water

MDPI

Article

What Participation? Distinguishing Water Monitoring Programs in Mining Regions Based on Community Participation

Claudio Pareja [1,*], Jordi Honey-Rosés [2], Nadja C. Kunz [3,4], Jocelyn Fraser [4] and André Xavier [3,5]

1 Centro de Estudios del Desarrollo Regional y Políticas Públicas, Universidad de los Lagos, Osorno 5310887, Chile
2 School of Community and Regional Planning, University of British Columbia, Vancouver, BC V6T 1Z2, Canada; jhoney@mail.ubc.ca
3 Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Vancouver, BC V6T 1Z4, Canada; nadja.kunz@ubc.ca (N.C.K.); andre.xavier@cirdi.ca (A.X.)
4 UBC School of Public Policy and Global Affairs, University of British Columbia, Vancouver, BC V6T 1Z4, Canada; jocelynfraser@shaw.ca
5 Canadian International Resources and Development Institute (CIRDI), University of British Columbia, Vancouver, BC V6E 3Z3, Canada
* Correspondence: cparejapineda@gmail.com; Tel.: +56-98-747-2450

Received: 19 July 2018; Accepted: 21 September 2018; Published: 25 September 2018

check for updates

Abstract: Water issues are a major concern for the mining sector and for communities living near mining operations. Water-related conflicts can damage a firm's social license to operate while violent conflicts pose devastating impacts on community well-being. Collaborative approaches to water management are gaining attention as a proactive solution to prevent conflict. One manifestation of these efforts is participatory water monitoring (PWM). PWM programs have the potential to generate new scientific information on water quantity and quality, improve scientific literacy, generate trust among stakeholders, improve water resource management and ultimately mitigate conflict. The emergence of PWM programs signals a shift toward greater stakeholder collaboration and more inclusive water governance within mining regions. In this article, we propose a new framework to evaluate the degree and extent of community involvement in PWM programs. This framework builds on citizen science literature. When applied to 20 cases in Latin America, notable differences in the degree of community and company participation between PWM programs are found. These differences suggest that companies and communities approach these programs from very different points of view. It is concluded that more attentive collaboration between firms and communities in the design of the program, the collection of data and interpretation of the results is needed to effectively build trust through PWM.

Keywords: water monitoring; mining; participation; citizen science; Latin America

1. Introduction

In the last 20 years, stakeholder engagement has become a central component for obtaining community approval of mining operations [1,2]. Stakeholder engagement has the potential to build trust between companies and communities, which can mitigate conflictual situations over a range of environmental issues [3]. However, despite efforts to increase community engagement in the mining sector, conflict between companies and communities has continued to escalate in the last 15 years [4–6].

Improving community members' perception of how fairly their opinions are considered by mining companies can help to build the trust companies seek when implementing community relationships [7].

Water, a critical input for mining operations, has become a major source of contention [8,9]. Many communities located near mining operations rank water related issues high on their list of concerns [5,10–12]. The significance of water as a hot-button issue cannot be overstated. Statistics from the International Finance Corporation (IFC), the world's largest global development institution focused exclusively on the private sector, reveal that between 2000 and 2017, water was associated with 58% of complaints about IFC investments in the mining sector [8]. Improved water management and governance has thus emerged as a key consideration for mining companies [13].

Some mining companies and communities have embraced participatory water monitoring (PWM) programs to address water management concerns and earn community approval. This study defines PWM programs as any program established in response to community concerns over mining operations that monitors the quality or quantity of water courses. Notably, these programs must involve locals in the design, oversight, execution, or interpretation of data. This definition encompasses current practices implemented in Latin America, especially Peru [14–16]. PWM is considered part of corporate stakeholder engagement. However, because it involves citizens in research-like monitoring, it is simultaneously considered an expression of citizen science. Similar linkages between community approval and citizen science have been made in other industries as well, such as marine conservation [17].

Collaborative and citizen-led approaches to data gathering and analysis have a long track record in the natural sciences and ecology [18]. One established example is the National Audubon Society's Christmas Bird Count that has invited citizens to count birds in their area every year since 1900 [18]. Citizen science is a process by which the public can participate in scientific research, for example, by providing collection samples [19,20]. It can support the development of ecological or environmental baselines, inform decision-making by providing more data [21], or by including local and traditional knowledge [22], contribute to the economies of scale by lowering the costs of data collection and provide quality assurance and quality control [18]. Scholars have argued that citizen science is necessary, both from a moral point of view, as it democratizes science and decision making and also from a pragmatic point of view, as it delivers more economical and implementable solutions to ecological problems [22]. Citizens, aided by accessible tools for data gathering and information dissemination, have embraced the right to have a greater voice in decisions that affect their communities [18].

Participatory water monitoring, on its own and as a manifestation of citizen science can benefit diverse stakeholders. For communities, involvement in the monitoring of water resources can provide learning opportunities, training in new skills or technologies and improved understanding about administrative procedures and environmental impact assessments [16]. In addition to building capacity and scientific literacy, local involvement in water monitoring may build a stronger sense of stewardship over water resources and generate new quantity and quality data [23]. Furthermore, these initiatives may help to translate local knowledge into scientific or bureaucratic language and thereby empower citizens [24]. For companies, PWM can identify resolvable tensions with local communities and create a context that facilitates open dialogue and builds trust [14]. These programs also help companies identify problems in projects that may be addressed with better processes or technology [14]. Finally, PWM programs can also generate valuable data on watershed hydrology that may assist local governments or regulatory bodies responsible for monitoring mining operations [15].

However, PWM may also have disadvantages. When involving volunteers within monitoring activities, issues surrounding non-comparability of the data collected and questions about data completeness arise [19,25]. Critically, errors in data collection may occur due to the lack of participant skills [26], although collaboration with scientists, proper training and quality assurance processes can reduce these issues [25–27]. In mining contexts, actual community participation in PWM and unequal power relationships between mining companies and associated communities are major concerns.

Company-funded PWM programs can either benefit a community [28] or become a springboard for questioning the program's intentions and credibility [15]. In one monitoring program in Peru, citizens only participated by overseeing a process that was designed and carried out by others [12]. In Ecuador, an organization that was excluded from participating in a mining company's monitoring program instituted their own campaign instead [29]. Although companies may have valid reasons and concerns for limiting citizens' involvement, like funding or data-integrity concerns, these cases show that program reception and participation can vary significantly in relation to common understanding between mining companies and communities about their respective roles.

Concerns over PWM's effectiveness and validity in mining have also been voiced in the literature. In Guatemala, a public report showing evidence of the relative cyanide concentration concerning residents near mining operations was based on only one visit to the area and showed no actual level of contamination [30]. In addition to regular monitoring, which is already difficult for community groups, safety and risk analysis are also important for addressing possible accidental episodes [30].

The literature on citizen science can inform stakeholder engagement initiatives in the global mining sector. In particular, it provides practical characterizations of community monitoring groups based on their degree of citizen involvement in the PWM process that can be used when designing and operating PWM programs. One such classification argues that the most appropriate type of monitoring scheme depends on the need for reliable data, funding, local expertise and interests and need of local knowledge and management [31].

The aim of this paper is to contribute to the growing interest in PWM in the mining sector by examining the intersections between PWM initiatives and the literature from citizen science. Specifically, the main goal of this paper is to adapt an existing framework to critically evaluate the degree and extent of community involvement in PWM programs in the mining sector. If this adaptation is successful, the framework can be used to facilitate improvements to the creation and establishment of PWM in mining contexts. A secondary goal is to provide a prospective view of the current state of community participation in PWM programs in the Latin-American mining sector. PWM programs are increasingly relevant in Latin-America and yet the current literature has not studied them beyond individual case studies.

This paper is organized as follows. Section 2 discusses different frameworks from citizen science that can be used to categorize the extent and depth of community participation in PWM. An adapted framework is proposed specifically for PWM in mining contexts. This framework presents a method to identify and evaluate PWM programs in Latin America. Section 3 presents the results of the framework application on 20 case study evaluations. Section 4 discusses the results and recommendations for practitioners interested in PWM based on the research findings. The paper then closes with conclusions regarding the applicability of citizen-science literature to the mining sector.

2. Materials and Methods. Characterizing Community Involvement in Participatory Water Monitoring in the Mining Sector

Some citizen science literature characterizes community involvement in participatory environmental monitoring as dependent on the role citizens hold during the process. Building on a literature review of different participatory environmental monitoring initiatives, three types of governance were identified that shape citizen roles in these initiatives [23]:

- A central agency identifies a situation to be monitored, designs a monitoring scheme and asks the community to operate it.
- A multi-actor board of directors is created in a collaborative fashion. Later, this board designs and performs the monitoring.
- The community identifies a situation to be monitored, designs a monitoring scheme and executes it.
- In this framework, the three stages of citizen participation are called conveying, designing and execution, respectively.

Another similar framework for environmental monitoring initiatives aims to help policy makers and communities study the degree of local involvement. Further, it aims to assess the corresponding suitability of each scheme depending on the context and objectives of the initiative [31]. Led by a major scholar in the field and involving diverse academic institutions, the authors built their framework by drawing from a wide range of monitoring programs related to conservation efforts across the globe [31]. This framework classifies participatory monitoring initiatives into five categories:

1. Externally driven and professionally executed, i.e., monitoring is designed, performed and interpreted by experts from outside the community.
2. Externally driven, with local data collectors, i.e., monitoring is designed and interpreted by outside experts, but data is collected by local community members.
3. Collaborative monitoring with external data interpretation, i.e., the monitoring program is designed in collaboration with the local community and the data is also collected locally. However, outside experts are responsible for the interpretation.
4. Collaborative monitoring with local data interpretation, i.e., the monitoring is collaboratively designed by community members and outsiders, the data is collected locally and management decisions and data interpretation is led by the local group. Since this is a collaborating approach, both the monitoring institution and the community participate.
5. Autonomous local monitoring, i.e., the monitoring program is completely designed, implemented and interpreted by community members. An external monitoring institution or company, does not participate.

Like the previous framework, this one has three stages, or features, for categorizing the monitoring initiative according to the degree of citizen participation. They are: conceptualization, collection and interpretation, respectively. Another recent review of participatory environmental monitoring programs assessed community involvement by explicitly identifying seven stages: ideation, design, data collection, evaluation and use of data [32].

The framework proposed in this paper builds on these approaches and also uses three main features [31]. However, this study appends additional categories relevant for mining that were not included in the original framework. These additional categories detail the ways in which the company or the community play specific roles beyond the three configurations identified in Reference [23] and the five categories in Reference [31] as follows:

- "Conceptualization" reflects which group convenes and designs the monitoring process and therefore acts as the leader. Like Reference [31], in this category PWM endeavors are classified as (a) "externally-led," when the company or the government leads and designs the process; (b) "collaborative," when the community has a say in the process design; and (c) "locally-led," when the community leads and designs the process by itself or with the support of a non-governmental organization (NGO).
- "Collection" distinguishes between (a) "professional" or (b) "local" data collection. Local collection refers to local residents or community members taking samples or collecting data.
- "Interpretation" is either (a) "external" or (b) "local". External interpretation occurs when the monitoring data or samples are sent to professionals for analysis and interpretation, such as when water samples are sent to laboratories for comparison to national standards. Local interpretation occurs when community members perform this work. Examples of local interpretation include a community member with the technical skills to perform or fully understand related data analysis, or when monitoring and analysis is made in vernacular terms such as color or taste of water.

The relevance and pertinence of the framework is tested by applying it to categorize PWM projects in Latin America, where a significant number of mining–community conflicts have occurred [4]. An analysis of international media coverage found that Peru, Chile and Mexico were experiencing the largest number of reported incidents of conflict between 2012 and 2015 [33]. While the causes of conflict can be complex, environmental concerns were reported as the most frequent triggers of tension, with conflict over water as the principal environmental issue [33]. This aligns with a 2008 study that found that since 2005, the perceived adverse impact of mining on water quality and quantity represents the most contentious issue for the sector [10]. Scholars have argued that better water governance is one key aspect for addressing mining conflicts in Latin America [30].

Participatory water monitoring programs implemented by the private sector and policy makers appear to be on the rise in Latin America, continuing a trend observed a decade ago [16]. This is particularly true in Peru. In 2016, the third national workshop of Participatory Environmental Monitoring Committees in Mining reunited over 200 participants related to 22 PWM programs [15]. Beyond this one Peru-specific conference, scholars have examined particular PWM experiences across the Latin-American mining sector and their operation on a case-by-case basis.

A review of the academic literature evidences a lack of overview in Latin-American PWM programs. Searching "participatory monitoring mining" on the Web of Science™ database (Clarivate Analytics, Philadelphia, PA, USA), resulted in 24 records. In comparison, the terms "community monitoring mining water", yielded 284 records. However, after reviewing all the articles' abstracts, only six mentioned PWM programs in Latin America. Two of the six discuss the Peruvian PWM programs already discussed [12,30]. Another proposed that a properly designed and executed PWM program may foster trust between the mining company and the community but did not detail the community's role in the program, focusing on environmental aspects instead [10]. The fourth paper proposed a method to create an indicator-based framework to monitor the social impacts of mining. Although this paper reported on a case study with an organization associated with various PWM programs, its focus was on the creation of indicators. The description of how such a monitoring program could be implemented was limited to one paragraph, with no details provided on the role community participation held during data collection and interpretation [34]. The last two papers related to Ecuador. One detailed the case presented in the introduction [29]. The other, rather than presenting the operation of an actual monitoring program, described the different challenges of implementing a monitoring program related to artisanal gold mining [35].

To address the knowledge gap related to a broader overview of the extent of community participation on PWM programs in Spanish-speaking Latin America, a systematic review of Spanish-speaking grey literature was performed. First, search terms in Spanish that would reveal participatory monitoring initiatives in Latin America were identified. This preliminary investigation returned PWM initiatives that were referred to as "participatory monitoring" (*monitoreo participativo*), "community monitoring" (*monitoreo comunitario*), or "company monitoring" (*veedurías*). The preliminary search using these terms yielded many results in Peru. To identify additional relevant cases elsewhere in Latin America, subsequent additional searches excluded Peru. Further, all searches (with and without Peru) were narrowed by adding "water" (*agua*) and three mining related words "mining, mining company, mine" (*mineria, minera, mina*).

In summary, the above considerations defined five searches:

1. Monitoreo participativo agua mineria OR minera OR mina
2. Monitoreo comunitario agua mineria OR minera OR mina
3. Veeduría ambiental agua minería OR minera OR mina
4. Monitoreo participativo agua mineria OR minera OR mina—peru–Perú
5. Monitoreo comunitario agua mineria OR minera OR mina—peru–Perú

The Google (Mountain View, CA, USA), search engine was used to identify relevant grey literature. As discussed earlier, PWM programs in the mining sector have not been widely published in academic literature, thereby justifying the use of the Google search tool. The built-in filter enabled a focus on websites updated after 1 January 2015, up to the day the search was done. All searches were performed between 28 June and 10 July 2017. Websites without a recorded time of publication were excluded.

The focus on recent literature was designed to obtain a clear sense of initiatives currently taking place in Latin America.

Each search produced an extensive list of websites and documentation that could reveal the existence of a PWM initiative. Each website was examined to see if it mentioned (i) mining or a mining company, (ii) community participation and (iii) water monitoring. A search return was excluded if it was a proposal to establish a PWM program, a court ruling, a law, or an environmental impact declaration/assessment. Other exclusions included if the PWM program was associated with artisanal or illegal mining, if it was executed by an external NGO without the community, or it was related to refineries or gravel extraction.

The title, the summary provided by Google and the full text of each returned website was reviewed until it was clear the inclusion criteria had been met. In cases where the information was in an appended file, this document was also considered.

The extensive lists produced by each search were narrowed further by examining only the first 100 returned websites. For completeness, if 15% (three) of the last twenty websites met the inclusion criteria, another additional twenty results were reviewed until the proportion of included websites was below the 15% threshold. The search returns were grouped and numbered according to their respective position in the results pages of Google.

The research was supported by keeping a complete list of all the returned websites. This was done to rapidly identify websites that appeared in more than one search and to address reported issues of replicability when using Google [36–38].

Selected websites and appended materials were studied to identify participant leadership of the program and, where possible, the river basin of concern. In some instances, multiple websites discussed the same initiative, providing more detailed information about each PWM group. To avoid double-counting, when there was a mention of a mining company, the specific project was identified and vice-versa. For this identification, a variety of specialized sources, like public sustainability or corporate reports, were used.

A case was built for each PWM program associated with a specific company, mine and leadership. If the website did not mention a company or mine, but mentioned an NGO or faith-based organization, the case was built from all the websites mentioning that identified organization. Finally, if a website mentioned many companies but the government was leading the PWM, the case was built using all websites that mentioned the government and a common river basin.

After websites were grouped and each case was defined, NVivo™ (QSR International, Melbourne, Australia) was used to catalogue each initiative according to the framework's three relevant features: conceptualization, collection and interpretation. Only cases with clear information on the websites were catalogued.

3. Results

3.1. Search Results and Case Identification

A total of 436 websites were examined, resulting in 108 relevant pages. From these pages, 55 PWM initiatives in the Latin-American mining sector were identified (Table 1). These programs operated in 10 countries plus one multi-country effort which provided training for monitoring schemes.

Table 1. PWM initiatives in Latin America.

Country	Criteria for Creating Case	Case Name
Argentina	Explicit mining company, project and leadership	Barrick Gold, Veladero (Community initiative)
	Explicit mining company, project and leadership	Barrick Gold, Veladero (Official initiative)
	Explicit mining company, project and leadership	Orocobre (Sales de Jujuy), Olaroz lithium
	Explicit mining company, project and leadership	Troy Resources, Casposo
Bolivia	Explicit mining company, project and leadership	COMIBOL, Huanuni
	Explicit mining company, project and leadership	Glencore, Sinchi Wayra
	Explicit mining company and leadership	Minera Bolivar
Chile	Explicit mining company, project and leadership	Andes Iron, Dominga
	Explicit mining company, project and leadership	Antofagasta Minerals, Los Pelambres (Cuenca del Choapa initiative)
	Explicit mining company, project and leadership	Antofagasta Minerals, Los Pelambres (Other initiatives)
	Explicit mining company, project and leadership	BHP, Escondida
	Explicit mining company, project and leadership	CODELCO, El Teniente
Colombia	Explicit mining company, project and leadership	Anglogold Ashanti, La Colosa
	Explicit mining company, project and leadership	Continental Gold, Buritica
Dominican Republic	Explicit mining company, project and leadership	Barrick Gold, Pueblo Viejo
Ecuador	Explicit mining company, project and leadership	ENAMI Ecuador, Llurimagua
	Explicit mining company, project and leadership	Lundin Gold, Fruta del norte
	Explicit mining company, project and leadership	Taller Caritas
Guatemala	Explicit mining company, project and leadership	Goldcorp, Marlin
Multi-National	Explicit mining company, project and leadership	Intercambio experiencias
Mexico	Explicit mining company, project and leadership	Goldcorp, Peñasquito
Panama	Explicit mining company, project and leadership	First Quatum, Cobre Panama
Peru	Explicit mining company, project and leadership	Aguila Dorada, Yaku Entsa
	Explicit mining company, project and leadership	Anglo American, Quellaveco (4th campaing)
	Explicit mining company, project and leadership	Anglo American, Quellaveco (5th campaing)
	Explicit mining company, project and leadership	Aruntani SAC, Arasi
	Explicit mining company, project and leadership	Aruntani SAC, Tucari

Table 1. *Cont.*

Country	Criteria for Creating Case	Case Name
Peru	Explicit mining company, project and leadership	BHP, Antamina
	Explicit mining company and leadership	Buenaventura
	Explicit mining company, project and leadership	Buenaventura, Orcopampa
	Explicit mining company, project and leadership	Buenaventura, Rio Seco
	Explicit mining company and leadership	CENTROMIN
	Explicit mining company, project and leadership	Cerro SAC, Cerro Pasco
	Explicit mining company, project and leadership	Coimolache, Tantahuatay
	Explicit mining company, project and leadership	Freeport McMoran, Cerro Verde
	Explicit mining company, project and leadership	Glencore, Antapaccay
	Explicit mining company, project and leadership	Goldfields, Cerro Corona
	Explicit mining company, project and leadership	Marcobre, Mina Justa
	Explicit mining company, project and leadership	Milpo, Cerro Lindo
	Explicit mining company, project and leadership	Minera Raura, Raura
	Explicit mining company and leadership	Minera Volcan
	Explicit mining company, project and leadership	Minsur, Pucamara
	Explicit mining company, project and leadership	Newmont, Yanacocha
	Not explicit mining company or project, but explicit civil society organization	Encuentro Macro Norte
	Not explicit mining company or project, but explicit civil society organization	Encuentro Sur Andino
	Explicit mining company, project and leadership	Peru LNG, LNG
	Multiple companies, Government-led	Peruvian Government, not explicit river basin
	Multiple companies, Government-led, explicit river basin	Peruvian Government, Canipia Salado river basin
	Multiple companies, Government-led, explicit river basin	Peruvian Government, Espinar river basin
	Multiple companies, Government-led, explicit river basin	Peruvian Government, Grande river basin
	Multiple companies, Government-led, explicit river basin	Peruvian Government, Huara river basin
	Multiple companies, Government-led, explicit river basin	Peruvian Government, Llaucano river basin
	Multiple companies, Government-led, explicit river basin	Peruvian Government, Moche river basin
	Explicit mining company, project and leadership	Southern Peaks Mining, Tia Maria
	Explicit mining company, project and leadership	Teck Resources, Zafranal

3.2. Characterizing of Monitoring Groups Using the Three Features

Of the 55 identified initiatives, it was possible to completely identify conceptualization, collection and interpretation methods for only 20 cases (36%). Web-based research for these cases provided explicit and consistent information about how programs were conceptualized and how data was collected and interpreted.

Of these 20 cases, the most frequent types were "externally-led, professionally executed and interpreted" (30%) and "autonomous monitoring" (25%) (Figure 1). The remainder of the cases were distributed through more collaborative PWM strategies, except that no programs fell into the categories involving external design and/or execution with local interpretation, or the reverse, local design with professional execution and/or interpretation (Figure 2).

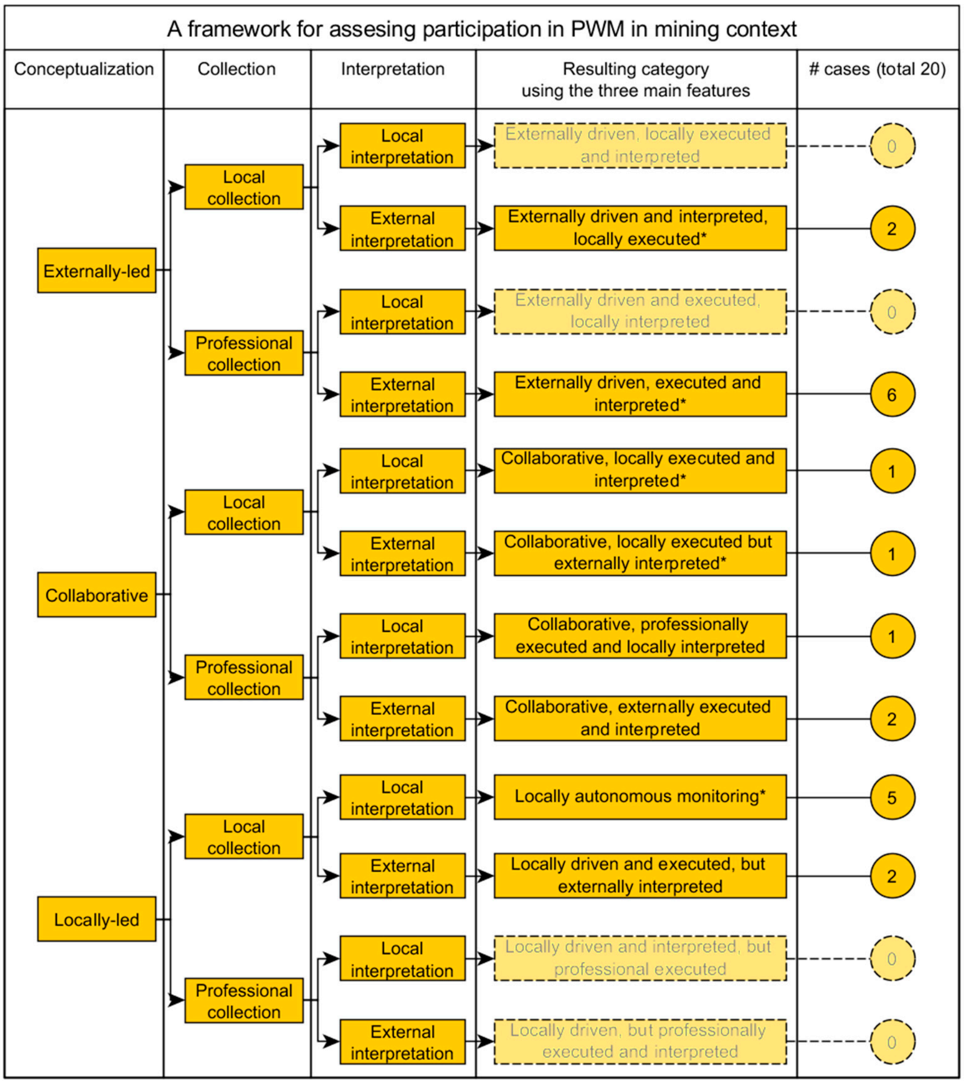

Figure 1. Proposed framework for PWM is based on partly conceptualizing the program (first column), actor collecting the data (second column) and data interpreter (third column). Categories that are consistent with the framework in Reference [31] are marked with an asterisk. Categories that were not found in the sample are shown as transparent. Circles represent the number of cases identified.

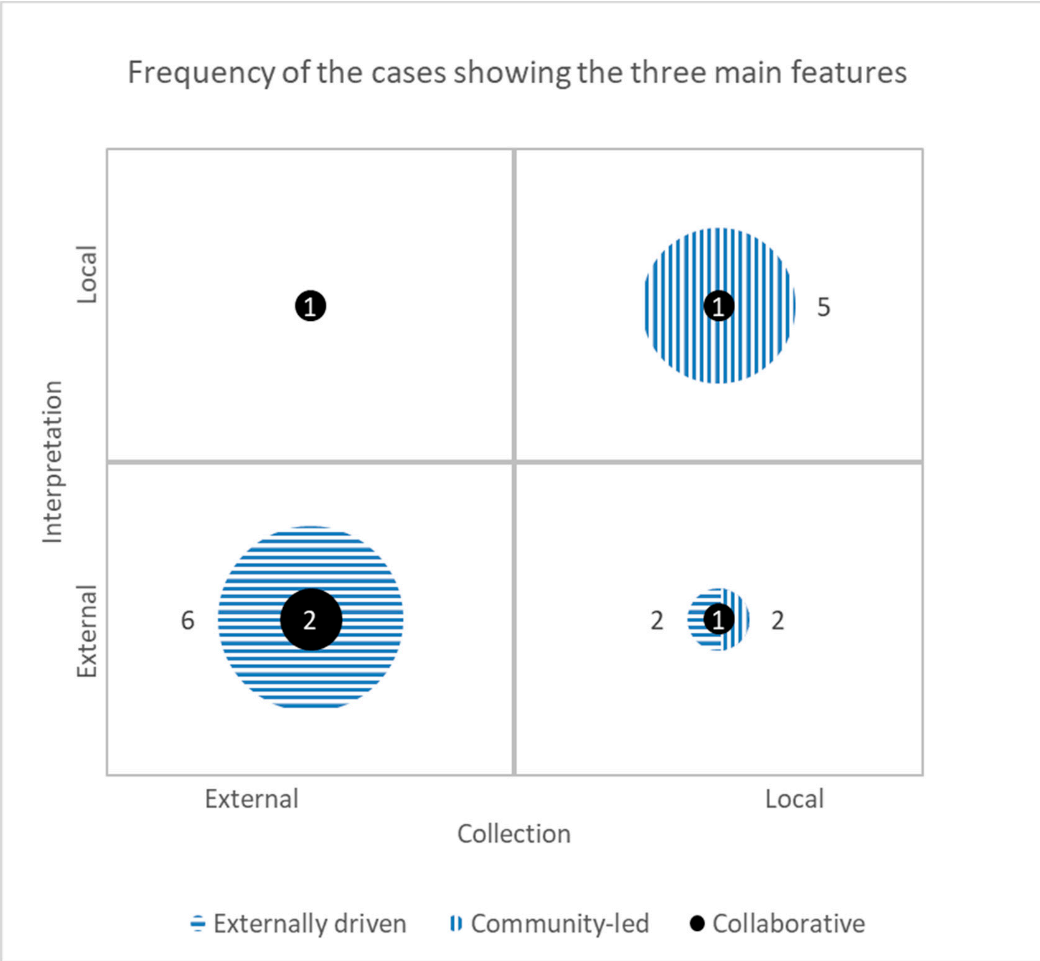

Figure 2. A summary of the number of PWM programs identified by collection approach (*X*-axis) and interpretation type (*Y*-axis) (N = 20) showing than no externally-led program considered local interpretation and that no community-led program considered external collection. The fill of the bubble identifies how the case was conceptualized: External (horizontal lines, number on the left of the bubble), collaborative (black, number at the center), or community led (vertical lines, number on the right). In the bottom-right quadrant, two cases were community-led and two cases were externally driven.

3.3. Partial Characterization

In 42 (76%) of the cases identified, including the above 20, at least one feature (conceptualization, collection, or interpretation) was categorized. For half of PWM cases, the projects were conceptualized and designed by external groups in 51% of 41 cases where conceptualization could be identified. Likewise, data were collected by "professionals" in 52% of 27 cases and data were interpreted by "external groups" in 74% of 27 cases (Table 2).

As shown in Table 2, most PWM cases could be characterized by combinations of two features. For example, initiatives were categorized as locally collected and externally interpreted programs, or professionally collected and locally interpreted and so on. No cases appeared that were externally-led and locally (community) interpreted, or were community-led and professionally executed. The combinations that were not found are shown with zeros in Table 2.

Table 2. Summary of partial classification using the three features of the proposed classification model: conceptualization (first column), collection (second row) and interpretation (first row).

Number of Cases	**Interpretation: External**			**Interpretation: Locally**			**Interpretation: No Information**		
	Collection: Local	**Collection: Professional**	**Collection: No info.**	**Collection: Local**	**Collection: Professional**	**Collection: No info.**	**Collection: Local**	**Collection: Professional**	**Collection: No info.**
Conceptualization: Externally-led	2	6	6	0	0	0	0	4	3
Conceptualization: Collaborative	1	2	0	1	1	0	0	1	4
Conceptualization: Community-led	2	0	0	5	0	0	1	0	2
No information	1	0	0	0	0	0	0	0	13

4. Discussion

When applying the proposed framework to 20 cases in Latin America, it was clear that the role of communities and companies varied considerably from one initiative to another even though all the initiatives self-identify as "participatory". In most cases, either the community or the company dominated, losing potential benefits from equal collaboration. The monopolization of leadership can become a possible source of confusion, misunderstanding and potential conflict if communities or companies have different expectations about their degree and extent of involvement. In contrast, a compromise between the extreme views that can occur when the community is a full partner in mining operations management or the company is the sole steward of watersheds should be achieved.

Private firms and communities seem to approach PWM from vastly different perspectives and therefore roll out their community monitoring programs in very different ways. This dichotomy is evident from two consistent observations: (1) externally-led programs often have professional collection and external interpretation and (2) community-led programs are more likely to incorporate local collection and local interpretation. While PWM programs are a likely response to the lack of trust between companies and communities, no actual collaboration seems to be occurring within company- or community-led programs. This finding brings forward the importance for both parties to acknowledge trust dynamics.

Disparate perspectives of private firms and communities toward the PWM process suggests different perspectives toward collection and analysis of data. Company and/or government preferences for professional collection and external interpretation suggest a greater reliance and trust in the scientific interpretation of data. On the other hand, the greater reliance on local collection and interpretation by community-led programs suggest stronger emphasis on context- and value-based analysis of water datasets and trends [39]. Differences in interpretation preferences may result in one stakeholder placing limited trust in another's data. However, arrangements where professional scientists, company and government personnel and community members collaborate in all stages of the process could overcome the drawbacks from this either/or scenario. For example, it is possible that community-collected data combined with training and a quality-assurance process provided by professionals could give both parties the certainty they need [27]. Furthermore, a professionally designed monitoring scheme that considers the community's everyday concerns could fulfill both parties' need to be heard [34,40].

In this context, process seems relevant for all parties. Communities are participating in PWM efforts and taking the design and execution of process into their hands. If data was the only important aspect, communities could use companies' or government's monitoring information. Therefore, companies need to acknowledge citizen participation as a sign that, beyond the data, the PMW process itself is also important. Formal monitoring is more likely to carry legal weight when measuring the environmental impact of mining processes, so firms might instead focus PWM efforts on building trust, communications and local capacity, rather than focusing on legal requirements. The opposite applies to communities: if they acknowledge that a PWM program with a formal monitoring process is likely to be more relevant to companies and governments, then they too could expand the focus of their efforts beyond their primary concerns and views. Therefore, a monitoring program that establishes common ground and a space for collaboration and mutual understanding, may contribute much more to water governance than the mere collection of the data itself. This conclusion aligns with the literature on democratic communicative actions that, for environmental situations, emphasize the role of proper rules and processes and the acknowledgement of existing power relationships [41,42]. Nonetheless, data is still important, since communities and companies want to know the current state of the water resources.

Restricted participation and reliance on scientific interpretation implies that companies are approaching PWM solely as a corporate initiative, representing an effort to earn and maintain community approval to operate. In this sense, companies engage local stakeholders around water use, recognizing that competition for this scare resource may create conflict. However, in this review, there is little evidence that companies share decision-making on water-related issues considering they do not share the design or interpretation of monitoring programs with communities. While the reverse may also be true, with communities not involving scientists or companies, past negative experiences and the extent of environmental damage that mining can produce [43] places the onus of responsibility on companies to act. Local citizens are likely to view PWM from the perspective of citizen science, believing that more knowledge will inform water stewardship and, further, it will position them as an equal partner in the process. The dichotomy between these two approaches and desired outcomes, may drive the type of conflict companies hope to avoid.

Geographically, our survey of the grey literature uncovered the most PWM initiatives in Peru (32 initiatives, 59% of our sample), establishing this country as a clear leader in community engagement for the mining sector. Studying the historical and social trends behind this phenomenon is beyond the scope of this article, but it is important to comment on reasons that could explain this result. Notably, the Peruvian legal framework is conducive to the establishment of PWM committees. The environmental law states that "everyone has the right to participate responsibly in the decision making process, as well as in the definition and application of policies and measures related to the environment and its components," further "mechanisms for citizen participation constitute instruments of environmental management" [44]. Specific to mining, state directives establish that project proponents should present information about a monitoring program with citizen participation [45] and that "communities of interest around mining projects have the right to monitor, control and follow up on the measures, actions, obligations and commitments adopted by the mining companies with respect to environmental and social aspects related to mining activity" [46]. Thus, validating the role of communities in the monitoring of mining companies.

5. Conclusions

This research critically reviewed PWM programs within the mining sector in Latin-America. It evaluated the extent of community involvement in 20 current initiatives by building on the literature from the broader field of citizen science. The proposed framework offers an improved means for classifying PWM based on a program's approach to conceptualization, data collection and data interpretation. These distinctions are valuable for recognizing differences between PWM programs and emphasize that there is no "one-size-fits-all" approach to program design. While similar conclusions have been found in other fields [32], this finding is novel within the mining sector. While the framework allowed us to assess the depth of community involvement in PWM projects design, data collection and interpretation, it lacks strong causal evidence to support the conclusion that these projects are succeeding in improving water governance or in reducing barriers to community approval for mining operations. Future research is needed to study the effectiveness and longevity of participatory projects, especially as they relate to who conceptualized the project or other aspects of the program design. In other words, not only it is important to understand if PWM projects make an impact, but it is also key to understand which features of their design lead to success.

Additional research could also explore other relevant impacts a PWM program may have. It has been suggested that involving citizens yields faster decision-making to tackle environmental challenges at the operational scale [47]. Similarly, then, locally owned programs may be more sustainable over long-term time frames, especially when they are integrated with an existing management system [24]. The data gathered for this review suggests PWM programs are not affecting decision making and that PWM programs have not yet been integrated to existing management systems. From a different perspective, scholars have also argued that monitoring programs could empower communities by allowing them to define the issues to be addressed by the company/government, to enforce the law, or to choose to move out of the development area [48].

The research team is aware that some PWM initiatives did not surface in the review. However, as the goal of the research is to present an overview of existing Latin-America PWM initiatives to test a framework, rather than to create a comprehensive list of existing programs, the review adds value to the current literature. Certainly, future research could expand the inventory of existing programs. Such an expansion could determine if all the categories of the framework are realistic. For example, there may be community-run programs that have enough connections or resources to delegate data collection to professionals. There could also be monitoring programs designed by mining companies with long-ranging community relationships that elect to leave data interpretation to citizens.

The framework proposed here offers a promising guide for companies, communities and governments to develop PWM programs according to features that seem the most important and relevant within a local context. By identifying relevant stages of a monitoring initiative, the framework also offers a valuable starting point for future research to evaluate which design is most effective for meeting its intended goals (e.g. reducing conflict, enhancing community understanding, or obtaining watershed resource data).

Bringing an updated framework from citizen-science to assess community participation in mining-related PWM projects has yielded valuable insights. Chief among them, the recognition that the term "participation" has multiple definitions and that it must be used carefully. Further, the review of projects within the proposed framework facilitated an exploration of how companies and communities differ in their approaches to PWM. It is expected that the framework will be useful to both companies and communities wishing to start or improve joint efforts for watershed management.

Author Contributions: Conceptualization, A.X., N.C.K, J.H.-R. and C.P.; Methodology, A.X., N.C.K, J.H.-R. and C.P.; Software, C.P.; Validation, C.P.; Formal Analysis, C.P.; Investigation, C.P.; Resources, A.X., N.C.K. and J.H.-R., Data Curation, C.P.; Writing-Original Draft Preparation, C.P.; Writing-Review and Editing, J.H.-R., N.C.K., A.X. and J.F.; Visualization, C.P., J.H.-R. and N.C.K.; Supervision, A.X.; Project Administration, A.X. and C.P.

Funding: This research received no external funding.

Acknowledgments: C.P. wishes to acknowledge that the initial work for this project was conducted while he was on a paid internship at the Canadian International Resource Development Institute.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Prno, J.; Scott Slocombe, D. Exploring the origins of "social license to operate" in the mining sector: Perspectives from governance and sustainability theories. *Resour. Policy* **2012**, *37*, 346–357. [CrossRef]
2. Zhang, A.; Moffat, K.; Lacey, J.; Wang, J.; González, R.; Uribe, K.; Cui, L.; Dai, Y. Understanding the social licence to operate of mining at the national scale: A comparative study of Australia, China and Chile. *J. Clean. Prod.* **2015**, *108*, 1063–1072. [CrossRef]
3. Beirele, T.; Cayford, J. *Democracy in Practice: Public Participation in Environmental Decisions*; Resources for the Future Press: Washington, DC, USA, 2002; ISBN 9781891853548.
4. ICMM. *Research on Company-Community Conflict*; ICMM: London, UK, 2015; Available online: https://www.icmm.com/website/publications/pdfs/social-and-economic-development/8515.pdf (accessed on 21 September 2018).
5. Franks, D.M.; Davis, R.; Bebbington, A.J.; Ali, S.H.; Kemp, D.; Scurrah, M. Conflict translates environmental and social risk into business costs. *Proc. Natl. Acad. Sci. USA* **2014**. [CrossRef] [PubMed]
6. Andrews, T.; Elizalde, B.; Le Billon, P.; Hoon Oh, C.; Reyes, D.; Thomson, I. The Rise in Conflict Associated with Mining Operations: What Lies Beneath? Canadian International Resources and Development Institute (CIRDI): Washington, DC, USA, 2017; pp. 1–127. [CrossRef]
7. Moffat, K.; Zhang, A. The paths to social licence to operate: An integrative model explaining community acceptance of mining. *Resour. Policy* **2014**, *39*, 61–70. [CrossRef]
8. International Finance Corporation (IFC) Infrastructure & Natural Resources Advisory Team. *Water in the Mining Sector: Shared Water, Shared Responsibility, Shared Approach*; IFC: London, UK, 2017. Available online: https://www.icmm.com/website/publications/pdfs/water/170321_icmm-ifc_shared-water-shared-responsibility.pdf (accessed on 21 September 2018).
9. Kunz, N.C.; Moran, C.J. Sharing the benefits from water as a new approach to regional water targets for mining companies. *J. Clean. Prod.* **2014**, *84*. [CrossRef]
10. Bebbington, A.; Williams, M. Water and Mining Conflicts in Peru. *Mt. Res. Dev.* **2008**, *28*, 190–195. [CrossRef]

11. Haslam, P.A.; Ary Tanimoune, N. The Determinants of social conflict in the Latin American mining sector: New evidence with quantitative data. *World Dev.* **2016**, *78*, 401–419. [CrossRef]
12. Himley, M. Monitoring the impacts of extraction: Science and participation in the governance of mining in Peru. *Environ. Plan. A* **2014**, *46*. [CrossRef]
13. Fraser, J.; Kunz, N. Water stewardship: Attributes of collaborative partnerships between mining companies and communities. *Water* **2018**, *10*, 1081. [CrossRef]
14. Bebbington, A.J.; Bury, J.T. Institutional challenges for mining and sustainability in Peru. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 17296–17301. [CrossRef] [PubMed]
15. Xavier, A.; Leon, A.; Carlier, A.; Bernales, M.; Klein, B. The role of participatory environmental monitoring committees in mining regions in Peru. *Geo-Resour. Environ. Eng.* **2017**, *2*, 176–181. [CrossRef]
16. CAO. *Participatory Water Monitoring: A Guide for Preventing and Managing Conflict*; CAO: Washington, DC, USA, 2008; Available online: http://www.cao-ombudsman.org/howwework/advisor/documents/watermoneng.pdf (accessed on 20 September 2018).
17. Kelly, R.; Fleming, A.; Pecl, G.; Richter, A.; Bonn, A.; Schiller, F.; Str, D. Social licence through citizen science: A tool for marine conservation. *bioRxiv* **2018**. [CrossRef]
18. Silvertown, J. A new dawn for citizen science. *Trends Ecol. Evol.* **2009**, *24*, 467–471. [CrossRef] [PubMed]
19. Burgess, H.K.; DeBey, L.B.; Froehlich, H.E.; Schmidt, N.; Theobald, E.J.; Ettinger, A.K.; HilleRisLambers, J.; Tewksbury, J.; Parrish, J.K. The science of citizen science: Exploring barriers to use as a primary research tool. *Biol. Conserv.* **2017**, *208*, 113–120. [CrossRef]
20. Kruger, L.E.; Shannon, M.A. Getting to know ourselves and our places through participation in civic social assessment. *Soc. Nat. Resour.* **2000**, *13*, 461–478. [CrossRef]
21. Farnham, D.J.; Gibson, R.A.; Hsueh, D.Y.; McGillis, W.R.; Culligan, P.J.; Zain, N.; Buchanan, R. Citizen science-based water quality monitoring: Constructing a large database to characterize the impacts of combined sewer overflow in New York City. *Sci. Total Environ.* **2017**, *580*, 168–177. [CrossRef] [PubMed]
22. Carr, A.J.L. Why do we all need community science? *Soc. Nat. Resour.* **2004**, *17*, 841–849. [CrossRef]
23. Conrad, C.C.; Hilchey, K.G. A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environ. Monit. Assess.* **2011**, *176*, 273–291. [CrossRef] [PubMed]
24. Danielsen, F.; Burgess, N.D.; Balmford, A. Monitoring matters: Examining the potential of locally-based approaches. *Biodivers. Conserv.* **2005**, *14*, 2507–2542. [CrossRef]
25. Gouveia, C.; Fonseca, A.; Câmara, A.; Ferreira, F. Promoting the use of environmental data collected by concerned citizens through information and communication technologies. *J. Environ. Manag.* **2004**, *71*, 135–154. [CrossRef] [PubMed]
26. Dickinson, J.L.; Zuckerberg, B.; Bonter, D.N. Citizen science as an ecological research tool: Challenges and benefits. *Annu. Rev. Ecol. Evol. Syst.* **2010**, *41*, 149–172. [CrossRef]
27. Fore, L.S.; Paulsen, K.; O'Laughlin, K. Assessing the performance of volunteers in monitoring streams. *Freshw. Biol.* **2001**, *46*, 109–123. [CrossRef]
28. Overduin, N.; Moore, M.L. Social license to operate: Not a proxy for accountability in water governance. *Geoforum* **2017**, *85*, 72–81. [CrossRef]
29. Leifsen, E.; Sánchez-Vázquez, L.; Reyes, M.G. Claiming prior consultation, monitoring environmental impact: counterwork by the use of formal instruments of participatory governance in Ecuador's emerging mining sector. *Third World Q.* **2017**, *38*, 1092–1109. [CrossRef]
30. Helwege, A. Challenges with resolving mining conflicts in Latin America. *Extr. Ind. Soc.* **2015**, *2*, 73–84. [CrossRef]
31. Danielsen, F.; Burgess, N.D.; Balmford, A.; Donald, P.F.; Funder, M.; Jones, J.P.G.; Alviola, P.; Balete, D.S.; Blomley, T.; Brashares, J.; et al. Local participation in natural resource monitoring: A characterization of approaches. *Conserv. Biol.* **2008**, *23*, 31–42. [CrossRef]
32. Turreira-García, N.; Lund, J.F.; Domínguez, P.; Carrillo-Anglés, E.; Brummer, M.C.; Duenn, P.; Reyes-García, V. What's in a name? Unpacking "participatory" environmental monitoring. *Ecol. Soc.* **2018**, *23*, 24. [CrossRef]
33. Fraser, J. From social risk to shared purpose: Reframing Mining's Approach to Corporate Social Responsibility. Ph.D. Thesis, University of British Columbia, Vancouver, BC, Canada, 2017.
34. Odell, C.J.; Scoble, M.; Bullard, J.R. Improving socio-environmental outcomes at Andean mines. *Int. J. Min. Reclam. Environ.* **2011**, *25*, 133–151. [CrossRef]

35. Adler Miserendino, R.; Bergquist, B.A.; Adler, S.E.; Guimarães, J.R.D.; Lees, P.S.J.; Niquen, W.; Velasquez-López, P.C.; Veiga, M.M. Challenges to measuring, monitoring andaddressing the cumulative impacts of artisanal and small-scale gold mining in Ecuador. *Resour. Policy* **2013**, *38*, 713–722. [CrossRef]
36. What's Wrong with Google Scholar for "Systematic" Reviews. Available online: https://etechlib.wordpress.com/2013/01/23/whats-wrong-with-google-scholar-for-systematic-reviews/ (accessed on 20 September 2018).
37. Mahood, Q.; Van Eerd, D.; Irvin, E. Searching for grey literature for systematic reviews: Challenges and benefits. *Res. Synth. Methods* **2014**, *5*, 221–234. [CrossRef]
38. Godin, K.; Stapleton, J.; Kirkpatrick, S.I.; Hanning, R.M.; Leatherdale, S.T. Applying systematic review search methods to the grey literature: A case study examining guidelines for school-based breakfast programs in Canada. *Syst. Rev.* **2015**, *4*, 138. [CrossRef] [PubMed]
39. Ottinger, G. Buckets of Resistance: Standards and the effectiveness of citizen science. *Sci. Technol. Hum. Values* **2010**, *35*, 244–270. [CrossRef]
40. Fraser, E.D.G.; Dougill, A.J.; Mabee, W.E.; Reed, M.; McAlpine, P. Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *J. Environ. Manag.* **2006**, *78*, 114–127. [CrossRef] [PubMed]
41. Gray, G.J.; Enzer, M.J.; Kusel, J. Understanding community-based forest ecosystem management: An editorial synthesis. *J. Sustain. For.* **2001**, *12*, 1–23. [CrossRef]
42. Ross, S.M. A feminist perspective on technical communicative action: exploring how alternative worlviews affect environmental remediation efforts. *Tech. Commun. Q.* **1994**, *3*, 325–342. [CrossRef]
43. Bridge, G. Contested terrain: Mining and the Environment. *Annu. Rev. Environ. Resour.* **2004**, *29*, 205–259. [CrossRef]
44. Ministry of Environment. *Ley General Del Ambiente*; Ministry of Environment: Lima, Peru, 2005. (In Spanish)
45. *Establecen Disposiciones Para La Prórroga Excepcional De Plazos Para El Cumplimiento De Proyectos Medioambientales Específicos Contemplados En Programas De Adecuación Ambiental*; Ministry of Energy and Mines: Lima, Peru, 2004. (In Spanish)
46. *Reglamento De Participación Ciudadana En El Sub Sector Minero*; Ministry of Energy and Mines: Lima, Peru, 2008. (In Spanish)
47. Danielsen, F.; Burgess, N.D.; Jensen, P.M.; Pirhofer-Walzl, K. Environmental monitoring: The scale and speed of implementation varies according to the degree of peoples involvement. *J. Appl. Ecol.* **2010**, *47*, 1166–1168. [CrossRef]
48. Ottinger, G. Constructing Empowerment through Interpretations of Environmental Surveillance Data. *Surveill. Soc.* **2010**, *8*, 221–234. [CrossRef]

© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).