Giant River Otter Conservation on the Amazon River

ENVS 193CP: Conservation Planning

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Executive Summary

The Amazon River is the second largest river in the world, and is home to many unique aquatic species, including the giant river otter. The giant river otter is the largest living river otter in the world, and it plays a key role in its ecosystem. However, populations of the giant river otter are declining due to a number of anthropogenic threats, including deforestation, mining, disease, and urbanization. This conservation plan seeks to address these issues by implementing proper management and enforcement in order to increase giant otter populations throughout the Amazon River region.

The success of this plan is dependent on the planning team and the decision makers that we will consult with. The planning team for this project consists of the local indigenous groups, such as the Yanomamo group, the team of experts at the Giant Otter Project, Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), and the United Nations Environmental Programme (UNEP). Additionally, there are multiple stakeholders engaged in sharing their expertise in the development of this plan.

There are seven fundamental objectives that we hope to achieve through the implementation of this plan. The environmental objectives outlined in this plan are to increase giant river otter populations, increase gene flow between populations, decrease industrial and agricultural degradation surrounding the river, and increase the protection of giant otter habitats. The economic objectives are to increase job opportunities for local people and increase well managed ecotourism in the area. Socially, stakeholders also value increasing local education on the importance of giant river otters and their ecosystem. Our target is to increase otter populations by 40% in 10 years, and targets for the other objectives were established spanning the 10-year time frame of this project as measured by objective-specific indicators.

Fifteen potential strategies were developed and assessed as to how well they could achieve the fundamental objectives, and the most feasible options were selected. These strategies include establishing protected areas and corridors for giant otter habitat in the Amazon region, introducing guidelines for the management of ecotourism in local communities, and promoting education and outreach about the giant river otter. The combination of these approaches effectively addresses every fundamental objective, making them the best options for conserving the giant river otter.

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Planning Context

Introduction & Rationale

The giant otter, or *Pteronura brasiliensis*, is endemic to South America and is distributed throughout the Orinoco, Amazon and La Plata River basins (Carter & Rosas, 2008). The focus of this project will be in the Amazon basin, as shown outlined in red in ***Figure 1***, This region is characterized by its rich biodiversity, lush, tropical rainforest, and for having the second longest river in the world: the Amazon River. The giant otter plays an important role in this river ecosystem by serving as one of the few apex predators. However, it has been driven out of many of the freshwater rivers and streams that it historically inhabited throughout South America (Carter & Rosas, 2008), and now there are few viable populations that exist outside the Pantanal and Amazonian regions (Tomas et al., 2015). Though the exact extent of their current distribution is unknown, it is undeniable that their range has shrunk considerably within the last century (Duplaix et al., 2015). This decrease in range is a result of habitat destruction and degradation, which is threatening the otter populations.

Giant river otters are classified as endangered on the IUCN Red List (2008) and have been included in Appendix I of the Convention on International Trade of Endangered Species since 1973 (Wildlife Conservation Society Peru, 2019). Otter populations began their sharp decline due to poaching and the fur trade, but numbers began to slowly recover when the fur trade was banned (Barocas, n.d.). Currently otters are facing other threats including logging, residential and agricultural expansion, and mining, which are all contributing to the destruction of otter habitats and the decline of their populations. Though giant otters spend most of their lives in the water, they are also impacted by what occurs outside the river. Otters go ashore to give birth, and the functionality of the ecosystems surrounding the river can have an impact on the health of otter populations.

This plan seeks to address the anthropogenic threats—including logging, mining, poaching, and habitat destruction—that are impacting the populations of giant river otters in the Amazon River region. These threats have negatively affected the health and well-being of the otters, driving them to near extinction in the 1970's (Duplaix & Savage,

2018). With proper management and planning practices, the impacts of threats can be mitigated, and populations of giant otters can begin to increase again.

Figure 1. Map of the Amazon River flowing through Brazil, Peru, and Ecuador. (Source: Contos & Tripcevich, 2014)

Planning Team and Management Process

Decision Makers and Target Audience

The primary decision makers and target audience of this project will be various agencies from the Brazilian government and the Amazon River Basin. For funding, legislation, and enforcement of the proposed policies, the Brazilian government, specifically their environmental agency, will be the main decision maker. They have the power and funds to approve and implement conservation plans such as this one. The

Brazilian Institute of the Environment and Renewable Natural Resources is the Brazilian Ministry of the Environment's way of implementing and enforcing policies, which will ensure that the strategies outlined in this plan are carried out.

Since the Amazon River Basin spans multiple countries, UNEP, or the United Nations Environmental Programme, will be the primary decision maker for the areas that fall outside of the Brazilian Ministry's jurisdiction. They have already managed other projects in the area, and can provide funding and the necessary enforcement for the project. They aim to conserve biodiversity and "protect and restore ecosystems and the goods and services they provide" (UNEP, n.d.), making their organization a great choice for assisting with this plan.

The researchers and staff at the Giant Otter Project, discussed below in ***Table 1***, will also be important advisors to both agencies. They have extensive knowledge and experience working with the giant otter and have many systems already in place for doing so. Though they will not necessarily be primary decision makers, they will be integral in advising and consulting and are therefore considered an important decision maker in this project.

Planning Team

Table 1 below represents the planning team for this project that will serve as advisors and decision makers for Giant Otter Conservation. This planning team is made up of experts and organizations that can provide the thorough and essential knowledge for carrying out a successful conservation plan for Giant Otters. The goal is to have a diverse team with different backgrounds to ensure the necessary skills and voices are represented in this plan.

Member	Organization	Skillset	Role
Biologists / Otter Experts	Giant Otter Project - Caroline Leuchtenberger	- Founder of Giant Otter Project - Focal species of her doctorate - Coordinator of IUCN otter expert group	- Provide insights for how past projects have gone - Expert on otter behavior and habitat - Access to and knowledge of previous conservation plans
Indigenous Group(s)	Yanomamo Group	- Extensive knowledge of river and rainforest - Cultural knowledge	- Cultural expertise - Local outreach
Local and National Brazilian government	Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA)	- Experience in environmental policing - Funding for enforcement - Knowledge of permits and legislation	- Enforce policy - Ensure compliance - Provide knowledge on feasible action - Approve permits
Non-profit Group(s)	United Nations Environmental Programme (UNEP)	- Supported by UN - Access to funding - Public outreach	- Provide volunteers - Provide funding - Access to governments and communities

Table 1. Members of the planning team for the conservation plan.

Stakeholders

The stakeholders outlined in ***Table 2*** below are groups that will be impacted by giant otter conservation or that are interested or concerned with the conservation plan. They will provide insight and ideas to the planning team. The stakeholders are integral members of the community and their livelihoods are important to the success of this project. The stakeholders' input and understanding of the plan is not only beneficial to them but for the planning team as well. Thus, stakeholder input will be considered throughout the process of planning and implementation of the conservation plan.

Member	Organization(s)	Skillset	Role
Miners / Mining Corporations	- Vale - Anglo American - Rio Tinto	- Knowledge of where valuable minerals are - Supports global economy	- Compliance to regulations and policies
Logging Companies	- Wilmar International Ltd. - JBS - Cargill	- Access roads already built - Supports local and global economy	- Compliance to policies - Use of infrastructure already in place
Indigenous groups and local villages	- Yanomamo Group - Local Villages	- Cultural knowledge - Knowledge of local ecosystem	- Ensure that project is not disturbing local people and their livelihoods - Provide insight on cultural practices
Tourists	- River tours - River cruises	- Supports local economy - Promote eco-tourism	- Compliance to policies - Educate tourists on otter conservation
Oil Companies	- Andes Petroleum - GeoPark - Frontera Energy	- Supports global economy	- Compliance to policies
Non-profit Groups	- WWF - IUCN - Giant Otter Project	- Experience conserving endangered wildlife - Public outreach	- Funding and outreach - Conduct research and provide technology for tracking populations

Table 2. Stakeholders of the conservation plan.

Decisions, Opportunities, Sideboards, and Constraints

A potential constraint for this project could be difficulty in creating policies that can be authorized and agreed upon by multiple countries. Though most of this plan focuses on the Amazon River in Brazil, the river still spans multiple countries, so enforcing some of the actions outlined in this project may be difficult in areas that fall outside of the jurisdiction of IBAMA. Including UNEP in this plan will hopefully aid in resolving these issues, but some countries may be less willing to adopt this plan or work with UNEP to enforce and apply these policies.

Since information on policies within the Amazon is limited and certain areas are remote and difficult to access, enforcing policies can prove to be difficult. Illegal mining has become a prevalent issue in the region, and though IBAMA and the Brazilian Federal Police have been actively involved in stopping these operations, it is difficult to enforce policies and make arrests in the region (Gonzaga, 2021). Enforcement may be difficult and complex, but policing and implementation of this plan is possible with the involvement of multiple organizations and stakeholders.

Another potential constraint may be resistance from the oil, mining, and logging companies in working with and complying with this plan. This conservation plan will force them to alter how they conduct their operations in the area. Having these companies comply with the plan, however, is crucial to the success of the plan as some of their actions are causing direct threats to the giant otter.

Situation Analysis

The main environmental target in the conservation plan is the giant otter species along the Amazon River in Brazil, whose populations are predicted to decline 50% in the next 25 years (Duplaix & Savage, 2018). At the same time, the human well-being target involves the livelihoods of those involved in the fishing, farming, tourism, mining, logging, and oil industries, along with local communities, whose reliance on the ecosystem services and resources of the Amazon affect giant otters greatly. The visual situation analysis depicted above in ***Figure 2*** demonstrates the direct threats to the giant otter. Contributing factors and applicable conservation strategies are also shown. Conservation strategies are discussed in more depth beginning on page 18 of this document.

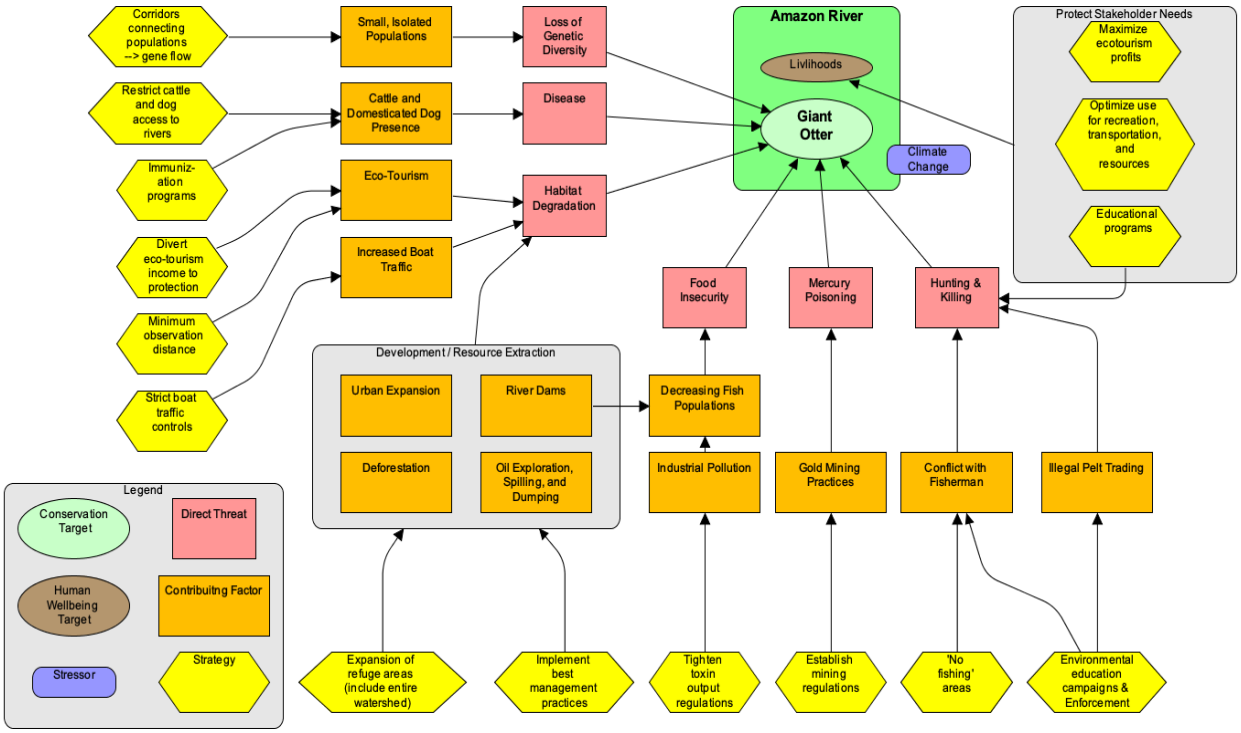

Figure 2. A situation analysis depicting the conservation target—giant otters along the Amazon River—and the livelihoods of stakeholders. Red squares represent the direct threats to otters, orange rectangles represent the contributing factors, and yellow hexagons represent proposed conservation strategies for these threats. (Designed using Miradi.)

Direct and Indirect Threats

One of the largest direct threats to the remaining populations of giant otters in the Amazon is habitat degradation. Giant otter habitat is becoming increasingly contaminated and damaged by human activities including the exploitation of timber, minerals, fossil fuels, hydroelectric power, and fisheries (Carter & Rosas, 2008). The expansion of cattle grazing and soybean production are driving forces of logging in the Amazon (Duplaix et al. 2015). As seen in ***Figure 3***, logging is often concentrated around riverbanks for convenient transportation of logs. This is a major disturbance that deteriorates the riparian habitat in which giant otters reside in and can impair a population's success in breeding (Uscamaita et al. 2010).

Figure 3. Logging concentrated near a meander in the Amazon River in Brazil. (Source: Spring, 2021)

The exploitation of oil resources is also a factor in this habitat degradation. While oil is being extracted in the Amazon Basin, ten thousand gallons of oil are spilled every week and over 4.3 million gallons of untreated toxic waste is dumped into the watershed daily, reducing water quality. In addition to these effects from the logging and oil industries, the roads being built to gain access to these resources contributes to destruction of the habitat and allows for more human encroachment. When large areas around extraction sites become available for hunters and settlers, they become less suitable for the giant otters (Carter & Rosas, 2008).

While human settlement and access are spreading in the Amazon, the giant otters are also threatened by diseases from cattle and domestic dogs (Duplaix et al. 2015), encroachment by increasing boat traffic (Tomas et al. 2015) and ecotourism (Duplaix et al. 2015), mercury poisoning from gold mining methods (Carter & Rosas, 2008), and loss of genetic diversity due to breeding in small isolated populations (Pickles et al. 2011).

Another threat giant otters face is food insecurity due to decreased fish populations. The fish that giant otters rely on for sustenance are affected by industrial pollution, and their migration patterns are blocked by the construction of hydroelectric

dams (Carter & Rosas, 2008). These dams also have various other consequences in the environment by drastically altering the hydrological cycle and flood regime (Duplaix & Savage, 2018). Dams are a major concern for the survival of giant otter populations because they have depleted their populations in the past. There are 184 new dams under construction or planned in the next two decades in the Amazon which will exacerbate major habitat fragmentation for giant otter populations (Duplaix & Savage, 2018).

Finally, global climate change is a stressor on the giant otter species because drought is predicted to become more severe and result in changing and shifting habitats. While it is something to keep in mind in all conservation strategies, this global stressor is beyond the scope of this conservation plan.

From this analysis, it is evident that human activities of various kinds are posing major threats to the giant otter species in the Amazon Basin. If development, encroachment, resource extraction, and pollution activities continue their course, habitable areas for giant otters will continue to dwindle and the survival of the species will become severely threatened.

Project Scope

This conservation plan focuses on the Amazon River in South America, as shown in ***Figure 1***. This region is one of the most biodiverse areas on the planet, with the second largest river in the world flowing through lush, species-rich rainforest. The Amazon River spans over 4,000 miles in length and is one of the last remaining regions that the giant otter species deems as suitable habitat. Though the majority of otter populations are located on the western stretch of the Amazon River, giant otter populations located downstream are impacted by upstream activities just as much. Therefore, this plan focuses on the Amazon River as a whole. The entire river system is susceptible to the impacts of humans and climate change, both of which are exacerbating many of the already present issues that the region is facing.

The World Land Trust estimates that currently only between 1,000 and 5,000 giant otters remain in the wild. Captive breeding programs have seen slight success but are unreliable, as female otters are highly sensitive to human presence and can stop lactating if under high levels of stress (Pickles et al., 2011). ***Figure 4*** below shows an estimate of

the past and current distribution range of where giant otter populations reside. It demonstrates that giant otters have lost almost 50% of their historical range, and that the surveyed current populations are patchily distributed in the region.

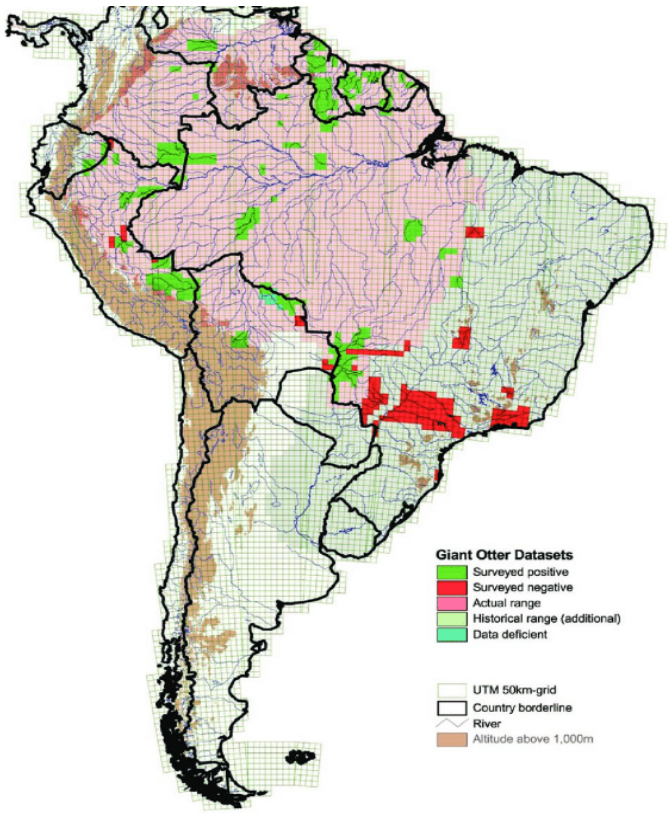

Figure 4. Geographic distribution of giant otter populations. The pink area represents their current range, the light-green area represents their historical range, and the dark-green patches represent where populations are present. (Source: Groenendijk et al., 2005)

The primary desired outcome of this conservation plan is to recover wild giant otter populations and restore suitable habitat along the Amazon River. The proposed time frame of this project will extend a 10-year period with an evaluation of progress at 5 years after its approval. At the evaluation point, the proposed targets will be reassessed and adjusted if needed. The success of this plan is dependent on the cooperation and implementation by the decision makers and planning team as well as the stakeholders. The plan will be evaluated and adjusted based on the input of the current team, and any additional stakeholders that may arise throughout the implementation of the plan.

Fundamental Objectives and Desired Outcomes

Giant River Otters on the Amazon River	Fundamental Objective	Features	Indicators (natural, proxy, or constructed)	Targets
	"What" & Direction	*"What" can be measured*	*How will "what" be measured*	*Goal/time*
Environmental - Biodiversity	Increase giant otter population	Number of giant otters Number of giant otter dens	Count number of giant otter dens along riverbanks *(natural)*	Increase giant otter population by 40% in 10 years
	Increase gene flow among giant otter populations	Connectivity of rivers that giant otters live on in the Amazon River	Count the number of corridors that connect rivers together *(natural)*	10 previously-degraded river corridors will be re-established and maintained by year 2 of the project
Environmental - Ecological Processes	Decrease industrial and agricultural activities around riverbank areas	Level of pollution in water Mining & logging frequency Urban development activities	Amount of disposed or leaked effluent into the environment *(proxy)* Counting number of unauthorized (not management/tourism- related) roads/cars going in and out of conservation region *(proxy)* Heatmaps *(proxy)*	Eliminate any and all industrial activities within conservation region by year 7 of the project
Environmental - Ecosystem	Increase protection of	Protected habitat	River km of giant otter habitat protected *(natural)*	Have 1000 km of the Amazon River protected for giant otter

	giant otter habitat	Giant otter presence		habitat by year 5 of the project, 2500 km by year 10
Economic	Increase local job opportunities for villagers	Number of villagers employed with the conservation team	Count number of villagers employed as guides/habitat management workers *(natural)*	Increase employment of villagers/locals within 3 years by 20%
	Increase in well-managed ecotourism	Number of tourists	Number of hotels rooms booked *(proxy)*	Increase number of hotel rooms booked by 10% in 3 years
Social	Increase local education on the importance of giant otters in the ecosystem	Knowledge and understanding of the ecology of giant otters	Knowledge index *(constructed)*	Have the Knowledge Index improve by 75% in 2 years

Table 3. Fundamental objectives, features, indicators, & targets for giant otter conservation.

Our project's fundamental objectives are presented above in ***Table 3*** and reflect the primary goals that this project ultimately aims to achieve. Emphasis on working with stakeholders is important for putting this project into motion and to ensure long-term success. Finding out how stakeholders are affected from the project plan and translating those sentiments into statements is how the planning team arrived at these fundamental objectives. The values and perspectives that stakeholders hold are imperative towards the project's goals and were carefully taken into consideration when devising the project's objectives.

In ***Table 3***, "Features" describes what aspects of the fundamental objectives can be measured. "Indicators" describes how these features will be measured to assess progress

and can be classified under three scales: natural, proxy, or constructed. Natural indicators are objective measurements that measure the level of success of a feature; proxy indicators measure feature progress by measuring a factor that indirectly gives an estimate of change in the feature; and constructed indicators are generally indefinite scales that represent a range from low to high. "Targets" states the goals for each fundamental objective. The fundamental objectives strive to improve giant otter populations and their habitat in tandem with bringing benefits to three classes of objectives: environmental (biodiversity, ecological processes, ecosystem), economic, and social. The different categories of ***Table 3*** are discussed in more depth below:

Fundamental Objectives: Environmental

Environmental objectives aim to represent the diverse aspects of nature in the project's planning. Fundamental objectives concerned with improving the environment can be divided into three sub-categories: biodiversity, ecological processes, and ecosystem.

Biodiversity

Increasing the population of giant otters on the Amazon River is paramount to this project. Giant otters are one of the few apex predators in their ecosystem and therefore bear a sizable responsibility for acting as regulators. If a dominant species lower in trophic level remains in occupation of several ecosystem niches, a potential pathogen or threat that sweeps through and eliminates this species can lead to disruption and degradation of the system. Increasing giant otter presence will inadvertently increase the biodiversity of the system by keeping certain species in check and allowing others to fill in niches that would otherwise be occupied by a single dominant species.

The second fundamental objective aimed to improve environmental biodiversity is to increase the geographic distribution of genetic variation in giant otter populations on the Amazon River. Giant otter populations are recovering in parts of their range, but the species remains patchily distributed and it is unlikely that gene flow is currently occurring among the populations (Pickles et al. 2011). Habitat for giant otters is limited and sparse, namely due to degradation and pollution, which leads to a smaller gene pool. Restoring habitat and connectivity between giant otter populations will diversify their gene pool and

increase resilience among populations. Improving river connectivity will also allow giant otters to perform giant otter functions—acting as system regulators and maintaining the biodiversity of their systems.

Ecological Processes

In order to improve habitat of giant otters, industrial and agricultural activities around riverbanks need to be decreased and eventually eliminated. Anthropogenic activities like urban development, mining, and logging introduce changes in the flow, turbidity, and contamination level of the Amazon River's water. Halting activities around riverbanks will support the livelihoods of not only giant otter populations, but the myriad of other forest and aquatic species that use it.

Ecosystem

The last environmental objective is expanding the protection of giant otter habitat. Giant otters build dens along the banks of the Amazon River, with the location being dependent on both the availability of food and spatial structure of the area (Pickles et al. 2011). Aiming to conserve kilometers of the river for giant otter habitat will not only encourage resurgences in their populations; habitat protection will also promote the return of other species that use the river. In addition to providing benefits to water qualities, a protected riverbank area will bring stabilization to the banks through the prevention and reduction of erosion.

Fundamental Objectives: Economic

Economic objectives aim to promote the profitable activities that can take place within a conservation plan's targeted zone. One fundamental objective is to increase the local job opportunities for villagers that are in the conservation region by opening positions to be a part of the giant otter conservation and management team. This will provide an optional source of income for villagers and can stimulate the economies of local municipalities.

Another economic objective is to increase the scale of well-managed ecotourism in the region. Giant otters are a highly sensitive species—especially reproductive females—and poorly-managed, uncontrolled ecotourism can disturb their populations, forcing them

to relocate (Schenck & Staib 1992). Irresponsible ecotourism leads to alteration of the natural landscape and unnecessary expansion of tourism-related lodging infrastructure. Well-organized ecotourism led by educated guides can provide a source of revenue for parties within the conservation region and parties outside of the region in local municipalities.

Fundamental Objectives: Social

Our social fundamental objective is to increase education on the importance of giant otters to the Amazon River ecosystem. Giant otters have and are still blamed by fishers for competing with their fish stock, chasing fish populations away, and damaging fishing equipment. This has led to a lasting conflict between giant otter populations and local fishers. An analysis by Rosas-Ribeiro et al. (2012) found that there are few similarities in the diets of humans and giant otters, there is a small overlap in the fish species consumed by giant otters and those that are exploited by commercial fisheries, and that giant otter presence does not significantly reduce captures. Giant otter presence can bring benefits to humans because they are more likely to prey on fish that are weaker and hosts of parasites and/or other pathological issues. They are also indicators of adequate water quality and a healthy, stabilized ecosystem. In addition to understanding the social benefit that giant otters bring in the form of safer food, increasing education will also allow locals to recognize the ecological role that other species play in the wider ecosystem. This objective may aid in lessening the frequency of giant otter killings by locals.

Conservation Features

As mentioned before, the features, indicators, and targets that follow each fundamental objective in ***Table 3*** represent how this conservation plan seeks to achieve said objectives. Features describe what aspects of a fundamental objective can be measured, indicators describe in what way these features can be measured to estimate progress, and targets are goals that are sought to achieve in a timely manner for each fundamental objective. These conservation features function as ways to gauge the level of accomplishment of the objectives. Conservation features are discussed in more detail below.

Features, Indicators, and Targets for Environmental Objectives

The measurable features for the first environmental biodiversity objectives of increasing giant otter populations are the number of giant otters and giant otter dens. The manual counting of the number of giant otters and giant otter dens is a natural indicator of whether this objective is being fulfilled or not. It is likely impossible to count every individual and den in the region. Using data from a combination of trap cameras, drone footage, and regular monitoring, estimates can be inferred. The desired target for this objective is to increase the giant otter population on the Amazon River by at least 40% in 10 years.

Our second environmental biodiversity objective is increasing the gene flow among giant otter populations. The feature that will be measured is the connectivity of smaller rivers in the larger Amazon River. Some giant otter populations have become isolated and fragmented due to the diminishing number of inter-drainage connection routes on the Amazon River (Duplaix et al. 2015). Gene pools in these populations may shrink to a point where the population becomes vulnerable to a single pathogen. The target is therefore to re-establish and maintain 10 previously degraded river corridors by year 2 of the project to encourage the geographic distribution of genes. Counting the number of connected river corridors will be a natural indicator of river connectivity.

Our environmental objective related to ecological processes will use the level of water pollution, frequency of nearby mining and logging, and amount of urban development activity as features to measure. The amount of disposed or leaked effluent from industrial activities into the environment will be a proxy indicator of water pollution; counting the number of unauthorized vehicles and unrecognized roads entering and leaving the region will be a proxy indicator of mining and logging frequency; and heatmaps can be used as a proxy indicator for the level of urban development activity in the region. Elimination of industrial activity in the conservation region by year 7 of the project is the goal to improve the conditions of habitat space for giant otters.

The final environmental objective is ecosystem-related and is to increase giant otter habitat protection. To measure the protection of habitat, the features are the number of active dens and the level of giant otter presence. More active dens and presence suggests that the objective is being met, and the kilometers of river habitat being protected can be

a natural indicator of how many active dens and giant otters can be spotted. The target is to have 1000 km of the Amazon River protected for giant otter habitat by year 5 of the project, and have 2500 km protected by year 10 of the project.

Features, Indicators, and Targets for Economic Objectives

The measurable features of the first economic objective of increasing local job opportunities is the number of villagers employed with the conservation team. A natural indicator of this is by simply counting the number of villagers that are employed with the team as guides or a part of the habitat management crew. The goal is to increase the level of employment of villagers and locals by 20% within 3 years of the project's start. This provides a source of income that locals may spend in local municipalities.

Our second economic objective is to increase well-managed tourism in the conservation region. Estimating the number of tourists is the measurable feature here. Observing the exact degree of how well ecotourism is doing may be approximated by using the number of local hotel rooms booked as a proxy indicator. The target with ecotourism is to increase the number of hotel rooms booked by 10% within 3 years of the conservation project's start, which will bring revenue to the local economy.

Features, Indicators, and Targets for Social Objectives

Our social objective is to increase local education on the importance of giant otters to the ecosystem. Local knowledge of giant otters in relation to the ecosystem is the feature that will be used to obtain an idea of the level of understanding. A knowledge index will be used as a constructed indicator for how informed locals are on this species, with a higher number meaning a better understanding. The target for this objective is to have the average number in the knowledge index improve by 75% in 2 years. This will reduce misconceptions that locals may have on giant otters and hopefully lead to fewer killings.

Range of Strategies

No action

Performing no action to address the threats affecting giant otters will likely cause their population to continue to decline (Groenendijk et al. 2020). Although some populations of the species have increased over the last decades, *P. brasiliensis* is still endangered in many parts of its range (Duplaix et al. 2015; Groenendijk et al. 2020). With no measures to regulate the threats caused by human development that come from gold mining, hunting, and habitat destruction, the survival of the species in the wild is uncertain.

Establish protected areas and corridors

The largest threat to the giant otter is habitat destruction. Many of the causes of the degradation of otter habitat is human related (Carter & Rosas, 2008; Duplaix et al. 2015; Schikora, 2020; Duplaix & Savage, 2018). There are currently several established preservation areas across South America, but few possess an adequate level of suitable habitat to sustain large populations of giant otters (Tomas et al. 2015). Additional protected areas will include an abundant range of river and land habitat, adequate water foraging areas, clean rivers and wetlands, and connecting corridors. Fish corridors will also be established to connect fragmented populations and protect stable populations with a reliable food supply (Duplaix & Savage, 2018). Unsuitable otter habitat will be remodeled in expansive projects that include the restoration of proper hydrodynamics in and around river and creek areas, reduction in pollution, invasive species removal, and changing the conditions of bankside and channel substrate and vegetation. Development projects will be banned in protected areas, including that of logging, mining, agriculture, construction, road building and damming. The local success of protected areas is largely dependent on integrating the local community with the project (Michalski et al. 2012). Preservation areas are to be protected and maintained regularly to ensure effective conservation and sustainability. Higher priority of protection and maintenance will come shortly after the establishment of these areas to ensure greater durability and longevity of these areas.

The establishment of connecting corridors between protected areas would be highly beneficial for giant otter conservation. It would alleviate the reduction in genetic diversity and improve resiliency in small otter populations and subpopulations (Pickles et al. 2011;

Van Damme et al. 2003). Greater genetic variation is crucial for populations of any organism to fight disease (Sommer, 2005). Corridors, both on land and in water, allow individuals or small groups of individuals to travel between otter subpopulations, thereby enhancing gene flow, the movement of genes in and out of a population. Increased gene flow raises the chance of strengthening genetic diversity, especially of small populations, and increases the likelihood of the species to survive (Choudhuri, 2014).

Implement restrictions on industrial and agricultural operations

The increasing development and subsequent expansion of human impact in large regions of the Amazon and waterways within the region is causing many areas to become incapable of supporting giant otter populations (Carter & Rosas, 2008). Human influence on the environment, ranging in industrial and agricultural operations, affects the species directly and indirectly in a multitude of ways. These effects can be grouped collectively for clarity, but each needs to be addressed independently to ensure optimal mitigation. Firstly, regulations on industrial and agricultural pollution will be established, including prohibition of the disposal of industrial and agricultural waste near water sources and in known giant otter range, an internal review of procedures to reduce nonrecyclable waste, and mandated waste treatment before disposal. Additional restrictions need to be placed on agricultural activities, particularly on the use of livestock, as they can transmit parvovirus, a deadly disease that *P. brasiliensis* is susceptible to (Duplaix et al. 2015; Dunstone & Gorman, 1998; Duplaix & Savage, 2018). Access to giant otter habitat and rivers by dogs and cattle will be restricted by the construction of barriers around either these zones or around farmland. Boat traffic will also be managed to limit disturbance on otters and their habitat (Tomas et al. 2015; Duplaix et al. 2015). Requirements on boat size and travel frequency will be instituted as well as speed and other traffic regulations.

Establish mining regulations

Gold mining threatens otters in a variety of ways, including through mercury poisoning, habitat destruction, and disruption of otter food supply (Carcelen, 2019). Mercury used in gold extraction can impact the ecosystem in a variety of ways, including through bioaccumulation in fish and giant otters (Carter & Rosas, 2008). The toxin can also

affect human health (Duplaix et al. 2015). It is recommended that measures be initiated by local and regional governments to reduce, if not ban, the use of mercury and other toxic compounds in gold mining, and environment-friendly alternatives should be used. In a recent study, the viability of using a byproduct of cassava plant to replace mercury use in gold mining was found to have potential (Torkaman et al. 2021). The practicality of this procedure and other methods will be assessed by the planning team and relevant stakeholders.

Resource extraction in the Amazon disrupts otter habitat through logging, river sedimentation, direct mining operations on river habitat, and other effects (Carcelen, 2019). Regulations on how much lumber is cut and removed per year and the areas in which tree-clearing is forbidden will be established, such as leaving a mandated width of riparian buffer. Tree logging companies will be mandated to alleviate the impact of tree-clearing by contributing to the formation of new preservation areas and by maintaining existing land. The mining impact also affects otter food supply. One way this occurs is with a mining process called dredging, which takes place directly in rivers. This procedure generates large amounts of particulate matter suspended in the water which suffocates fish (Carter & Rosas, 2008). To mitigate this and other effects from mining, mining operations will be banned on recognized otter habitat and in areas that can affect otter habitat, including regions upstream from established habitat.

Institute management guidelines for ecotourism

Ecotourism is popular in many regions in South America. Expeditions featuring giant otters are no exception. Ecotourism can be detrimental to the environment and to otter populations if not conducted vigilantly. Poorly managed practices can decrease otter habitat quality by path-clearing adjacent to shorelines (Duplaix et al., 2015). To mitigate this issue, management guidelines will be put in place to reduce the impact of tourism on giant otters and their habitat. Some standards include zoning and the inauguration of refuge areas for otters, establishment of an appropriate observation distance to prevent stress on otters from the presence of tourists, supplemental education for tourists and local guides, strict control of boats, and improved trail design with protection of the shoreline (Duplaix et al., 2015). Additionally, local members of the community who have

the greatest knowledge on the region and exhibit regard for the natural environment will be hired as tour guides and as contributors in the management process. The successful application of these guidelines would likely improve the well-being of giant otters and increase their numbers, making it beneficial to local tourist industries because it would increase otter sightings. Local communities that practice safe and favorable ecotourism regard otters not as a competitor but as a valuable asset, which has benefited local otter populations and the local economy (Duplaix et al. 2015). This is the goal for local regions throughout the Amazon.

Regulate overfishing

Though giant otters are often blamed for diminishing fish abundance, overfishing and poor fishing practices are a major cause (Duplaix et al. 2015). These operations not only threaten the survival of the species, but also increase competition between local fishers and otters as fish abundance drops. Giant otters are accused of interfering with fisheries by eating fish, driving them away, and damaging equipment (Rosas-Ribeiro et al. 2012). However, otters can drown, get stuck in fishing gear, and then get blamed for damaging them (Duplaix & Savage, 2018). Management plans will be developed to regulate fisheries and their fishing practices to prevent overfishing to reduce conflict between otters and humans. The establishment of no-fishing areas will be imposed. Limitations will be established on the types of fishing gear used near known otter range. Daily quotas will be enforced on the quantity of fish large fisheries can catch. These methods will likely allow fish populations to rebound and reduce direct competition between otters and fishers.

Provide workshops for wildlife law enforcement to eliminate illegal trade

Though the value of otter pelts, and subsequently the trade of otter pelts, have decreased significantly since the 1960s, giant otters are still hunted and captured for sale as pets (Carter & Rosas, 2008; Pickles et al. 2011). Trade has been banned internationally since the 1970s but illegal poaching and trading has subtly made a small impact on the number of giant otters, especially in small remote populations that may be affected by more significant threats (Duplaix et al. 2015). Tighter restrictions will be put in place to

reduce illegal trade with the goal of complete elimination. This would be done by strengthening wildlife law enforcement in range and consumer countries through providing instructional workshops. These workshops would train law enforcement personnel on how to effectively identify otter pelts, other otter parts, and live animals. Sessions on appropriate local, regional, and international wildlife regulations will also be included to increase awareness among law enforcement. Additional indirect actions can also be accomplished to reduce illegal trade, like decreasing the demand for otters and otter products and increasing border and traveling surveillance.

Promote education and outreach

Providing environmental education can alter human perceptions on giant otters and their environment. Teaching locals, tourists, and other communities about the ecological role of the giant otter and its importance in the Amazon ecosystem, as well as how human impact threatens the species, can influence human behaviors favorably. Effective education can alleviate the number of conflicts between humans and wildlife, promote conservation of both biodiversity and the environment, and reduce the impact individuals have on the environment (Michalski et al. 2012). It is important to provide educational programming in communities that coexist with otters so that otters are considered less as competitors and threats to human wellbeing and livelihood. Education can promote respect for giant otters and reduce conflicts between the species and fishers (Tomas et al. 2015). Recognition of the ecological role of giant otters can be accomplished through information packets and manuals based on reputable scientific research and literature (Duplaix & Savage, 2018). It will be made available online and physically distributed through local communities to all ages through schools, community centers, local leadership, and municipal governments. Information in these packets will include details on the habitat and behavior of giant otters, the species' conservation status and an indication of their need for protection, the legality of the pelt and pet trade, material to aid conflict resolution, knowledge of the threat of human impact on otters and their habitat, and local and regional regulations on the trade and protection of the species.

Environmental and otter education can also extend beyond South America. By reaching communities in other nations, the issue of giant otter conservation can have

increased recognition. This global awareness of the issue can have supplemental effects. For instance, increased perception of the conservation issue can persuade additional researchers to focus on otter research, inspire more people to care about the environment and respect wildlife, and promote campaigns and conservation of other species (Milner-Gulland, 2013). Further outreach can be obtained through social media, news coverage, press releases, online blogs and articles, and research articles published in credible scientific journals (Duplaix & Savage, 2018).

Strategy Selection

A consequence table (***Table 4***) and a Multi-Criteria Decision Analysis (MCDA; ***Table 5***) were constructed to compare the advantages and drawbacks of each strategy in order to understand which proposals are most effective. The "No Action" approach is used as a baseline for each other measure to be compared to. These analyses help visualize which strategies are most important for the conservation of the giant otter, which methods may be not cost-effective, and which should be prioritized.

Consequence Table

This Consequence Table (***Table 4***) displays the impact of each proposed strategy on each of the fundamental objectives and their indicator. The measure of impact is denoted by a "+," "–," or "/" symbol. The "+" mark indicates a positive effect on the fundamental objective, while the "–" symbol specifies a negative result. The "/" figure depicts no change or a neutral outcome on the fundamental objective. Each consequence value is predicted by direct estimation and evaluated by the planning team.

Fundamental Objectives	*Increase giant otter popula-tion*	*Increase gene flow among giant otter populations*	*Decrease industrial and agricultural activities around giant otter riverbank habitats*	*Increase protection of giant otter habitat*	*Increase local job opportunities for villagers*	*Increase in well-managed ecotourism*	*Increase local education on the importance of giant otters in the ecosystem*

Indicators **Strategies**	Number of giant otter dens among riverbanks	Number of corridors that connect rivers together	Amount of disposed or leaked effluent into the environment; counting number of unauthorized roads/cars	River kilometers of giant otter habitat protected	Number of villagers employed as guides/habitat management workers	Hotel rooms booked	Knowledge index
No action	–	–	–	–	/	/	/
Establish protected areas and corridors	+	+	+	+	/	+	/
Implement restrictions on industrial and agricultural operations	+	/	+	/	–	/	/
Establish mining regulations	/	/	+	+	–	/	/
Institute management guidelines for ecotourism	/	/	+	+	+	+	+
Regulate overfishing	+	/	+	+	–	/	+
Provide workshops for wildlife law enforcement to eliminate illegal trade	+	/	/	+	+	/	+
Promote education and outreach	+	/	/	+	/	+	+

Table 4. Consequence Table for the Amazon River ecosystem.

Multiple Criteria Decision Analysis

The Multiple-Criteria Decision Analysis (***Table 5***) is useful in identifying which strategies are the most beneficial in relation to the value of each fundamental objective to distinguish which methods should be prioritized. Risks, uncertainties, and other issues may emerge when implementing the target strategies, and this analysis can incorporate those additional elements. ***Table 5*** is used to help determine which strategies would be most cost-efficient and worthwhile of the time, effort, and resources determined by the planning team.

The MCDA designates numerical values for each strategy that indicate how effective each one addresses each fundamental objective, and the sums of the values for each strategy are compared. Each fundamental objective is assigned a "Weight" value to establish its relative significance, with "1" being the least important and "5" being the most. Each strategy is also appointed a value ranging from 1-10 to indicate its effectiveness at addressing each fundamental objective, with the least effective as "1" and the most effective as "10". This value is multiplied by the "Weight" values to produce a number that incorporates both attributes, designated in parenthesis. Both values were determined by stakeholders and the planning team. The product values in parentheses are aggregated for each strategy at the bottom of the table in the "Total" row. The figures in this row are the values used for strategy comparison and analysis.

Fundamental Objectives	**Weight (1-5)**	**Strategy Options (1-10)**							
		No action	*Establish protected areas and corridors*	*Implement restrictions on industrial and agricultural operations*	*Establish mining regulations*	*Institute manage-ment guidelines for ecotourism*	*Regulate overfish-ing*	*Provide workshops for wildlife law enforcement to eliminate illegal trade*	*Promote education and outreach*
Increase giant otter population	4	1 (4)	9 (36)	3 (12)	5 (20)	7 (28)	6 (24)	7 (28)	6 (24)

Increase gene flow among giant otter populations	2	1 (2)	10 (20)	2 (4)	3 (6)	3 (6)	2 (4)	3 (6)	3 (6)
Decrease industrial and agricultural activities around giant otter riverbank habitats	3	1 (3)	9 (27)	10 (30)	10 (30)	5 (15)	8 (24)	1 (3)	5 (15)
Increase protection of giant otter habitat	5	1 (5)	10 (50)	8 (40)	8 (40)	8 (40)	7 (35)	4 (20)	7 (35)
Increase economic opportunities for local villagers	2	1 (2)	1 (2)	1 (2)	1 (2)	9 (18)	3 (6)	9 (18)	5 (10)
Increase in well-managed ecotourism	3	1 (3)	6 (18)	5 (15)	1 (3)	10 (30)	1 (3)	3 (9)	8 (24)
Increase local education on the importance of giant otters in the ecosystem	3	1 (3)	3 (9)	2 (6)	2 (6)	8 (24)	7 (21)	10 (30)	10 (30)
Total:		**22**	**162**	**109**	**107**	**161**	**117**	**114**	**144**

Table 5. Multiple-Criteria Decision Table (MCDA) for the Amazon River ecosystem.

The highest scoring strategy that most effectively addresses the fundamental objectives is to establish protected areas and corridors for giant otter habitat in the Amazon region. The strategy obtained a "Total" score of 162 in the MCDA, the greatest among all the proposals. This method most effectively addressed the fundamental

objectives of increasing gene flow among giant otter populations, decreasing industrial and agricultural activities around giant otter riverbank habitats, increasing giant otter population, and increasing the protection of giant otter habitat", acquiring 9's or 10's in each of these factors. The latter two were the highest weighted fundamental objectives. Establishing protected areas and corridors is most important in the conservation of *P. brasiliensis* because it addresses many of the causes of decline of otter habitat due to human development, including, but not limited to, logging, agriculture, mining, and damming (Carter & Rosas, 2008; Duplaix et al. 2015; Schikora, 2020; Duplaix & Savage, 2018). Preservation areas throughout the distribution range of the giant otter need to be established that prohibit these practices in order to provide suitable habitat that allows otter populations to improve. The establishment of these areas will contribute to increasing gene flow between subpopulations, enabling the species to become more resistant to and resilient in battling disease. Though this strategy is predicted to consume the most time, deplete the most resources and be unproductive in providing for the local economy, the planning team agreed to prioritize it.

Instituting guidelines for the management of ecotourism in local communities was the second highest scoring strategy in the MCDA with a score of 161. It most effectively addresses the fundamental objectives of increasing well-managed tourism and increasing local job opportunities for villagers, along with the top weighted objectives. This approach will increase job opportunities for the locals because part of the strategy includes hiring local members of the community as tour guides and in management of tourist attractions. Additionally, implementing good practices in the tourist industry will allow it to be sustainable by limiting the disturbance of giant otters and their habitat, encouraging populations to remain near human populations. This will, in turn, improve local economic activity in the long run (Duplaix et al. 2015, Duplaix & Savage, 2018). Establishing management standards will also increase education and awareness on the importance of giant otters in the ecosystem. Locals who work in tourism will be trained on how to treat otters respectively and how to distinguish their behaviors. Tourists will benefit by learning more about the species on giant otter expeditions, carrying that knowledge with them across borders. This reasoning justifies the planning team's decision to rank this strategy among the highest priority.

The third leading strategy in "Total" scoring is the strategy of promoting education and outreach, with a score of 144 (***Table 5***). This strategy addresses each fundamental objective moderately but is most effective in increasing local education on the importance of giant otters in the ecosystem and increasing well-managed ecotourism. It is also effectively addressing the two highest objectives of increasing the giant otter population and increasing protection of otter habitat. This is because providing education on the environment and the role the giant otter plays in it can improve the impression of the animal to locals and tourists as well as help eliminate any false or negative perceptions (Duplaix & Savage, 2018). Education and awareness is important in avoiding conflict between fishers and giant otters (Tomas et al. 2015). A widespread positive view of the species can help establish *P. brasiliensis* as a flagship species, thereby increasing other conservation efforts for the species and other related wildlife not just in the Amazon region but also globally (Michalski et al. 2012). This shows that greater education on a single species and on the issue of conservation can promote further action in protecting the environment, making this strategy an important one to prioritize.

These three strategies are the highest-ranking strategies in the MCDA by a wide margin as shown in ***Table 5***. The combination of these approaches also effectively addresses every fundamental objective, making all three the best to prioritize based on the limitations of the conservation plan. Promoting education and outreach along with incorporating perceptive management guidelines in the tourism industry may garner greater environment-focused thinking in local communities, which can foster further acceptance of conservation projects, giant otter related or not, in the future. This is why these strategies would be most beneficial for prioritization for both the immediate conservation of *P. brasiliensis* and for future direction in conservation in the region.

Data and Knowledge

For a conservation plan to be successful, it is essential that decisions are guided by a variety of knowledge and data. As with having unique types of people and groups on the decision-making team, the conservation plan requires direction from different sources to make the best decisions possible for every stakeholder. The plan will be backed by types of information from expert, local, and traditional sources.

Expert Knowledge

Expert knowledge is important for getting solid data backed by science and experienced people in the field to inform conservation decisions. Biologists like Caroline Leuchtenberger who have dedicated years to studying giant otters and are part of organizations such as the IUCN are essential to understanding the otters and their needs, threats, and roles in the ecosystem. Though relatively limited, scientific studies and data about the giant otters are also useful for understanding and creating a plan for them. Using past expert knowledge such as conservation projects that have been done also indicate which actions may be successful and which to avoid. It is important to access and pay great attention to this expert knowledge, as scientists and experts publish their findings for the purpose of guiding others' actions and environmental management.

Local Knowledge

It is imperative for conservationists to lift and hear the voices of the local human population in the area they are conducting conservation. In many cases, conservationists can implement their project and go home where they do not have to live with the consequences while locals do. It is important to listen to the local population to understand their needs and to gain any insight they may have on the subject matter or local area. For example, interviewing locals to find out if they have seen any giant otters can help fill the knowledge gap from a lack of data on otter distribution. Conducting surveys in local communities to survey their thoughts about a conservation plan or species can have great influence on the project.

Traditional Knowledge

Traditional knowledge of indigenous peoples can provide information passed down from generation to generation of people that have lived in the Amazon alongside the otters and river for thousands of years. Their knowledge can help understand how the land has changed over time and how they have been successful in being a part of the same ecosystem as the giant otters. Many indigenous groups have also had history fighting against environmental destruction, and face similar threats to the otters as colonization and urban expansion enters their lands. For example, the Yanomami people who live in the

Amazon in Brazil have experienced displacement and threats from the mining industry for decades (Amazon Aid Foundation, 2014). Their insight on dealing with the mining industry may help conservationists understand what they must do to get the industry's cooperation.

Risks

Risk 1 (severe) - Industry Opposition

There are several different industries that pose threats to giant otters and their habitats along the Amazon River, and it is highly likely that these industries and their supporters will oppose the tighter regulations and expansion of otter refuges that this conservation plan proposes. Each industry has different threats and risks of opposition and will require unique strategies to work with for the protection of the giant otter species. One reason for opposition all these industries likely have in common is the potential losses in profit from tightened regulations.

Logging and Agriculture Industries

The logging and agriculture industries have linked threats on otters and have similar reasons for opposing the expansion of protected otter habitats. Logging is driven mostly by agriculture and the global demand for cattle and soy. Because Brazil is the second largest producer of soy in the world and demand is rising, it is likely that the industry will continue to expand further into forests, and the industries will need the land inside the proposed protected areas (Ritchie & Roser, 2021). Conservation needs stakeholder support, and there is a risk that the agriculture and logging industries could have more support and funding than this conservation plan. They provide people with wood, food, and income, while otters may not be valued as highly.

Oil Industry

Similarly, the oil industry will have to keep expanding into new lands for oil extraction as long as the world relies on this fossil fuel. There is a large risk that switching to other sources of energy will be a slow transition and the oil industry will need land in the giant otter habitat in the future. Unfortunately, this is likely, as Brazil has increased their oil production in recent years despite the decrease in global demand (EIA, 2021).

Fishing industry

The fishing industry will likely oppose the conservation of the giant otters in general. In the past, fishers have had much conflict with these otters. Fishers fish close to the giant otters because they both require the river for hunting fish. The fishers see giant otters as pests because they believe the otters are competition for fish, scare away fish, and damage fishing equipment (Duplaix et al. 2015). This is a concern for conservation because fishers want less otters to survive due to their misinformed position.

Mining Industry

The gold mining industry uses mercury in the process of separating out the gold from other substances in the river, leaking about half of the mercury directly into the water (Carter & Rosas, 2008). This may be causing mercury poisoning in the giant otters due to biomagnification (Duplaix et al. 2015). There is a large risk that this industry will oppose the tightening of regulations to protect the otters. It will be especially challenging to reduce this risk, because the recent administration of Brazil has shown support of the mining industry by loosening regulations and allowing illegal mining to increase greatly (Skidmore, 2022).

Risk 2 (severe) - Lack of Funding

A risk that any conservation plan must consider is the need for funding that might not be there. This conservation plan will require a relatively large amount of funding because of the sheer size and scope of the issue. The Amazon River spans over 4,000 miles long and its main waterway crosses through three countries (Parsons, n.d.). This means that there would have to be negotiations and campaigning in multiple different countries with multiple different governments and political climates to get the conservation strategies put into place to cover as much of the giant otters' historical range as possible. While the giant otter populations are scattered and fragmented, this makes it uncertain that they will be able to return to their entire historical range if there is not enough funding. The large number of industries that are likely to oppose the conservation plan also requires the project to have more funding. Having to negotiate and make sure these

stakeholders are not going to put the success of the project at risk will take lots of time and money that is not guaranteed.

Risk 3 (moderate) - Lack of data and knowledge

In addition to the risk of insufficient funding, there is the risk of insufficient data about the giant otter populations. They are known to be endemic to South America and distributed throughout the Orinoco, Amazon and La Plata River basins and some areas in the Guyanas (Carter & Rosas, 2008), but there is limited data on the abundance and distribution of existing populations (Tomas et al. 2015). To address this and narrow down the locations of populations, there may need to be additional studies in the Amazon area to be sure of their distribution.

Responding to Risks

Responding to these risks will include minimizing, compensating for, and living with them. To minimize the risk of industry opposition, educating people and campaigning for governmental interference and economic incentives are some strategies that can be done. This risk can also be compensated for by creating funds to make up for the costs of conservation to the industries. Education and campaign programs in the Amazon and in other countries, such as the US, can also help to minimize the risk of not having enough funding for the project.

Conservation takes the support and cooperation of many different types of people, allowing for many sources of risk and conflict. Considering these risks ahead of time and planning to respond is essential to ensure the success of any conservation plan.

Conclusion

Despite the various threats the giant otters face in the Amazon, there is hope for them. Otters are resilient animals, and there have been several success stories for otters all over the world in places including Singapore, the UK, and the North American Pacific Coast (Duplaix & Savage, 2018). Protecting these apex predators will minimize habitat destruction and allow them to keep their ecosystems healthy. The giant otters in the Amazon need this conservation assistance to increase their numbers which have fallen from human treatment and habitat destruction. This plan to increase the populations and health of the giant otter species can help by educating people, increasing reasonable regulations, and implementing proper management practices to protect the otters' habitat.

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