Summary of Data Collection and Evaluation at Long-Term Monitoring Sites in the four *cuencas* (2016 – mid 2018)

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In 2016, long-term monitoring sites were established in four *cuencas* – Marañon, Pastaza, Corrientes and Tigre – in Loreto, Peru to evaluate oil activities in *lotes* 192 and 8. These sites are intended to serve multiple functions but primarily are to be used for training the environmental monitors. Collection of data repeatedly at the same sites permits a deeper understanding of the effects of climate, season, anthropogenic disturbances, and use of different methodologies for sampling and analysis. They may also be useful to track changes in characteristics of the contaminated site over time due to remediation, to restoration, or to natural degradation and movement of contaminants.

Each *cuenca* has a contaminated site ("contaminado") and a site not believed to be contaminated ("blanco") but otherwise is similar to the contaminated site in as many aspects as possible. The selection of the sites was ultimately the decision of the monitors however, we suggested criteria such as making them easily accessible and on the list of the 32 sites proposed to FONAM for remediation. Additionally, among the 4 *cuencas* we attempted to represent a variety of habitat types and contaminant issues.

What follows is a description of each of the sites chosen, by *cuenca* (Table 1), using information gathered from the field complemented with data from other sources. We provide tables and graphs when there have been sufficient data to show trends. Following these descriptions is an evaluation of the process to date and recommended changes or improvements.

Table 1. Locations of long-term sampling sites and dates visited.

Cuenca		**Marañon**		**Pastaza**		**Corrientes**		**Tigre**	
Site		Carococha	San Pedro	Piri Piri	Ushpayacu	Antonia	Huayuri	Poroto	Cuicayacu
***Blanco* (B) / *Contaminado* (C)**		B	C	B	C	B	C	B	C
Habitat		*Cocha*	*Cocha*	*Cocha*	*Cocha/Quebrada*	*Quebrada*	*Quebrada*	*Quebrada*	*Quebrada*
Coordenates	**x**	0602618	0494418	0340840	0342747	0367397	0363266	0408759	0404406
	y	9498052	9479569	9698280	9692012	9716202	9713193	9741253	9742377
Visit	**2016**	---	---	15 june	16 june	20 june	21 june	17 june	18 june
	2017	3 february	3 february	19 april	18 april	---	---	---	---
	2018	10 april	---	---	---	---	---	---	---

1. Marañón

Carococha was selected as an uncontaminated site because it is readily accessible by boat from Dos de Mayo at approximately 2 km north of the Tipischca San Pedro road. It is a small shallow lake in a wooded area that seasonally floods. It is fished by the communities, but not heavily because there are very few fish. The soils around the lake are silt with clay. There are not many contaminated aquatic habitats near Dos de Mayo. Therefore, it was necessary to go to San Pedro where at least two oil spills have occurred in 2014 and 2016. The soils around San Pedro are sandy gravel.

San Pedro is quite far by boat from Dos de Mayo. Unfortunately, the contaminated areas are quite different from Carococha. It may be better to add the Tipischca San Pedro which lies immediately in front of Dos de Mayo as a second uncontaminated site as it would serve as a better *blanco* for comparison with the San Pedro contaminated areas. There are more possibilities of getting fish from the Tipischca as well. Fish in both the Tipischca and the San Pedro sites, and to some extent Carococha, are less restricted in their movements thus, we cannot be certain exposure to contamination occurred where they are caught.

The two oil spills occurred in different locations near the community of San Pedro. When we visited (February 2017) the 2014 oil spill near San Pedro, the water was shallow and heavily covered in vegetation. As a result, the oxygen was extremely low (Figure 1 and Figure 2). pH and conductivity were also low suggesting that the metal ions in the spilled oil had moved into the sediments or out of the system. By contrast, they were still cleaning up the oil at the second San Pedro site. This spill occurred in 2016 in what is known as the flotation canal – an artificial water-filled *quebrada* around the *oleoducto* intended to retain spilled oil. Previous studies by OEFA have demonstrated that metals and hydrocarbons are in the sediments. In the flotation canal they have found:

1. Hydrocarbons in water that has been removed or not removed exceeded one or more standards in one or more samples: oils and grease, TPH (Total Petroleum Hydrocarbons), acenaphthene, fluorene, pyrene, chrysene, phenanthrene: these last four are PAHs.
2. Levels of hydrocarbons in removed water were elevated over waters without removal, indicating that most of the hydrocarbons are in the sediments.
3. There are no standards for TPH (C5-C10) and TPH (C10-C40) in water, but for Total Petroleum Hydrocarbons (TPH): in the report they did not report TPH, we calculate it by adding TPH (C5-C10) and TPH (C10-C40).
4. In the water analysis of BTEX hydrocarbons, they are represented in the sum TPH (C5-C10) with limit of detection (LD) of < 0.04 mg/L but the toxic levels of the BTEX chemicals are benzene 0.046 mg/L , toluene 0.0098 mg/L, ethylbenzene 0.0073 mg/L, xylene 0.013 mg/L. These chemicals are very volatile and likely no longer exist in dangerous amounts. However, it cannot be shown because the LD is higher than the toxic level.
5. Some of the following elements - aluminium, copper, iron, magnesium, and zinc - exceeded standards in one or more water samples. These are not very toxic to humans in comparison to others, however, they can be toxic to aquatic life. Copper is very toxic to aquatic life, especially for algae.
6. The same elements in water and sediments exceeded standards, except for copper that exceeded only in water samples with removed sediments. In general, the values were usually higher in the water removed.
7. PAHs and mercury exceeded one or more standards in one or more sediment samples.
8. There is no standard for barium in sediment for aquatic life.
9. Lack of environmental quality standard (ECA) for sediments in Peru: however, most of the pollutants are sequestered in sediments which, in rivers, are very mobile.
10. Samples of removed and not removed water and sediments indicate that the contamination is highest between 3 and 400 m below the spill point.
11. In general, the data indicate that the contamination extends at least 600 m downstream from the point of spill and at least 200 m upwards from the point.

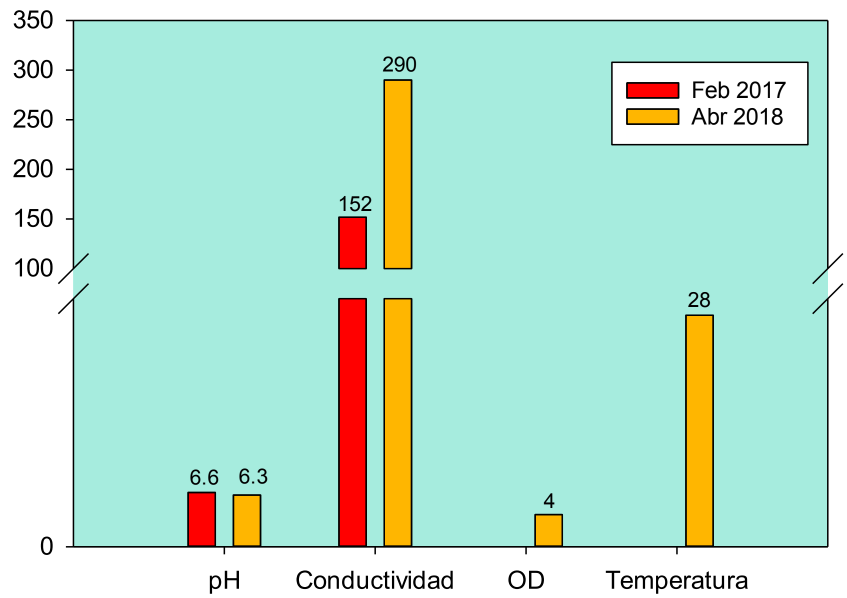

Figure 1. Physical-chemical data collected from the 'blanco' site Carococha, in the cuenca of the river Marañón. The specific values are mentioned above the bars. (OD = dissolved oxygen in mg/L; *Conductividad* in µS/cm; *Temperatura* in C°.)

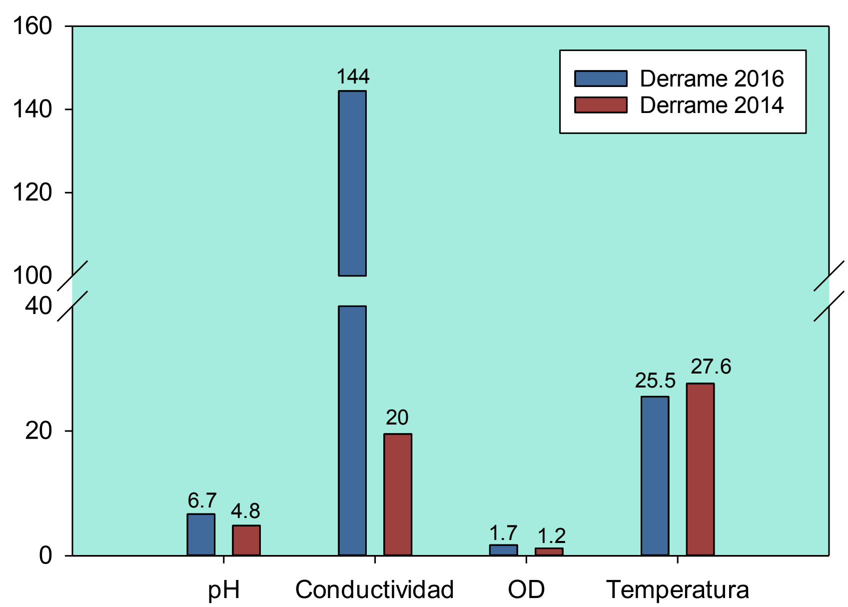

Figure 2. Physical-chemical data collected in February 2017 at the two San Pedro oil spill sites (2014 and 2016 respectively), *cuenca* Marañón. The specific values are mentioned above the bars. (OD = dissolved oxygen in mg/L; *Conductividad* in µS/cm; *Temperatura* in C°.)

Within the sites selected as ‘blanco’, only two fish, a Fasaco (*Aequidens sp*.) from Carococha and an Acarahuazú (*Astronotus ocellatus*) (Figure 3) from the Tipischca, have been necropsied (Figure 4) to date, and these had Health Index scores of 80 and 110, respectively. Fasaco is a carnivore eating mainly fish and crustaceans whereas Acarahuazú is a planktivore. The Health Index is calculated for a fish from the assigning of points for each observation of an anomaly, lesion, or parasite. The higher the index, the poorer the health. Both fish had erosion on the fins and full green gall bladders. The health index scores are higher than expected for uncontaminated areas. Although, it is too early to determine causes, we have to consider that fish come into and go out of the *cocha* during the *creciente* and *vaciente* and the Tipischca has a semi-permanent connection to the Marañon river and therefore the fish may be contaminated elsewhere. Also, the high conductivity in this *cocha* is unusual and the *cocha* may not be as uncontaminated as thought.

Figure 3. An opened Acarahuazú from the Tipischca in the community of Dos de Mayo, *cuenca* Marañón. The inside of the fish appeared healthy despite fin erosion.

Figure 4. Practicing fish necropsy in the community of Dos de Mayo, *cuenca* Marañón.

2. Pastaza

Piri Piri *cocha* and Ushpayacu are the pairs of sites selected for the *cuenca* of Pastaza. Neither has a direct connection to the Pastaza river. Piri Piri cocha is not a perfect reference site match for Ushpayacu, since Ushpayacu is actually a very large *quebrada* that was altered by the oil company many years ago. Functionally however, it is more like a *cocha* than a *quebrada*. According to many government reports, Ushpayacu is highly contaminated with heavy metals and hydrocarbons.

Both sites were sampled twice, once in April before the rising water (2017), and once in June during the rainy season and the ‘*creciente’* (Figure 6 and Figure 5 respectively). The additional water may have lowered the pH (rainwater being more acidic) and diluted the concentration of dissolved solids thus lowering the conductivity. Regardless, the difference in conductivity between the two sites, especially apparent in June of 2016, is great and reflective of the many years of produce water that was stored in Ushpayacu.

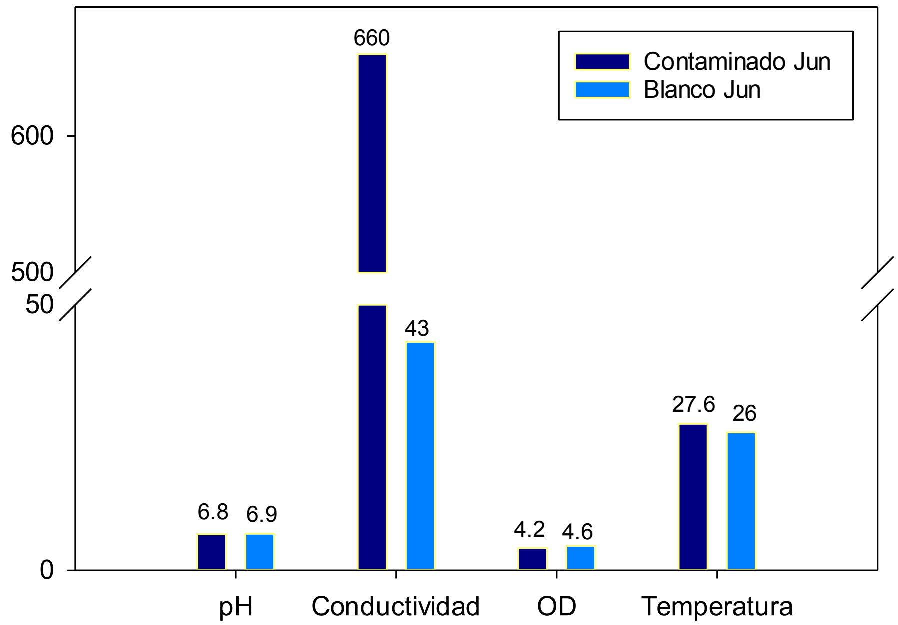

Figure 5. Physical-chemical data collected in Piri Piri *cocha* (*blanco*) and Ushpayacu (*contaminado*) in June 2016. The specific values are mentioned above the bars. (OD = dissolved oxygen in mg/L; *Conductividad* in µS/cm; *Temperatura* in C°.)

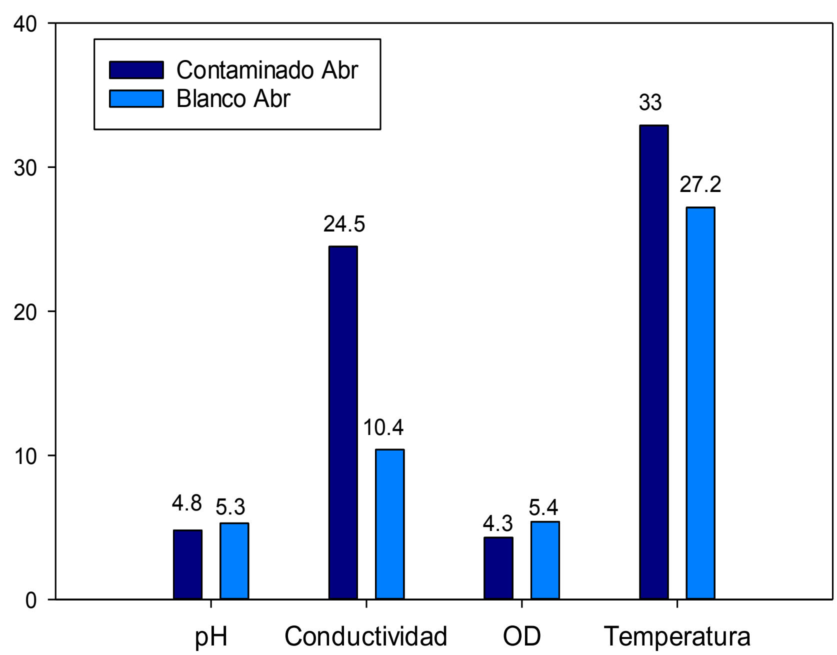

Figure 6. Physical-chemical data collected in Piri Piri *cocha* (*blanco*) and Ushpayacu (*contaminado*) in April 2017. The specific values are mentioned above the bars. (OD = dissolved oxygen in mg/L; *Conductividad* in µS/cm; *Temperatura* in C°.)

A total of 11 fish were caught from Piri Piri *cocha* and 13 from Ushpayacu. Although we attempt to catch only Fasaco (*Pachin* in Quechua) as our indicator species, there are never enough and rather than forgo an opportunity to teach the necropsy techniques (Figure 7) we use whatever is caught.

Figure 7. Work station for fish necropsy.

The health index for the various species is listed in Table 2. As expected, Fasaco from Piri Piri *cocha* have a lower health index than those from Ushpayacu and the median health index for all the species combined is lower for Piri Piri *cocha* than for Ushpayacu (Figure 8). The anomalies observed included slight hemorrhages, lesions on gills and fins, and fat accumulation in liver (Figure 9) and body cavity. Average Fasaco liver to body weight ratio was greater for Ushpayacu fish (n = 4; HSI (hepatosomatic index) = 0.014) than for Piri piri cocha fasaco (n = 4; HSI = 0.007), and spleen to body weight ratio was lower for Ushpayacu Fasaco (n = 2; SSI (splenosomatic index) = 0.0007) than for Piri Piri *cocha* Fasaco (n = 2; SSI = 0.001). Larger livers of contaminated fish may have been due to the lipid accumulation observed. Similarly, contaminated fish may be under greater immunological stress, and therefore have smaller spleens.

Table 2. Health index for each species from Piri Piri cocha and Ushpayacu.

Species	N	Mean	Trofic level
Piri Piri cocha			
Fasaco	5	34	Carnívoro
Bujurqui	6	32	Planctíoro
Ushpayacu			
Pirana	1	20	Piscivoro
Fasaco	9	86	Carnivoro
Novia	1	60	Omnívoro
Machete	1	120	Piscivoro
Lisa	1	140	Piscivoro

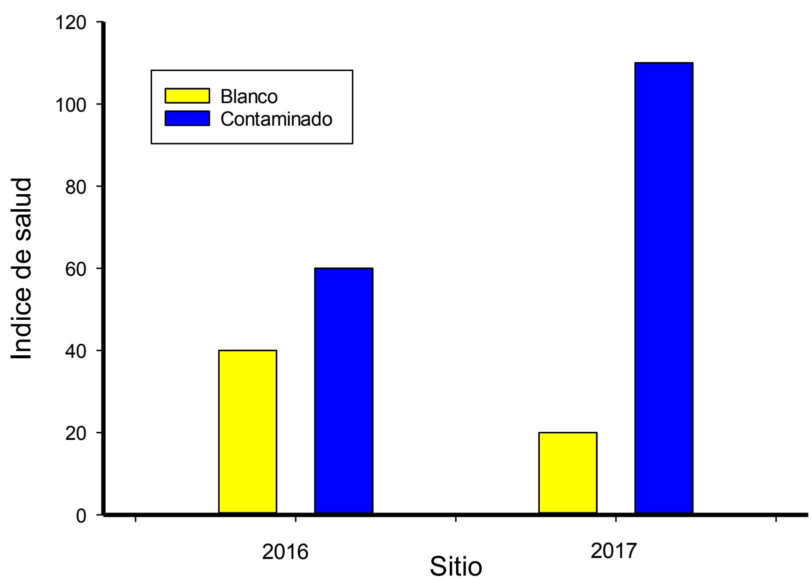

Figure 8. Comparison of the median health index for fish from Piri Piri *cocha* (*blanco*) and Ushpayacu (*contaminado*) during two years.

Figure 9. Pale Ushpayacu fish liver (must be dark red) with fat.

3. Corrientes

The Antonia and Huayuri *quebradas* are the *blanco* and *contaminado* sites, respectively, selected in the Corrientes *cuenca*. Huayuri (Figure 10) is the site of a very old oil spill that was never adequately cleaned-up and has visible hydrocarbons in the sediments. The soil profile of Antonia is silt and clay. Huayuri is clay down to 220 cm followed by sandy silt. Water is reached 70 cm and hydrocarbons are found to a depth of 220 cm. These sites have only been visited once. Physical-chemical parameters (Figure 11) appear to be normal for these sites suggesting that although there are visible hydrocarbons in the sediment, they are very weathered and there do not appear to be current inputs of produced water with its load of cations and anions. This may be supported by the results of the evaluation of fish health (Figure 12), but because of the limited number of fish collected it is too early to conclude. At Antonia, four Fasaco and one Bujurqui were captured whereas only one Bujurqui was captured at Huayuri and the Bujurqui from the *blanco* site had a Health Index of 50 compared to 30 for the Bujurqui from the *contaminado* site. The hepatosomatic index for these fish was 0.008 for Antonia and 0.009 for Huayuri (HSI for Fasaco was 0.009). At the *blanco* site the median for all fish combined was 30 but the five values ranged from 0 to 50.

Figure 10. The Huayuri *quebrada*, selected as a *'contaminado'* site in the Corrientes cuenca

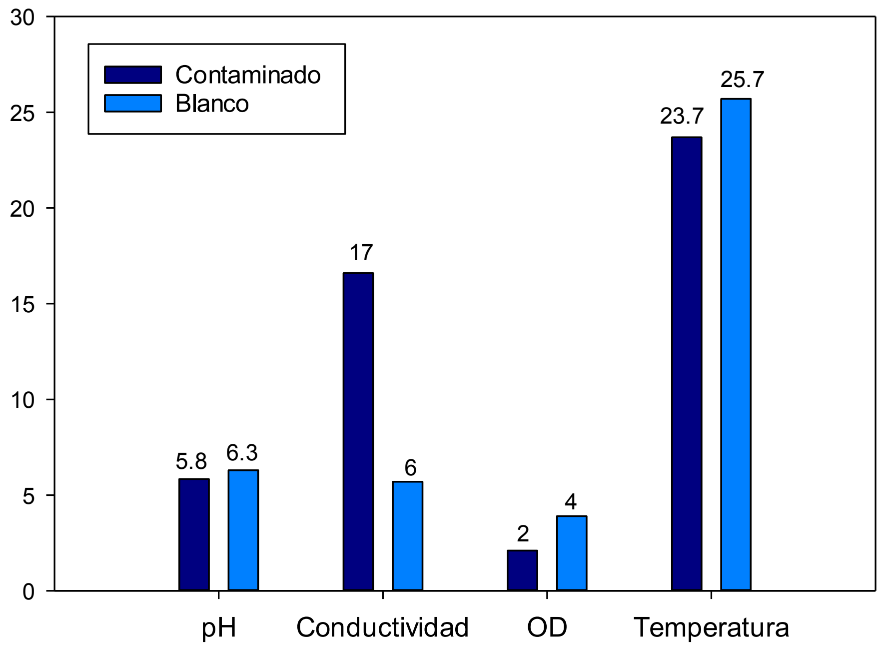

Figure 11. Physical-chemical data for the Antonia (*blanco*) and Huayuri (*contaminado*) sites, selected in the Corrientes *cuenca* in 2016. The specific values are mentioned above the bars. (OD = dissolved oxygen in mg/L; *Conductividad* in μS/cm; *Temperatura* in C°.)

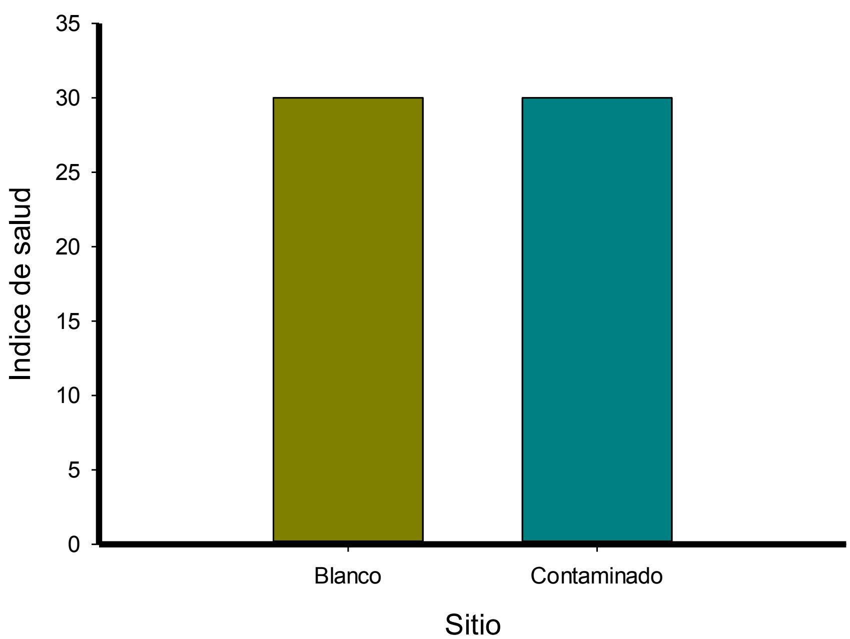

Figure 12. Health index for fish from the Antonia (*blanco*) and Huayuri (*contaminado*) sites, selected in the Corrientes *cuenca* in 2016.

4. Tigre

Quebradas Poroto (*blanco*) and Cuicayacu (contaminated with hydrocarbons and heavy metals) have been visited once in June 2016. Cuicayacu is a small *quebrada* about 300 m from a well. Both have predominantly clay soils (Figure 13). The odor of hydrocarbons could be detected at Cuicayacu to 93 cm. The extreme conductivity in Cuicayacu suggests that produced water may have been dumped into this *quebrada* (Figure 14).

Figure 13. Analysis of soil and groundwater in the Tigre *cuenca*.

Ten fish were collected at Cuicayacu (shuyo, fasaco, mojarra, aniashuya (sp?), cumbaromio (sp?), bujurqui) whereas only 1 bagre was collected at Poroto. No abnormalities were detected in the bagre from Poroto. The fish from Cuicayacu did have abnormalities and the Health Index ranged from 20 to 170 with a median value of 70 (Figure 15). There were a variety of problems with these fish from parasites to excessive fat and damaged fins.

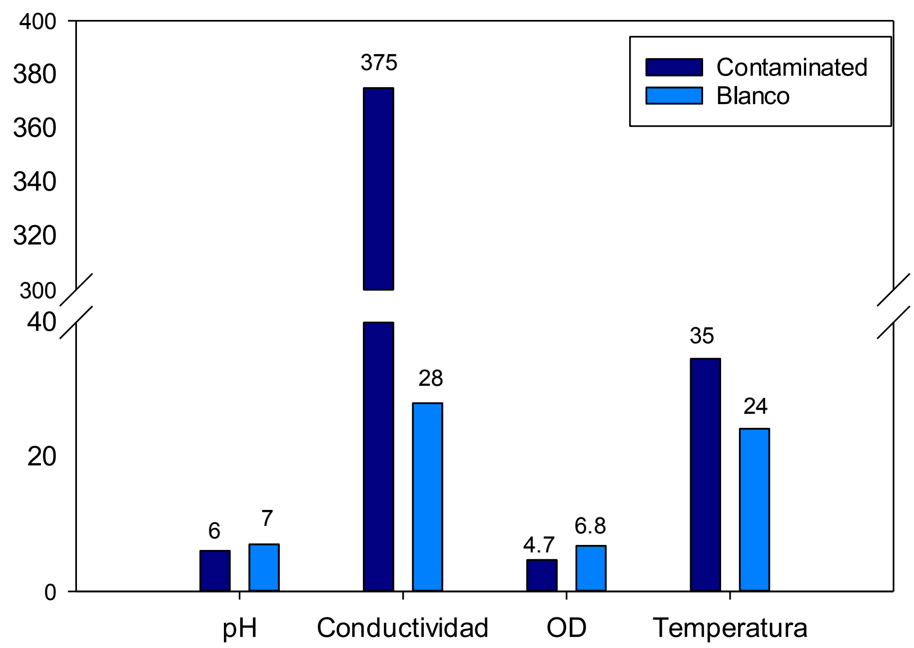

Figure 14. Physical-chemical data for the *quebradas* Poroto (*blanco*) and Cuicayacu (*contaminado*), selected in the Tigre *cuenca* in 2016. The specific values are mentioned above the bars. (OD = dissolved oxygen in mg/L; *Conductividad* in µS/cm; *Temperatura* in C°.)

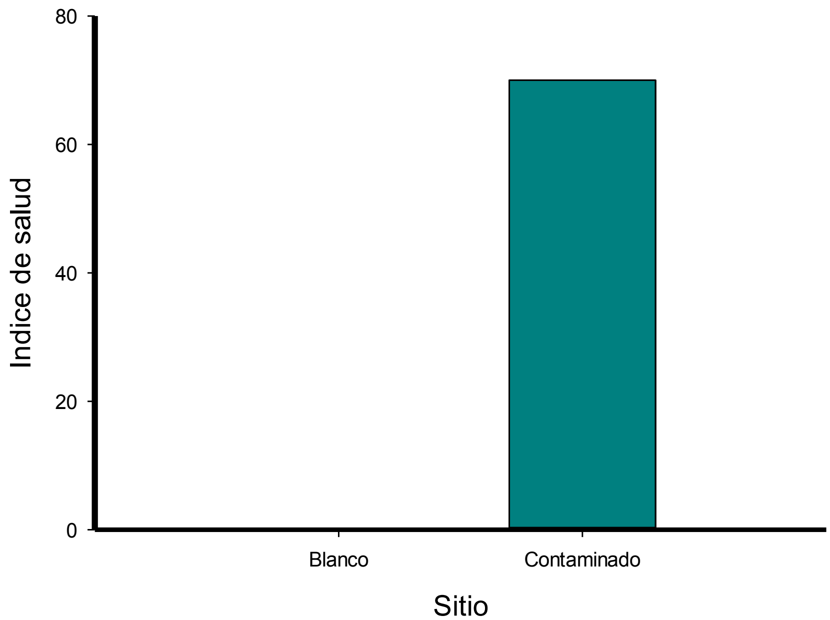

Figure 15. Health index for fish from the *quebradas* Poroto (*blanco*) and Cuicayacu (*contaminado*), in the Tigre *cuenca* in 2016.

5. Conclusion

Repeated sampling at specific sites has several benefits among them observation of trends and monitoring of the effect of stochastic and deterministic events on environmental function and quality. The long-term sampling sites E-Tech has established in the four *cuencas* are primarily for training purposes, however, the data collected may be useful for future remediation and restoration efforts. With only one or two visits to the sites it is too soon to describe patterns or compare and contrast the paired sites. Nevertheless, the experience acquired to-date indicates adjustments should be made to better match some of the reference sites to the contaminated sites, find sites that have easier access, and to ensure that sites will have biological samples (fish and/or macroinvertebrates and/or other?) to evaluate. A major challenge is finding sufficient individuals of a single fish species to collect and use as an indicator. Our expectation was that the monitors would visit the sampling sites at a minimum twice a year and preferably quarterly whether or not E-Tech trainers could be present. Unfortunately, this is not occurring for a number of reasons but most likely because of a lack of time and because environmental monitors are not full-time or monetarily compensated and spend time outside of monitoring to provide for their families.