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Concepts and Questions

Identifying technology solutions to bring conservation into the innovation era

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Innovative conservation technologies

Innovation has the potential to enable conservation science and practice to keep pace with the escalating threats to global biodiversity, but this potential will only be realized if such innovations are designed and developed to fulfill specific needs and solve well-defined conservation problems. We propose that business-world strategies for assessing

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the practicality of innovation can be applied to assess the viability of innovations, such as new technology, for addressing biodiversity conservation challenges. Here, we outline a five-step, “lean start-up” based approach for considering conservation innovation from a business-planning perspective. Then, using three prominent conservation initiatives – Marxan (software), Conservation Drones (technology support), and Mataki (wildlife-tracking devices) – as case studies, we show how considering proposed initiatives from the perspective of a conceptual business model can support innovative technologies in achieving desired conservation outcomes.

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In a nutshell:

- Biodiversity conservation has been slow to identify viable innovative solutions to enhance conservation efforts and counteract threats to species persistence
- Business models used to design start-ups, projects, and strategic management can help conservation practitioners develop plans, evaluate the effectiveness of new innovations, and improve existing and long-term integration of innovation in conservation efforts
- Three case studies of high-profile conservation technology initiatives illustrate how the viability of innovation for conservation applications can be assessed

Technological innovation is a mainstay of our era and has driven tremendous progress, fundamentally altering many aspects of society (Chesbrough 2003). However, despite calls to embrace new technology in the search for solutions (Pimm *et al.* 2015; Berger-Tal and Lahoz-Monfort 2018), biodiversity conservation has not realized the full benefits of recent technological advances. Instead, conservation efforts often involve strategies that rely on “old technologies” (eg static maps to inform fisheries closure; Joppa 2015); meanwhile, threats to biodiversity accelerate due to the development and acceptance of new technologies (eg sophisticated fish-finding sonar; Villasante and Sumaila 2010). To propel conservation practices into the 21st century, it will be necessary to identify opportunities where technology can be developed or adopted to support conservation strategies. Here, we adapt the “lean start-up” business development methodology (Osterwalder and Pigneur 2010; Ries 2011) to rapidly assess the potential impact of technological innovations on conservation success (Johnson *et al.* 2008).

If the growing pains of implementation are overcome (Joppa 2015; Pimm *et al.* 2015), technological innovation could be used to address critical conservation needs. For example, innovation can support adaptive management (Walters 1986) by providing better ways to measure changes in populations and threats, monitor assets, and enforce regulations (see Panels 1–3; Snaddon *et al.* 2013; Marvin *et al.* 2016). However, many technological advances fail to deliver their potential conservation outcomes (McGowan *et al.* 2017). Trialing these advances can therefore be risky for conservation initiatives for which there is little time or money to waste investing in approaches that may not work.

Recent publications identify common issues that arise with new conservation technology initiatives (Lahoz-Monfort *et al.* 2019). These include failure to properly identify an end user for the technology, production inefficiencies due to the tendency among developers to “go it alone” in response to commercial competitiveness, failure to properly test prototypes of tools before scaling up their use, and failure to grasp the effort required to ensure substantial uptake and effective end-user experiences. Several of these problems stem from a belief that technology is a silver bullet when in reality it is often only part of the overall solution to a larger problem. Others are the result of a failure to assess the technology’s ability to achieve the desired outcome (ie by failing to develop a business plan; Johnson *et al.* 2008) rather than to the shortcomings of the technology itself.

Conservation technology development and implementation is essentially a business process: it must provide desired conservation benefits that support conservation goals and strategies, and it must do so in a financially sustainable manner that complements existing work and future efforts. In the business start-up world, entrepreneurs can avoid unrealistic expectations by using tried-and-tested strategies to evaluate the viability of a new product or idea. Such strategies require confirmation from the outset that the suggested innovation can be developed and implemented, and will be able to provide the anticipated outcomes. This approach is useful when applying any type of innovation to conservation, particularly for those developing new technologies who want to ensure that it will be used effectively (developers), as well as those who use existing technologies to address conservation needs (deployers). We focus on technological innovations to simplify our explanation of the approach and because of our own experience and expertise, but these strategies could likely be applied to other innovative conservation techniques (eg assisted migration, genetic transformation) with minimal modification.

We demonstrate how business model assessment can inform development, evaluate effectiveness, and enhance existing and long-term use of innovative technologies for

improving conservation outcomes. These assessments do not require the innovations to have a business intent (ie a desire for profit); instead, they provide a framework for determining whether an adequate funding stream is feasible and will allow the innovation to fulfill its purpose. In our five-step approach to assessing innovations for conservation, the lean start-up methodology is used to identify which aspects of product development and deployment can be improved to facilitate conservation efforts.

The lean start-up approach for conservation technology initiatives

Identifying viable technological solutions to conservation problems has proven difficult (Lahoz-Monfort *et al.* 2019). The lean start-up methodology for business planning is iterative (incremental steps allow for updates to strategy) and can be used to rapidly identify whether proposed innovations can provide solutions (Ries 2011; Blank 2013). It calls for a structured approach to considering business goals before testing ideas and prototypes, and has been successfully applied to support innovation by several large international corporations (Blank 2013); moreover, it has been adopted across a wide range of sectors (Khan *et al.* 2011; Lopes *et al.* 2015).

To apply this thinking to conservation problems, we propose a five-step iterative approach (Figure 1):

- Step 1: define end users and their desired conservation outcomes;
- Step 2: identify the value of the innovation in achieving conservation outcomes;
- Step 3: assess the feasibility of the innovation according to the business model;
- Step 4: test the ability of the innovation to deliver the desired conservation outcomes;
- Step 5: deploy the innovation and continuously update the business model.

To apply the lean start-up methodology to conservation innovation, we use two templates for exploring the validity of proposed solutions: the Business Model Canvas (BMC) and the Value Proposition Canvas (VPC) (Osterwalder and Pigneur 2010). The BMC consists of nine elements that describe a business idea (Figure 2). Together, these elements identify the users (“customers”) and their needs; define the Value Proposition (service or product) that solves the user’s needs; and describe the innovation’s capacity to create value, transfer that value to customers, and generate benefits. In developing these elements, the VPC (Figure 3) is used to map the needs of the end user to the services provided by the proposed

innovation being examined with the BMC. Copies of both canvases (formatted for brainstorming) are provided in WebFigures 1 and 2.

We illustrate this structured approach using retroactive assessment of the observed business models of three prominent conservation technologies: Marxaan, a widely used conservation planning software (Panel 1, Figure 4); Conservation Drones, a company that supports the use and data needs of unmanned aerial vehicle (“drone”) technology as field devices for conservation (Panel 2, Figure 5); and Mataka, an open-source, low-cost, wirelessly enabled, wildlife-tracking platform (Panel 3, Figure 6). We examine the Marxaan case study from two perspectives – that of the developer and that of the deployer.

Step 1: define end users and their desired conservation outcomes

Step one is to identify both the conservation problem to be addressed by an innovation and the stakeholders who can implement it. These stakeholders are considered *Customer Segments* in the BMC (Figure 2). In conservation, Customer Segments include end users of the technology, such as field staff and landscape managers, non-governmental organization (NGO) and foundation personnel who want to deploy a piece of technology, citizen scientists, and academics and scientists conducting conservation research. Grouping target stakeholders into Customer Segments allows the technology to be developed and deployed as needed by relevant end users; for example, Conservation Drones and Mataka provide services to managers and researchers who wish to monitor species’ movements (WebTable 1).

The problems that a Customer Segment needs to solve to achieve their conservation mission are identified in the right-hand side of the VPC shown in Figure 3. The VPC explores the possible actions that can be performed (*Jobs*) and the current obstacles to performing them (*Pains*). If Pains can be overcome, then there are benefits (*Gains*) in achieving the conservation mission. Pains can include an undesired status quo, obstacles that hinder current actions, and risks that influence the current approach, whereas Gains are a measure of success and should consist of concrete results or benefits.

In the case of Conservation Drones, for instance, the Jobs required of the protected area’s managers are to know the status and location of the target species and habitats across large landscapes in order to carry out timely conservation interventions (Johnson *et al.* 2005). The chief Pains identified are the inaccessibility of the terrain; the high costs associated with monitoring and enforcing conservation actions; the difficulty of using available surveillance technology; and the challenges involved in processing, managing, and analyzing large

amounts of data (Szantoi *et al.* 2017). Because drones allow managers to access and assess vast expanses of land more rapidly than traditional field surveys (Wich and Koh 2018), the Gains for managers in this example are an improved understanding of landscape conservation needs with reduced risk to staff (WebTable 1).

Step 2: identify the value the innovation could provide

The next step is to assess whether a proposed innovation can perform the Jobs the Customer Segment needs to have done, termed the *Value Proposition*. Each Value Proposition that a piece of technology could potentially provide can be assessed with the left-hand side of the VPC (Figure 3), which relates *Products and Services* that the proposed innovation can deliver to the required Jobs. Here, we consider whether the potential Products and Services provided can remove the obstacles that prevent conservation actors from performing necessary actions (*Pain Relievers*), and how the potential Products and Services provide conservation benefits (*Gain Creators*).

Designing a Value Proposition is a trial-and-error process that requires critical thinking. Identifying key Customer Segments suffering from the Pains and wanting Gains that the proposed technology can provide is key to a strong Value Proposition. Defining the Value Proposition should be done interactively by interviewing potential customers in order to ensure that the assumptions are accurate; this includes understanding public perception of the application of the technology and gauging whether the Value Proposition can be achieved in the presence of the public's opposition or acceptance. It is also likely that the Value Proposition will evolve as the Pains and Gains of the Customer Segment change over time (eg Marxan has shifted from a tool used for research to one used by practitioners; Sinclair *et al.* 2018).

Step 3: assess feasibility of the innovation

The next step uses the BMC to assess the feasibility of developing and distributing the technology and determine its potential to benefit conservation. Developing a technology-based innovation requires identification of the *Key Partners* who complete the tasks necessary to successfully achieve conservation outcomes, from designing technology to processing data, disseminating findings, and saving species. Key Partners enable the technology to fulfill the conservation need and are motivated to collaborate on the project. Alliances can be formed to optimize revenue, reduce risks, or acquire knowledge, skills, and resources (Osterwalder and Pigneur 2010). Partnerships can be strategic alliances between

organizations that work in different fields (eg drone manufacturers and Conservation Drones; WebTable 2), between aligned organizations (eg Conservation International and The Nature Conservancy), joint ventures to develop new businesses (eg the collaboration of Microsoft, Zoological Society of London, and University College London in developing Mataka) or buyer–supplier relationships (eg drone manufacturers and Conservation Drones). *Key Resources* are the physical, human, and financial resources necessary to develop the technological innovation to the point where it can provide the desired Value Proposition. Based on our own experience, conservation initiatives often underestimate this area. These resources would typically include people with the ability to create the proposed technology, such as a software developer (Marxan), an ecologist or an engineer to develop a tracking system (Mataka), and an analyst to explore complex data (Conservation Drones). Physical resources may include tools, computers, software, or a shop or website. *Key Activities* are those required to develop and distribute the technology so that it can meet the Value Proposition (including risk assessment). For example, a product such as Marxan requires software development, training modules, maintenance, and research activity.

Distributing the conservation innovation is the next challenge. *Channels* describe how the Customer Segments learn about and obtain the technology; for instance, Marxan benefits from promotion by a prominent conservation figurehead (coauthor HPP). Technology-based conservation innovations are useless if they cannot be delivered to the end users who can implement or use them. It is therefore necessary to consider whether existing or potential Channels are convenient for the users, whether they are integrated with other aspects of the business, and whether they allow the Value Proposition to be achieved by the Customer Segments.

Customer Relationships give Customer Segments the support they need to achieve the Value Proposition of the proposed innovation. Important considerations include whether users require support following the purchase or deployment of a new technology – such as helping with regulatory approval – and whether user feedback is valuable for improving the product. In our experience, user support is highly variable for not-for-profit technology initiatives, and attention to this aspect of the BMC is therefore critical. Beyond the classic strategies (eg one-on-one support), Customer Relationship approaches associated with conservation technology include encouraging self-service through publications and web resources, supporting community knowledge exchange (eg via online platforms like www.wildlabs.net), and providing opportunities for users to participate in co-creation, such as open-source software development.

Finally, two financial aspects must be considered. The first is the *Cost Structure* of developing and implementing the innovation. This includes all costs incurred during the creation, delivery, and support during ongoing use of the proposed conservation technology. These costs can be fixed (independent of production volume) or variable (proportional to the volume), and can be subject to economies of scale (cost per unit decreases with volume) and/or economies of scope (cost per unit decreases with multiple products). Naturally, the initiative may be more viable if the costs and financial risks are minimized; software features of Marxan, for example, were primarily tested and advanced through economical student projects.

The second financial aspect is to identify current and potential *Revenue Streams*. Neglecting this aspect is a common shortcoming in conservation innovations, yet considering it from the start can enhance the viability of the initiative. These Revenue Streams may be diverse, can change over time (eg one-off versus ongoing funding), and can be obtained through grants or in the form of revenue generated by the innovation itself. Several revenue models can be considered (Gassmann *et al.* 2014). For instance, Marxan generates limited revenue from consultation fees, while construction of personalized units has funded some aspects of Mataka. Regardless, a business plan highlighting the “customer’s” willingness-to-pay for an innovation (Meertens *et al.* 2014) and its ability to counteract their Pains or to provide Gains will help determine the success of an initiative.

Step 4: test the technological innovation’s ability to deliver the desired conservation outcomes

This step involves developing a prototype and testing the innovation, then updating the business model as necessary. Following an iterative process similar to adaptive management cycles (Chadès *et al.* 2017) and structured decision making (Gregory *et al.* 2012), the lean start-up literature recommends evaluating prototype performance against the components of the BMC, and revising and improving the business plan (Gelobter 2015). This iteration is rarely planned when developing conservation technology (but see the Marxan case study in Panel 1 for an example of successive iterations). The BMC provides a template for considering applicability, feasibility, and viability of the technology venture but initiating development and deployment must also occur (Blank 2013).

Step 5: deploy the innovation and continuously update the business model

Deployment of a product to the people who can use it to achieve conservation benefits is the goal for any conservation innovation. Following the philosophy of “agile development” (Cockburn 2002), iterative deployment addresses the challenge of an unpredictable world. After deploying the product, it is essential to obtain feedback on its performance and to update the product and business model accordingly. These steps will improve the product’s effectiveness over time and help ensure that the Value Proposition is achieved.

Lessons learned

To our knowledge, the lean start-up methodology has not yet been used to implement a conservation-related technology initiative, but the process can also be used to retroactively assess and improve the business model of existing conservation initiatives. Working through the current business models of the case studies we selected provided insights into why these products have been successful, revealed opportunities for improvement in their business models, and demonstrated how the lean start-up methodology can be implemented for conservation initiatives. In each case, the people responsible for the projects we used as case studies agreed that the process has suggested improvements to their business model.

Our case studies indicate that these conservation innovations were developed in response to legitimate Value Propositions, but their development often overlooks the resourcing and customer relationship aspects of the business model. This is a problem because clear thinking about resources from the start helps to identify viable initiatives. Revenue tends to be particularly underdeveloped in not-for-profit conservation tech, which is understandable given that making money is rarely an aim of conservation initiatives. We contend that revenue is essential for an initiative to achieve the Value Proposition into the future. If the Value Proposition is carefully designed to address a real Pain (Figure 3), this should lead to easier revenue generation.

The Marxan business model for deployers is well resolved, with a clear Value Proposition, using freely available software to generate spatial conservation plans that inform policy and practice. However, from the perspective of the Marxan developers, several improvements could be made to the business model. For instance, the developers could improve how they draw on deployer resources to support their ongoing initiative, possibly through avenues such as co-funding of contracts for updates to the innovation over time. Currently, there is limited support for Customer Relationships due to shortcomings in Key Resources and Revenue Stream. The key activities for continued development and support of Marxan are known but are not currently being conducted because of a shortage of dedicated

staff (ie a Key Resource issue). As with many other academic-driven projects, limitations in Revenue Streams reflect how this initiative has historically been funded through the cobbling together of grants and volunteer support.

Conservation Drones' Value Propositions are more limited than their potential clients may realize. The company stresses that certain monitoring and surveillance needs can be supported with drone technology, but that many other applications are not appropriate. The VPC details the specific jobs that drone technology can provide to rangers and managers but also points out that a great Value Proposition is in technical support. Customer Relationships and Channels are another focus of Conservation Drones' business strategy and this enables the company to successfully provide its Value Proposition.

Mataki has identified a Value Proposition focused on resolving the need for an inexpensive and customizable wildlife-tracking device. Where this initiative falters is in Customer Relationships, as support for end users is limited. This limitation also extends to the Channels, as end users must be technologically proficient enough to interpret the provided schematics and construct the devices. These shortcomings in Customer Relationships and Channels likely result from incorrect estimates of the costs associated with end-user support and maintenance or improvement of the software over time. Therefore, despite Key Activities and Key Resources being known, lack of adequate funding prevented the innovation from achieving its full potential. Such issues are being addressed during the development of Mataki v2.0.

Conclusions

Technology is not a panacea for conservation problems, but there are situations where it can play a critical role in supporting biodiversity recovery efforts. Our structured approach can aid in identifying those situations where a technological innovation can fill a conservation need now and into the future. With this approach in mind, we call upon conservation scientists, agencies, and funders to adopt a business mindset when assessing the viability of technological advances for conservation. Traditional business approaches seek to maximize profits, and conservation science seeks to maximize conservation benefits. Because conservation practitioners are not using the best available techniques for considering the potential for technological innovations to achieve conservation benefits (Black and Groombridge 2010), their efforts are failing to keep pace with the threats that compound with technological advances, such as in resource extraction and development operations (Arts *et al.* 2015).

The approach that we have described has been widely used and adapted outside of business (Maurya 2016), including for creating social change (Gelobter 2015). It has even started to influence how research is assessed within scientific organizations. For example, the Commonwealth Scientific and Industrial Research Organisation in Australia now uses the BMC to explore research project feasibility, and their scientists are trained in the approach through the ON program (<http://oninnovation.com.au>). Using business model thinking does not prevent technological innovations from failing, but the process can head off avoidable shortcomings and increase the chance that technology will effectively support biodiversity conservation efforts.

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Supporting Information

Additional, web-only material may be found in the online version of this article at

Figure 1. A five-step process for using the lean start-up approach to assess the viability of conservation technology. Colors in this figure correlate with the relevant sections of the Business Model Canvas (BMC; Figure 2), Value Proposition Canvas (VPC; Figure 3), and the case study tables (WebTables 1 and 2).

Figure 2. The BMC for conservation technology innovation. Adapted for conservation use with permission from Strategyzer.com and Strategyzer AG.

Figure 3. The VPC for conservation technology innovation. Adapted for conservation use with permission from Strategyzer.com and Strategyzer AG.

Figure 4. Illustration of conservation priorities identified by Marxan.

Graphic credit:

J McGowan

Figure 5. Using a drone to map a dry forest in New Caledonia for conservation purposes.

Graphic credit:

LP Koh

Figure 6. A Mataka wireless tag.

Photo credit:

A Davies

[SPS – although there are callouts to Figures 4, 5, and 6 inside these Panels, the figures are also called out in the main text. Place the figures near the main text callouts. Do not attempt to fit them inside these Panels]

Panel 1. Conservation planning software: Marxan

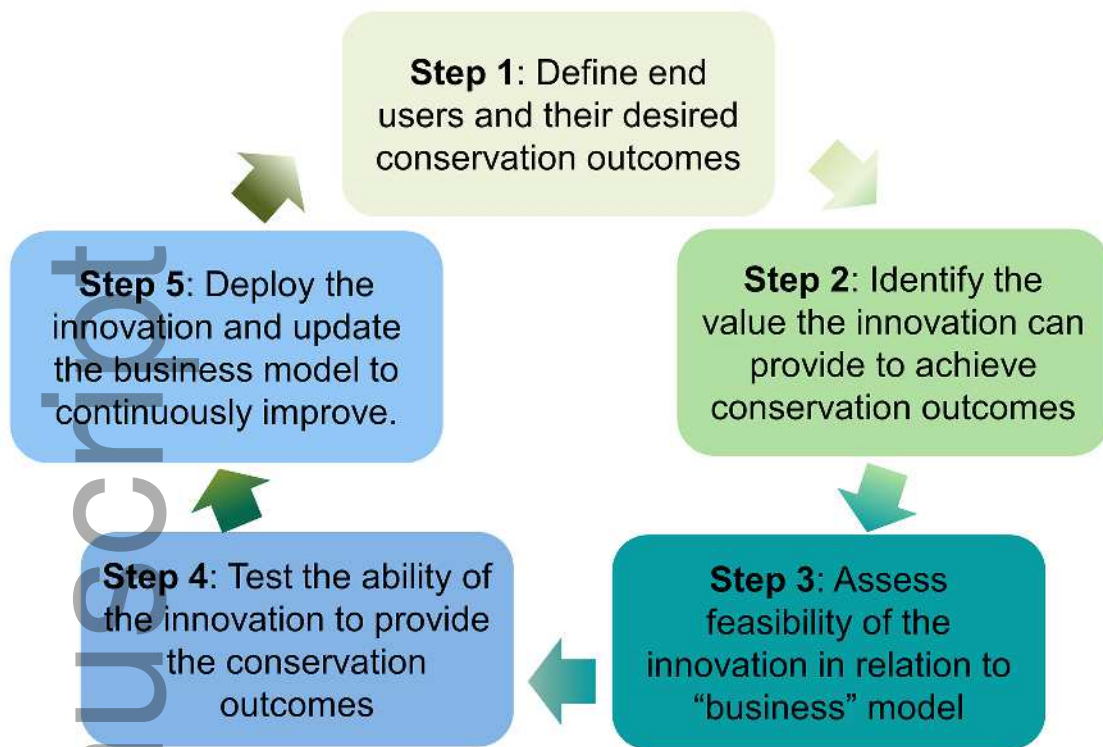
Marxan (<http://marxan.org>) was developed as a modification of spatial-planning software used to support Australia's regional forest agreements (Ball *et al.* 2009; Watts *et al.* 2009; Figure 4). Its first major successful applications were the rezoning of Australia's Great Barrier Reef Marine Park (Fernandes *et al.* 2005), and the development of California's marine protected areas and many of The Nature Conservancy's ecoregional plans. Research now shows that Marxan has been used for more protected area implementations than any other spatial-planning software (Sinclair *et al.* 2018). Marxan software is free to download, and as of 2018, it has been mentioned or implemented in over 250 published studies (Web of Science topic search on 21 Apr 2018). Support for the development of Marxan software derived largely from consultancies, small contracts, grants from the Australian Government, and volunteer support from students and collaborators around the world. It is a constantly evolving tool that moves from platform to platform, with a broad array of volunteer supporters contributing add-ons, user interfaces, and code revisions.

Panel 2. Field equipment and associated data support: Conservation Drones

Conservation Drones (<https://conservationdrones.org>) is a company dedicated to technology transfer and training that support the use of drones for biodiversity conservation (Figure 5). Since its establishment in 2012, Conservation Drones has helped conservation researchers and practitioners to explore the use of drone technology in a wide variety of conservation-related applications around the world (Wich and Koh 2018). Conservation Drones acts as an intermediary between drone manufacturers and end users whose conservation goals can be addressed with drones. Actions range from consulting with potential users or funders about the feasibility of drones for meeting their project goals, to retrofitting drones to meet conservation needs. Examples of applications that have been trialed with Conservation Drones' clients include the spotting and counting of wildlife species, mapping and monitoring of native habitats, and surveillance of protected areas for illegal activities (Wich and Koh 2018). Conservation Drones also provides on-the-ground support and data analysis services to NGOs and conservation researchers.

Panel 3. Species-tracking platform: Matak

Matak is a wildlife-tracking system that provides low-cost, lightweight, wireless transmitter devices and associated software designed to be easily customizable by the end user (Figure 6). The system provides the unique capability of wireless transmission of data from one device to another, making recovery of all devices unnecessary. The devices can be constructed and customized by downloading the open-source schematics or can be ordered directly from the organization, and software can be downloaded from the organization's website (<http://matak.org>). The system was developed through a collaboration of Microsoft Research, the Zoological Society of London, and University College London, with the specific intent of providing highly customizable and affordable technology to conservation researchers and practitioners. Because Matak was released as an open-source design, researchers can customize the technology to match their needs, and private companies can modify and enhance the platform. For example, scientists tracking the black-capped petrel (*Pterodroma hasitata*) employed a Matak-LITE variant of the standard tracking tag. This variant included geofencing, a method to change the behavior of the Matak tag based on the GPS location of the tagged species at a certain point in time (www.wildlabs.net/community/thread/573).

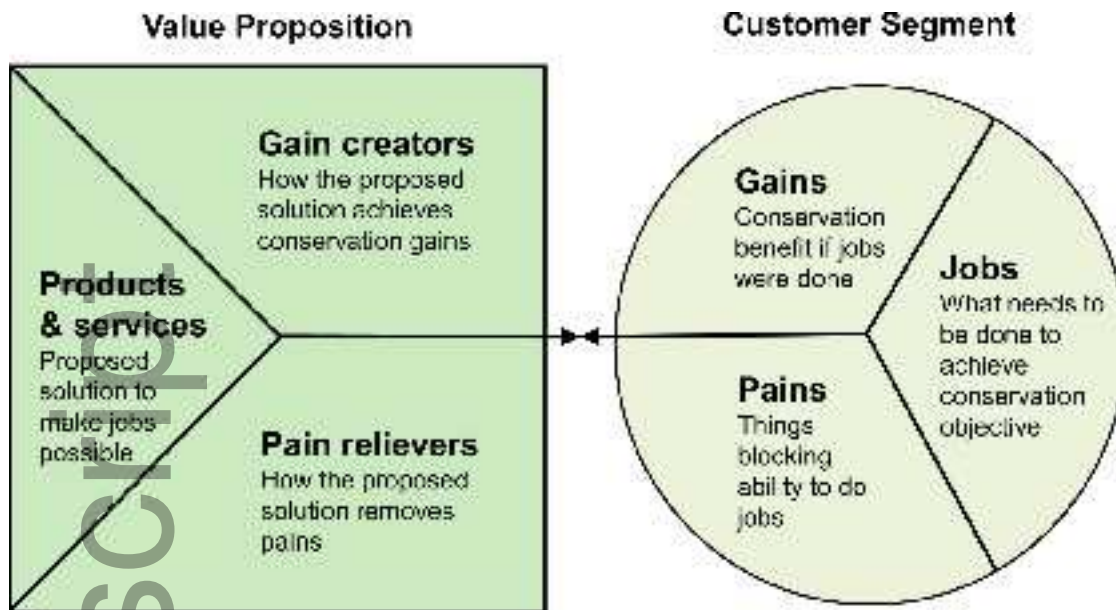


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Key Partners Who needs to be involved to develop the technology?	Key Activities What needs to be done to develop the technology?	Value Proposition What conservation need will the technology fill?	Customer Relationships How will the users of the technology be supported?	Customer Segments Who will use the technology to achieve a conservation outcome?
	Key Resources What is needed to develop the technology?		Channels How will the users learn about and obtain the technology?	
Cost Structure How much will it cost to develop the technology and make it viable over the long term?		Revenue Streams How will the technology be financed to enable it to fulfill the value proposition?		

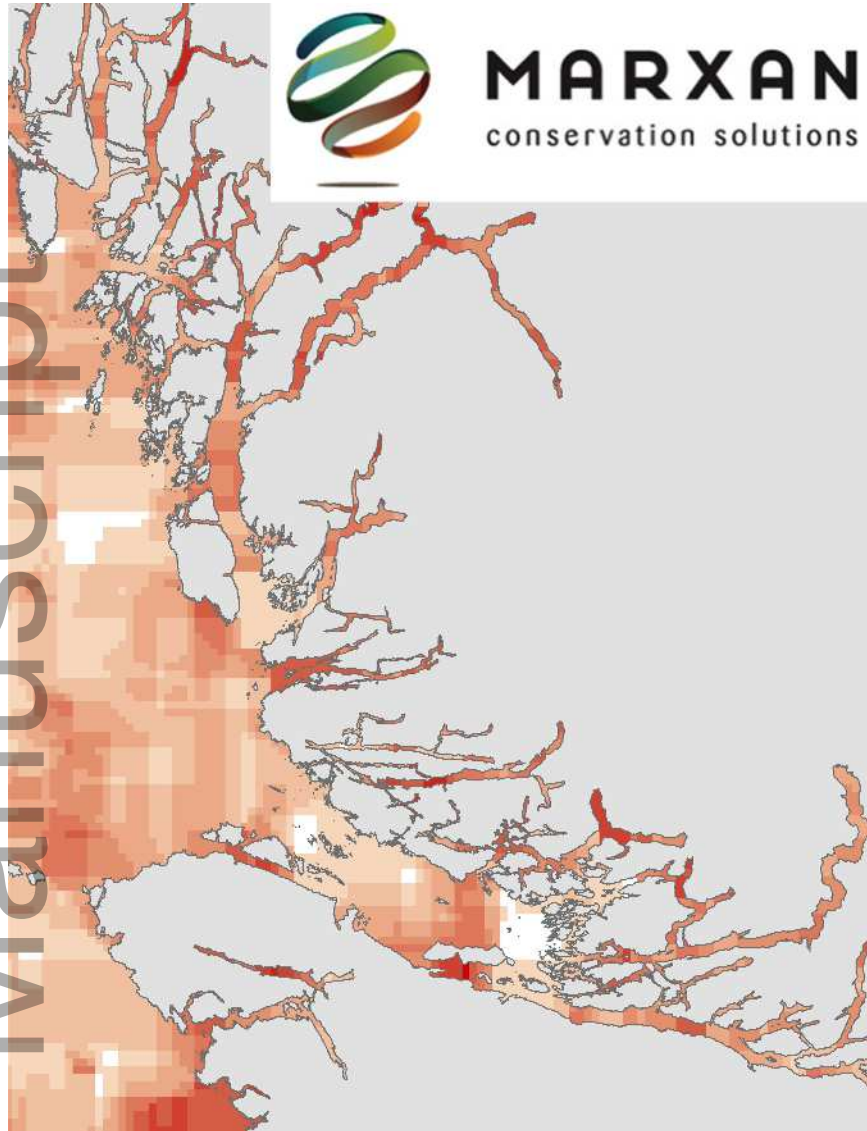
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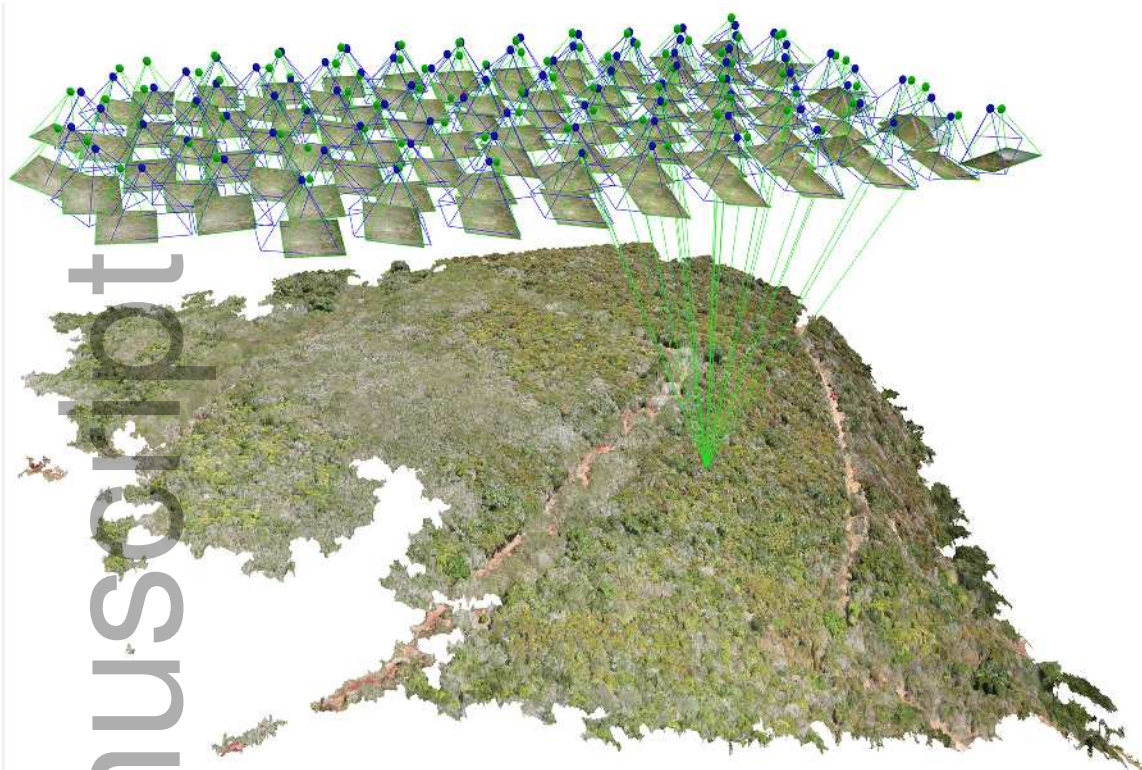
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