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Geography 333
Research Report Rough Draft

Restoring the Mauri to Kopeopeo Canal: Integrating indigenous knowledge with bioremediation and the Mauri Model

Abstract

This study assesses the technique of bioremediation as a method of pentachlorophenol (PCP) and dioxin decontamination at the Kopeopeo Canal in Whakatane, New Zealand using the Mauri Model. The Mauri Model integrates indigenous knowledge with science to assess the mauri, or life force, of a contaminated site by identifying environmental, cultural, social, and economic indicators of mauri based on a point assessment system. The Mauri Model was used to assess the mauri of the Kopeopeo Canal before waste discharge (when the mauri was at its fullest potential), the present, and the hypothetical mauri of the canal immediately and 20 years after bioremediation. While the results of this study using the Mauri Model indicates that bioremediation alone is not sufficient to restore the mauri of the Kopeopeo Canal, bioremediation will still significantly improve the mauri of the canal when compared to present conditions. Additional methods (yet to be determined) will need to be employed to fully restore the mauri of the canal in conjunction with bioremediation. This study also demonstrates the power of the Mauri Model as an assessment tool for management and conservation solutions and the importance of utilizing methods from two different knowledge systems to create enhanced solutions in the face of decreasing natural resources and diminished ecosystems.

Introduction

As a species, *Homo sapiens* contaminate many natural sites and affect natural resources and ecosystems. It is not only critical to our survival as a species to adopt new conservation and management practices for these natural resources, but according to Maori worldview, it is also our role as kaitiaki (guardian) to responsibly conserve and manage these resources for every other species we share this Earth with. In New Zealand, there is a unique meeting of two cultures: Maori and European New Zealand. To address the issue of contaminated sites, a relatively new solution involves the integration of indigenous knowledge (Maori) with scientific knowledge (Western) to find a superior solution that encompasses both forms of knowledge (Hikuroa et. al., 2011). Morgan (2006) created the Mauri Model as an assessment tool for this purpose.

The Mauri Model is gaining popularity and credibility as an effective assessment and restoration tool in New Zealand. Dan Hikuroa, Angela Slade, and Darren Gravley (2010) used the Mauri Model to assess the effect on mauri at Te Kete Poutama following dumping by Tasman Pulp and Paper. They successfully assessed the impact on mauri and the findings provide a basis for the planning of physical restorative works. Furthermore, the Mauri Model allowed Hikuroa et. al. to

organize and present a plethora of multi-disciplined information in an understandable fashion to the trustees of the contaminated land so that the trustees could make an informed decision.

The Kopeopeo Canal is located outside the western boundary of Whakatane, New Zealand. It has been identified to have pentachlorophenol (PCP) and dioxin contamination at 36 different sites from contaminated storm water discharge from a timber mill. Dioxin is an associated contaminant of PCP and has numerous effects on human health in addition to ecological impacts to the environment (Lamar et. al., 2010). In the past, multiple Maori tribes used the canal for various cultural and economic functions. Following contamination from 1950-1989, these tribes have reduced or completely stopped their use of this site due to detrimental health effects.

Figure 1. Kopeopeo Canal (Godfrey and Clark, 2011).

Bioremediation has been proposed as a solution for decontaminating the canal. It uses natural processes to restore a contaminated to site to its original state. However, the residents near the canal have expressed that even if the canal is fully decontaminated, they will not consider the mauri, or the life force, of the canal restored. Bioremediation can be an effective decontamination tool, but it is not sufficient to restore the mauri of the canal. Thus, it is critical to utilize both indigenous knowledge and scientific knowledge to restore of the mauri of the Kopeopeo Canal using the Mauri Model.

The Mauri Model will assess the mauri of the canal using a numerical value system for multiple indicators of mauri. A “score” of the mauri of the canal will be given to the canal before contamination, the canal at present conditions, and the canal immediately following bioremediation as well as 20 years after initial bioremediation efforts. Using the Mauri Model to assess the efficacy of bioremediation will not only assess bioremediation as a decontamination tool, but by considering other factors that might be overlooked through a strictly scientific lense using the Mauri Model, the

restoration efforts of bioremediation will hopefully be enhanced and supplemented with other solutions to fully restore the mauri to the Kopeopeo Canal.

Background

Kopeopeo Canal & Contamination

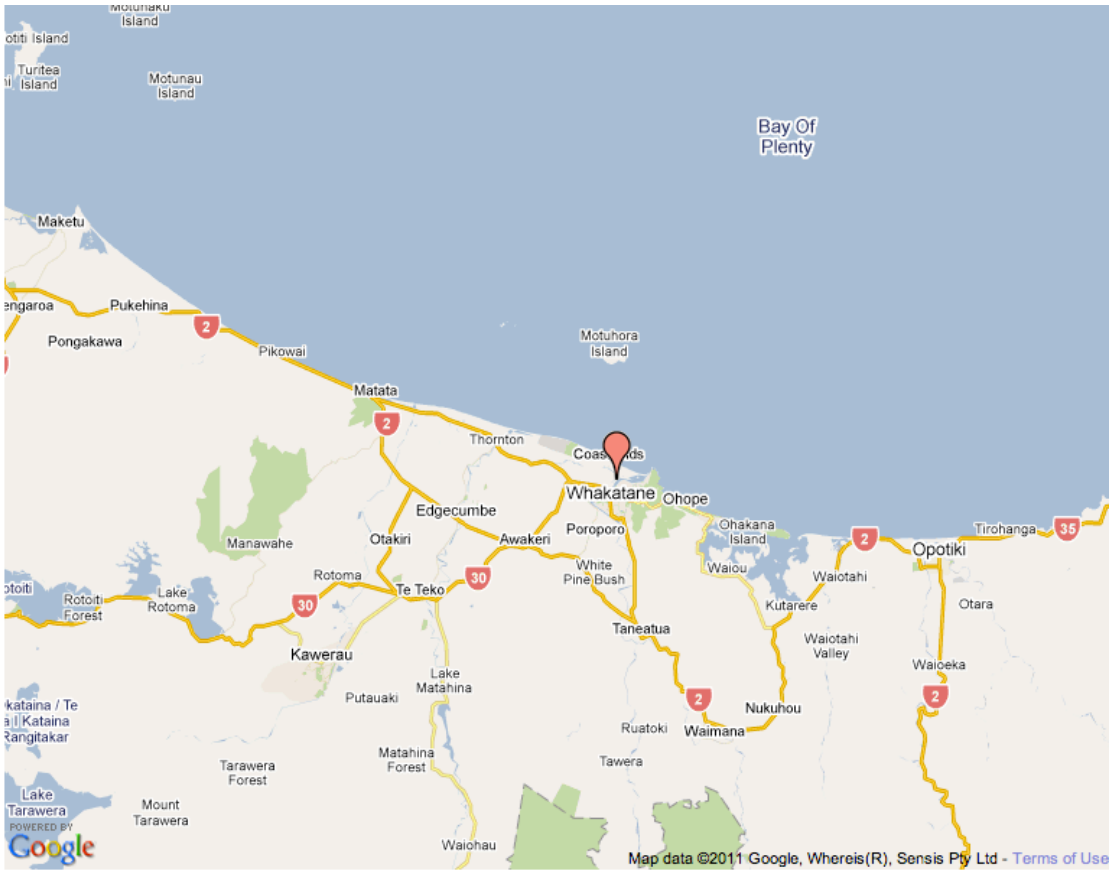

Figure 2. Map of Kopeopeo Canal (maps.google.co.nz)

The Kopeopeo Canal is located outside the western boundary of Whakatane, New Zealand. Between 1950 and 1989, the canal received discharges of surface run-off and storm water from the NZ Forest Products, Ltd., Pinex Saw and board mills. These discharges included pentachlorophenol (PCP), polychlorinated dibenzo dioxins (PCDDs) and polychlorinated dibenzo furans (PCDFs) in the wood preservative these companies used. The contaminants discharged at the canal have spread.

Sampling surveys were conducted by Gwilyn Environmental Services and Gulf Resource Management Ltd. to identify contaminated sites at the canal. It was concluded from these studies that contaminants at present levels posed minimal health risks given that suitable measures were taken to prevent spreading of the contaminants. Following recommendation for further studies, another study of the site was completed that involved the collection of water, sediment, and biota samples for PCP and dioxin analyses. This time, results from this study indicated elevated level of contaminants, prompting even further investigation of the canal that emphasized the effect of PCP

and dioxins on eels. It was concluded that there is an estimated 40,000 m^3 of highly contaminated sediment at the canal that require remediation. As of today, 36 sites in the Whakatane district have been confirmed to have PCP and dioxin contamination (Lamar et. al., 2010).

Contaminants (PCP & Dioxins) and Their Effects

PCP is a chlorinated aromatic hydrocarbon. Dioxin refers to the family of structurally and chemically related PCDDs and PCDFs. Dioxin is usually an associated contaminant of PCP. Dioxins, being fat soluble, tend to accumulate in higher mammals and humans, where they may persist for months or years. They may be transported over long distances because they have a natural resistance to degradation and are semi-volatile. In addition, their resistance allows dioxins to persist for many years and contribute to current day human exposure at the Kopeopeo Canal. Effects of high-level dioxin exposure are linked with chloracne, a skin disease marked by severe acne-like pimples (Lamar et. al., 2010). There are studies indicating that high-level dioxin exposure cause increased risk of cancer, reproductive and developmental problems, and an increased risk of heart disease (Brown, 2008).

Bioaccumulation refers to the accumulation of substances, including toxins, in an organism. Bioaccumulation occurs when an organism absorbs a toxic substance at a greater rate than which the substance is lost. Given that the Maori tribes near the canal consume some of the fauna from the canal, particularly eel, the contaminants pose a serious threat to their health as the effects of dioxins are greatly magnified through bioaccumulation.

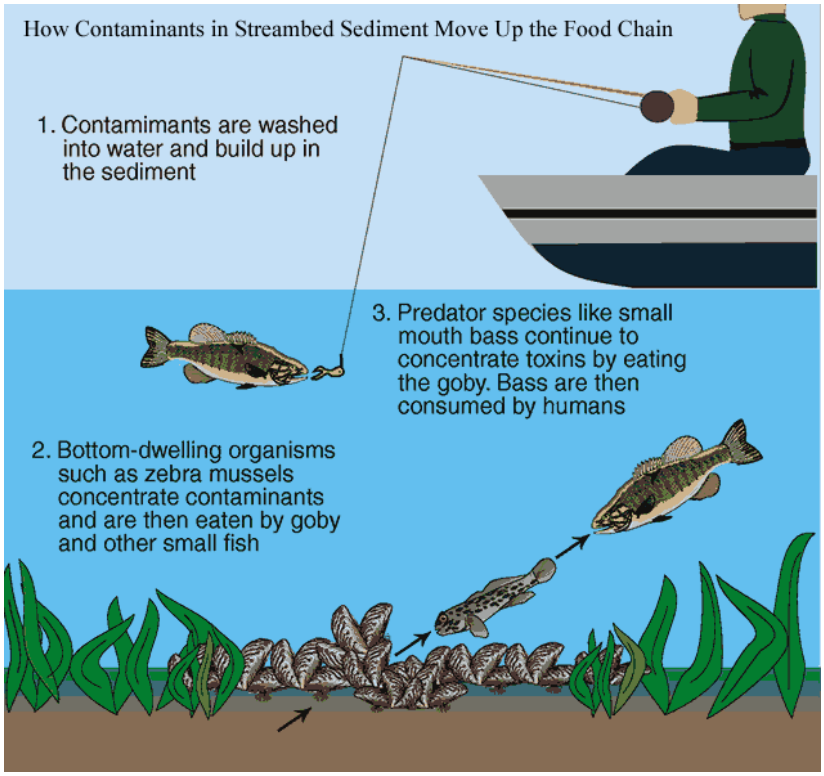

Figure 3. Bioaccumulation of Toxins (water.usgs.gov). The concentration of toxins is magnified further up the food chain. Toxin concentrations are greatest for organisms at the top of the food chain (e.g. humans fishing at the Kopeopeo Canal). Thus, the effects of toxins are also magnified further up the food chain.

Bioremediation

Bioremediation can be defined as any process that uses microorganisms or their enzymes to return the environment altered by contaminants to its original condition. Richard Lamar et. al. are conducting a bioremediation project that includes a fungal-based remediation (mycoremediation) and plant-based remediation (phytoremediation) at Kopeopeo Canal.

Mycoremediation is a process where hazardous organics are degraded or detoxified by fungi that are introduced to the contaminated soil. Lamar et. al. are using white-rot fungi (*Pleurotus pulmonarius* and *Trametes versicolor*) that use a lignin-degrading system that is responsible for pollutant degradation. These fungi are also good dioxin degraders. The contaminated soil from the canal is transplanted to a test site (also near Whakatane) where the fungus has to be carefully cultivated with ideal conditions for fungal growth.

Phytoremediation is the use of plants to remove, degrade, or render harmless environmental contaminants, usually in combination with other technologies. Some plants, like the poplar tree in this case, have the ability to accumulate high levels of some contaminants into their tissues, removing the contaminants from the soil. The poplar trees are currently being grown at the test site and Lamar et. al. are trying determine the best type of natural fertilizer to enhance the efficacy of phytoremediation.

Maori Worldview & Mauri

The western perception of “humans and nature” indicates the ideology that humans are separate and removed from nature. On the other hand, Maori worldview emphasizes “humans with nature,” which indicates that humans are a part of nature. The survival of humans is directly linked with the health of world and all its other inhabitants. Furthermore, the Maori have a sense of responsibility and guardianship (kaitiakitanga) for all living things.

Mauri is a Maori term that refers to the life force of an organism. It is “the binding force between the physical and spiritual” (Barlow, 1991). It is the “…land, forests, waters, and all the life they support, together with natural phenomena such as mist, win and rocks, possess mauri” (Marsden, 1992). The mauri of Kopeopeo canal was compromised because of the PCP/dioxin contamination.

Integrating indigenous knowledge with science

Most indigenous peoples use a traditional knowledge system to understand and interpret the environment around them. Their survival is directly contingent on the management and conservation of the environment around them. As such, the Maori have developed systems and strategies to ensure the conservation of resources for generations to come. As the natural resources and ecosystems on Earth are becoming more limited, the pressure to employ indigenous knowledge to find alternative management solutions is becoming recognized internationally (Hikuroa et. al., 2011).

Even if/when the contaminants are removed from Kopeopeo canal, the community living near the canal will not consider the mauri to be restored. It is important to recognize that removal of the contaminants does not mean the life force of the canal will be restored to the state it was in before the waste was discharged. There are aspects contributing to the mauri of the canal that will experience long-term effects from contamination and will not necessarily be repaired through bioremediation. Integrating indigenous knowledge with science through the Mauri Model allows the user to consider multiple aspects of the health of the study site and possibly a superior solution as to how to restore the site.

Mauri Model

The Mauri Model was created by Morgan (2006) to assess the impact of a certain event on the mauri of a specific site. The Mauri Model was created to improve water management processes by making them inclusive of all knowledge sources available (indigenous and science based). It is used as a decision-making tool that allows integration of seemingly unrelated pieces of information. It was constructed around kaitiakitanga (guardianship) principles and assesses the impact of mauri on environmental, cultural, social, and economic indicators (Hikuroa et. al. et. al., 2011).

Methods

Field Work and Data Collection

Main data collection was completed during field camp while in the Bay of Plenty, NZ. The bioremediation test site in Whakatane, NZ was visited first for one day. This was a basic introduction to the process of mycoremediation and phytoremediation. This was followed by a one day visit with Tracey Godfrey and Liliana Clarke in Whakatane, NZ for a presentation of the bioremediation project at the Kopeopeo Canal that outlined the objectives of their “Te Ohu Mo Papatuanuku” project, which emphasized their objective to integrate indigenous knowledge with bioremediation to enhance the success of bioremediation. Both visits occurred in February 2011. Presentations, papers, and general background were all successfully collected within these two

visits. Additional emails and phone calls with Godfrey and Clarke throughout the semester were utilized as necessary.

The data collected from Godfrey and Clarke were supplemented with additional presentations from Daniel Hikuroa throughout the course of the first semester at Auckland University (March – May 2011) about the Mauri Model as an assessment tool for restoring mauri to contaminated sites in New Zealand (not Kopeopeo Canal).

Data Assessment

The efficacy of bioremediation at the Kopeopeo Canal was assessed using the Mauri Model of Morgan (2006). A brainstorming session of environmental, cultural, social, and economic factors with Geog333 peers was completed to come up with indicators of mauri for the Kopeopeo Canal specifically. These factors were refined to a list of 20 factors (5 for each category). Additionally, some factors were modified from Hikuroa et. al. (2011) for the Kopeopeo Canal and included in the list of 20 factors. When formulating the indicators for the Mauri Model, it is important to have an equal number of indicators for each category so that each category is represented equally in the overall mauri of the site in question.

	Indicator
Environmental	Waste dumped on banks
	Waste dumped into canal
	Toxins in waste
	Native biodiversity in canal
	Native biodiversity on canal banks
Cultural	Mahinga kai (collecting food)
	Waahi tapu (sacred place)
	Rongoa (medicinal purposes)
	Kokowai (red ochre for pigmentation)
	Flora collection
Social	Swimming
	Health
	Fishing camps
	Gathering place
	Loss of respect
Economic	Cost of bioremediation
	Food costs
	De-valued adjacent land
	Research costs
	Loss of potential earnings

Table 1. List of indicators of the impacts of dumping waste in Kopeopeo Canal.

Environmental Indicators

- Waste dumped on banks – Waste was dumped on the surface of the banks of the canal.
- Waste dumped into canal – Waste was dumped into the canal.

- Toxins in waste – The primary toxins in the sawmill waste include pentachlorophenol (PCP), polychlorinated dibenzo dioxins (PCDDs), and polychlorinated dibenzo furans (PCDFs).
- Native biodiversity in canal – The presence of the waste and the toxins contained in the waste affect the native biodiversity of the flora and fauna in the canal.
- Native biodiversity on canal banks – The presence of the waste and the toxins contained in the waste affect the native biodiversity of the flora and fauna on the banks of the canal.

Cultural Indicators

- Mahinga kai – The collection of food at the canal (fish, eel) was affected. The effects of bioaccumulation make the food collected at the canal dangerous to consume.
- Waahi tapu – The canal was once used by multiple Maori tribes for food collection and as a gathering place.
- Rongoa – The flora by the canal used for rongoa/medicinal purposes were affected by the waste.
- Kokowai – Waste contamination affected the various sources of pigment the Maori used.
- Flora collection – The abundance and diversity of the flora that was used for various cultural purposes were diminished due to the waste.

Social Indicators

- Swimming – It is no longer safe to swim in the canal.
- Health – PCP and dioxins have a number of effects on human health.
- Fishing camps – Families once spent time at the canal collecting fish and eel.
- Gathering place – Kopeopeo canal was once used as a meeting place for the Maori. Following contamination, it is unsafe to gather here.
- Loss of respect – The Maori used to be able to harvest eels at the canal. Loss of eels results in the loss of respect for the tribe.

Economic Indicators

- Cost of bioremediation – The cost of implementing bioremediation at the canal, including cultivating the fungus and planting of trees.
- Food costs – The loss of the food sources supplied by the canal means residents must spend more money on food acquired elsewhere (i.e. market).
- De-valued adjacent land – Dioxins are high resistant contaminants that are able to spread and pollute adjacent lands.

- Research costs – The cost of researching the effects of the contaminants as well as the effects of bioremediation.
- Loss of potential earnings – This indicator leaves room for the potential earnings the land may have produced for its inhabitants from a wide range of sources if it was not contaminated.

The Mauri Model was then used to assess the mauri of the canal for each indicator at multiple points in time (pre-dumping, present, immediately following bioremediation, and 20 years after bioremediation). A numerical value was given for each indicator. If the mauri is at its fullest potential for the particular indicator, it was given a score of +2. If mauri is enhanced or somewhat restored, it was given a score of +1. When no change to mauri occurs, the indicator was given a score of 0. If the mauri for an indicator is diminished, it is given a score of -1. When the mauri for an indicator is fully denigrated, it was assigned a score of -2. The average mauri "score" was found for each point in time being assessed to give the overall mauri "score."

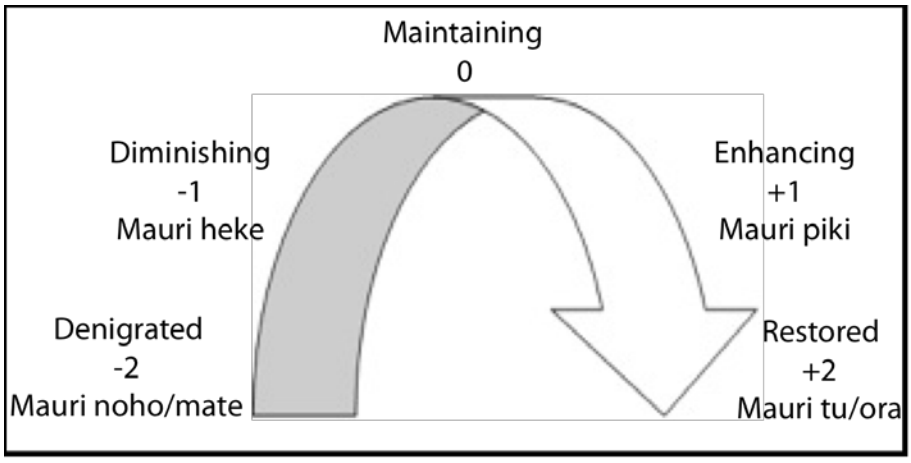

Figure 4. A graphical representation of the mauri assessment (Hikuroa et. al., 2011). The impact to mauri for each indicator is assessed on a integer scale of -2 to +2. +2 indicates that the mauri is at its full potential or is fully restored; +1, mauri is at partial potential or is partially restored; 0, no change on mauri; -1, partial degradation of mauri; and -2, complete degradation of mauri.

Results

	Indicator	Pre-dumping	Present	Post Bioremediation	
				Immediately Following	After 20 years
Environmental	Waste dumped on banks	2	-1	1	2
	Waste dumped into canal	2	-1	1	2
	Toxins in waste	2	-2	1	2
	Native biodiversity in canal	2	-1	1	2
	Native biodiversity on canal banks	2	-1	1	2

Cultural	Mahinga kai	2	-2	1	2
	Waahi tapu	2	-1	1	2
	Rongoa	2	-1	1	2
	Kokowai	2	-2	1	2
	Flora collection	2	-1	1	2
Social	Swimming	2	-2	1	2
	Health	2	-2	1	1
	Fishing camps	2	-1	1	2
	Gathering place	2	-2	1	2
	Loss of respect	2	-1	1	2
Economic	Cost of bioremediation	2	-1	-1	1
	Food costs	2	-1	-1	1
	De-valued adjacent land	2	-1	1	2
	Research costs	2	-1	1	2
	Loss of potential earnings	2	-1	1	2
	Mauri Assessment	**2**	**-1.3**	**0.80**	**1.85**

Figure 5. Mauri Model for the Kopeopeo Canal. Bioremediation will partially restore the mauri of the Kopeopeo Canal immediately following initial bioremediation efforts, with greater mauri restoration long term. However, the mauri of Kopeopeo Canal will not be fully restored to its pre-dumping condition even after 20 years following bioremediation.

Discussion

The mauri of the Kopeopeo Canal was at its fullest potential prior to the waste discharge, as expected. Presently, the mauri of the canal is greatly reduced and all aspects of the canal have been diminished as a result of the waste. Bioremediation will only partially restore the mauri immediately following initial efforts. However, even 20 years after initial bioremediation efforts will not result in complete mauri restoration. As dioxin has long-term effects on human health, the health indicator will not be returned to a 2. Along the same lines, food costs will not be fully restored as the biota of the canal will still be affected long-term. Additionally, the cost of bioremediation is not yet cost-effective and would need to be continually maintained. The results of this project demonstrate that bioremediation is a viable solution to restoring the mauri to the canal even if not completely. Additional methods need to be employed to fully restore the mauri.

Future studies regarding the Kopeopeo Canal are necessary. This includes further research to make bioremediation a more cost-effective and efficient process. In addition, supplemental solutions addressing the few mauri indicators that long-term bioremediation will not restore can be researched. Alternatively, the Mauri Model can be used to assess other potential solution paths and then the results can then be compared to choose the most effective solution (Hikuroa et. al., 2010). Lastly, it is critical to remember that the Mauri Model created for the Kopeopeo Canal in this project is subject to differing opinion. The indicators themselves and the numbers given to each

indicator are open for critique and improvement, especially from the residents that live near the canal as the results of this study affect them the most.

The Mauri Model is an effective tool to create solutions for contaminated sites. By measuring the mauri of the site instead of whether or not is still contaminated, a deeper and more thorough assessment regarding the health of the site is achieved. The Mauri Model demonstrates the benefit of incorporating knowledge systems from two disciplines to create a superior solution to the ever-increasing demands of resource management and conservation.

Conclusion

Using bioremediation as a method of restoring the mauri of the Kopeopeo Canal was assessed using the Mauri Model, which utilizes both indigenous, traditional knowledge with science based knowledge. The results from this project demonstrate the necessity of incorporating indigenous knowledge with science-based knowledge to create a superior, all encompassing solution to our modern problems with contaminated sites. Either alone is not sufficient for tackling the challenges our world faces in regards to managing and conserving our resources and ecosystems. Traditional knowledge considers important factors otherwise overlooked by science, which has become the dominant global knowledge system. The Mauri Model is a power tool to assess proposed solutions for contaminated sites and the mauri of the site. As for the Kopeopeo Canal itself, bioremediation alone is not sufficient to restore the mauri of the canal to its full potential. Further studies about bioremediation and alternative solutions addressing the contamination at the canal are necessary.

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