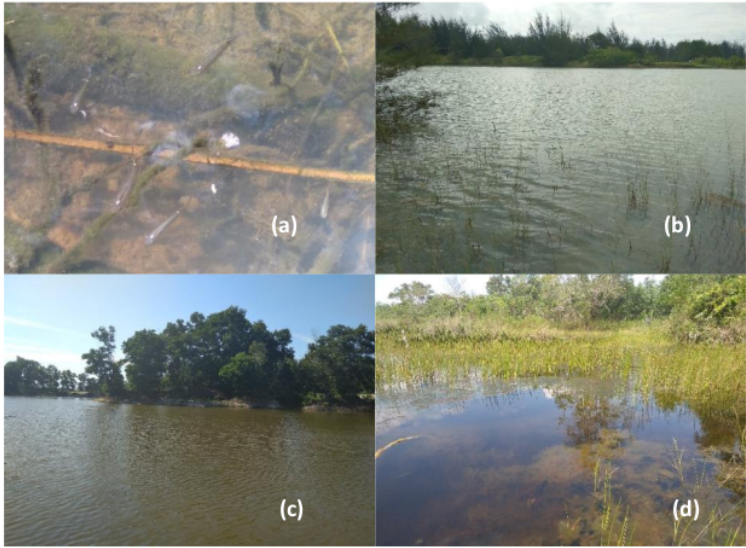


Figure 7. Characteristics of abandoned tin mining pits with *Aplocheilus panchax*. Station A and Station B were <5 years, Station C and Station D were between 5 and 15 years, Station E and Station F were between 15 and 25 years, Station G was between 25 and 50 years, Station H was between 50 and 100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

A correlation value of PCA analysis

Table 4

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

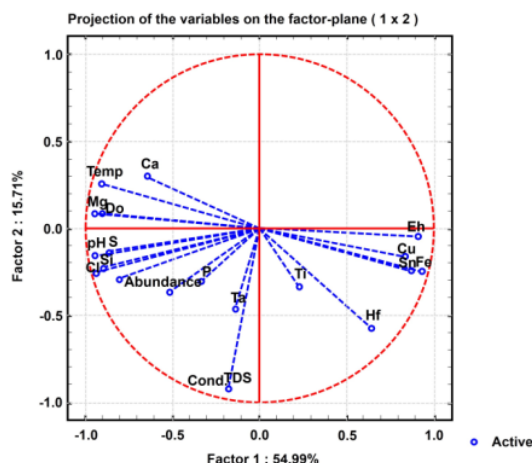


Figure 8. PCA analysis between the abundance of *Aplocheilus panchax* and the ecosystem parameters.

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 (°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.

Acknowledgements. The authors would like to thank the Ministry of Education and Culture, Republic of Indonesia, and the University of Jenderal Soedirman, which have facilitated this research through their contribution to the funding of the Doctoral Dissertation Research (Penelitian Disertasi Doktor-PDD) Grants.

References

- Andersen C. B., 2002 Understanding carbonate equilibria by measuring alkalinity in experimental and natural systems. *Journal of Geoscience Education* 50(4):389-403.
- Ashraf M. A., Maah M. J., Yusoff I., 2011a Heavy metals accumulation in plants growing in ex tin mining catchment. *International Journal of Environmental Science and Technology* 8(2):401-416.
- Ashraf M. A., Maah M. J., Yusoff I., 2011b Analysis of physio-chemical parameters and distribution of heavy metals in soil and water of ex-mining area of Bestari Jaya, Peninsular Malaysia. *Asian Journal of Chemistry* 238:3493-3499.
- Ashraf M. A., Maah M. J., Yusoff I., 2012 Speciation of heavy metals in the sediments of former tin mining catchment. *Iranian Journal of Science and Technology* 36(2):163-180.
- Bruni J., Canepa M., Chiodini G., Cioni R., Cipolli F., Longinelli A., Marini L., Ottonello G., Zuccolini M. V., 2002 Irreversible water-rock mass transfer accompanying the

- generation of the neutral, Mg-HCO₃ and high-pH, Ca-OH spring waters of the Genova province, Italy. *Applied Geochemistry* 17(4):455-474.
- Campaner V. P., Luiz-Silva W., Machado W., 2014 Geochemistry of acid mine drainage from a coal mining area and processes controlling metal attenuation in stream waters, Southern Brazil. *Anais da Academia Brasileira de Ciências* 86(2):539-554.
- Celebi E. E., Oncel M. S., 2016 Determination of acid forming potential of massive sulfide minerals and the tailings situated in lead/zinc mining district of Balya (NW Turkey). *Journal of African Earth Sciences* 124:487-496.
- De Saedeleer V., Cappuyens V., De Cooman W., Swennen R., 2010 Influence of major elements on heavy metal composition of river sediments. *Geologica Belgica* 13(3):257-268.
- Dopson M., Johnson D. B., 2012 Biodiversity, metabolism and applications of acidophilic sulfur-metabolizing microorganisms. *Environmental Microbiology* 14(10):2620-2631.
- Fernandes L., Nayak G. N., Ilangoan D., Borole D. V., 2011 Accumulation of sediment, organic matter and trace metals with space and time, in a creek along Mumbai Coast, India. *Estuarine, Coastal and Shelf Science* 91(3):388-99.
- Furness A. I., 2015 The evolution of an annual life cycle in killifish: adaptation to ephemeral aquatic environments through embryonic diapause. *Biological Reviews* 91(3):796-812.
- Gaikwad R. W., Gupta D. V., 2008 Review on removal of heavy metals from acid mine drainage. *Applied Ecology and Environmental Research* 6(3):81-98.
- Ghoshal S., Hazra M. K., 2015 H₂CO₃ → CO₂ + H₂O decomposition in the presence of H₂O, HCOOH, CH₃COOH, H₂SO₄ and HO₂ radical: Instability of the gas-phase H₂CO₃ molecule in the troposphere and lower stratosphere. *RSC Advances* 5(23):17623-17635.
- Gibert O., De Pablo J., Cortina J. L., Ayora C., 2002 Treatment of acid mine drainage by sulphate-reducing bacteria using permeable reactive barriers: a review from laboratory to full-scale experiments. *Reviews in Environmental Science and Biotechnology* 1(4):327-333.
- Gonzalez-Toril E., Gomez F., Malki M., Amils R., 2006 The isolation and study of acidophilic microorganisms. *Methods in Microbiology* 35:471-510.
- Gyang J. D., Ashano E. C., 2010 Effects of mining on water quality and the environment: a case study of parts of the Jos Plateau, North Central Nigeria. *The Pacific Journal of Science and Technology* 11(1):631-639.
- Hatar H., Rahim S. A., Razi W. M., Sahrani F. K., 2013 Heavy metals content in acid mine drainage at abandoned and active mining area. *AIP Conference Proceedings* 1571(1):641-646.
- Heidel C., Tichomirowa M., 2011 Galena oxidation investigations on oxygen and sulphur isotopes. *Isotopes in Environmental and Health Studies* 47(2):169-188.
- Huang H. H., 2016 The Eh-pH diagram and its advances. *Metals* 6(23):1-30.
- Huang J. Z., Ge X., Wang D., 2012 Distribution of heavy metals in the water column, suspended particulate matters and the sediment under hydrodynamic conditions using an annular flume. *Journal Environmental Science* 24(12):2051-2059.
- Irawan R. R., Sumarwan U., Suharjo B., Djohar S., 2014 Strategic model of tin mining industry in Indonesia (case study of Bangka Belitung Province). *International Journal of Business and Management Review* 2(3):48-58.
- Johnson M. P., 2016 Photosynthesis. *Essays in Biochemistry* 60:255-273.
- Karuppaiah K. P., Ramesh U., 2016 Studies on the physicochemical and biological parameters of River Vaigai, Madurai Dist, Tamilnadu, India. *International Journal of Current Microbiology and Applied Sciences* 5(1):788-795.
- Khatoun H., Solanki P., Narayan M., Tewari L., Rai J. P. N., 2017 Role of microbes in organic carbon decomposition and maintenance of soil ecosystem. *International Journal of Chemical Studies* 5(6):1648-1656.
- Kolmert A., Johnson D. B., 2001 Remediation of acidic waste waters using immobilised, acidophilic sulfate-reducing bacteria. *Chemical Technology and Biotechnology* 76(8):836-843.

- Kurniawan A., 2017 Chronosequence effect of post tin mining ponds to metals residue and microecosystem change. *Omni-Akuatika* 13(1):60-65.
- Kurniawan A., 2019 Diversitas metagenom bakteri di danau pascatambang timah dengan umur berbeda. Universitas Jenderal Soedirman, Fakultas Biologi, 99 p.
- Kurniawan A., Kurniawan A., 2012 Analisis variasi genetik ikan di kolong pascatambang timah dengan metode elektroforesis. *Akuatik: Jurnal Sumberdaya Perairan* 6(2):6-10.
- Kurniawan A., Mustikasari D., 2019 Review: Mekanisme Akumulasi Logam Berat di Ekosistem Pascatambang Timah. *Jurnal Ilmu Lingkungan* 17(3):408-415.
- Kurniawan A., Oedjijono, Tamad, Sulaeman U., 2018 The phosphorus and sulphur distribution and culturable bacterial in time chronosequence of ex-tin mining ponds. *Omni-Akuatika* 14(3):26-33.
- Kurniawan A., Oedjijono, Tamad, Sulaeman U., 2019 The pattern of heavy metals distribution in time chronosequence of ex-tin mining ponds in Bangka Regency, Indonesia. *Indonesian Journal of Chemistry* 19(1):254-261
- Loerting T., Bernard J., 2010 Aqueous carbonic acid (H_2CO_3). *ChemPhysChem* 11(11):2305-2309.
- Mejia E. R., Ospina J. D., Marquez M. A., Morales A. L., 2009 Oxidation of chalcopyrite (CuFeS_2) by *Acidithiobacillus ferrooxidans* and a mixed culture of *Acidithiobacillus ferrooxidans* and *Acidithiobacillus thiooxidans* like bacterium in shake flasks. In *Advanced Materials Research* 71-73:385-388.
- Naudet V., Revil A., Rizzo E., Bottero J. Y., Begassat P., 2004 Groundwater redox conditions and conductivity in a contaminant plume from geoelectrical investigations. *Hydrology and Earth System Sciences* 8(1):8-22
- Prasad A. G. D., Venkataramana G. V., Thomas M., 2009 Fish diversity and its conservation in major wetlands of Mysore. *Journal of Environmental Biology* 30(5):713-718.
- Raja M., Ramkumar R., Kavitha M., Perumal P., 2015 Distribution pattern, threatened status and conservation measures of fishes with relation to water quality and habitat characteristics of Bhavanisagar Reservoir, Tamil Nadu. *International Journal of Fisheries and Aquatic Studies* 2(6):11-18.
- Rosidah., Henny C., 2012 Kajian logam Fe, Al, Cu dan Zn pada perairan kolong paska penambangan timah di Pulau Bangka. *Prosiding Seminar Nasional Limnologi* 6:611-619.
- Rukshana F., Butterly C. R., Baldock J. A., Tang C., 2011 Model organic compounds differ in their effects on pH changes of two soils differing in initial pH. *Biology and Fertility of Soils* 47(1):51-62.
- Sadeghi S. H. R., Harchegani M., Younesi H. A., 2012 Suspended sediment concentration and particle size distribution, and their relationship with heavy metal content. *Journal of Earth System Science* 121(1):63-71.
- Sanderman J., 2012 Can management induced changes in the carbonate system drive soil carbon sequestration? A review with particular focus on Australia. *Agriculture, Ecosystems and Environment* 155:70-77.
- Strom D., Simpson S. L., Batley G. E., Jolley D. F., 2011 The influence of sediment particle size and organic carbon on toxicity of copper to benthic invertebrates in oxic/suboxic surface sediments. *Environmental Toxicology and Chemistry* 30(7):1599-1610.
- Sudiyani Y., Ardeniswan, Rahayuningwulan D., 2011 Determinasi arsen (As) dan merkuri (Hg) dalam air dan sedimen di kolong bekas tambang timah (air kolong) di Propinsi Bangka Belitung, Indonesia. *Ecolab* 5(2):55-66.
- Syarbaini, Warsona A., Iskandar D., 2014 Natural radioactivity in some food crops from Bangka-Belitung Islands, Indonesia. *Atom Indonesia* 40(1):27-32.
- Tan G., Shu W., Hallberg K. B., Li F., Lan C., Huang L., 2007 Cultivation-dependent and cultivation-independent characterization of the microbial community in acid mine drainage associated with acidic Pb/Zn mine tailings at Lechang, Guangdong, China. *FEMS Microbiology Ecology* 59(1):118-126.

- Turko A. J., Wright P. A., 2015 Evolution, ecology and physiology of amphibious killifishes (*Cyprinodontiformes*). *Journal of Fish Biology* 87(4):815-835.
- Zhang C., Yu Z., Zeng G., Jiang M., Yang Z., Cui F., Zhu M., Shen L., Hu L., 2014 Effects of sediment geochemical properties on heavy metal bioavailability. *Environment International* 73:270-281.
- Zhao H., Li X., Wang X., Tian D., 2010 Grain size distribution of road-deposited sediment and its contribution to heavy metal pollution in urban runoff in Beijing, China. *Journal of Hazardous Materials* 183(1-3):203-210.

Received: 19 January 2020. Accepted: 04 September 2020. Published online: 14 September 2020.

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How to cite this article:

Mustikasari D., Nuryanto A., Suryaningsih S., 2020 The existence of blue panchax (*Aplocheilichthys panchax*) in the abandoned tin mining pits water with different age contaminated by heavy metals. *AACL Bioflux* 13(5):2538-2550.

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