

1 **A call for international leadership and coordination to realize the potential of conservation**
2 **technology**
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51 **Abstract**

52 Advancing technology represents an unprecedented opportunity to enhance our capacity to conserve
53 Earth’s biodiversity. However, this great potential is failing to materialize and rarely endures. We
54 contend that unleashing the power of technology for conservation requires an internationally
55 coordinated strategy that connects the conservation community and policy-makers with
56 technologists. We argue an international *conservation technology* entity could (i) provide vision and
57 leadership, (ii) coordinate and deliver key services necessary to ensure translation from innovation
58 to effective deployment and use of technology for on-the-ground conservation across the planet, and
59 (ii) help integrate innovation into biodiversity conservation policy from local to global scales,
60 providing tools to monitor outcomes of conservation action and progress towards national and
61 international biodiversity targets. This proposed entity could take the shape of an international
62 alliance of conservation institutions or a formal intergovernmental institution. Active and targeted
63 uptake of emerging technology can help society achieve biodiversity conservation goals.

64
65 **Keywords:** conservation, technology, open-source, innovation

66
67 **[Main text]**

68 With global climate systems changing at unprecedented rates (IPCC 2014), land-use intensification
69 commandeering primary production, and continuing biodiversity loss thrusting us into the sixth
70 mass extinction event, salvaging ecosystems and species has never been more challenging (Butchart
71 et al. 2010). Many anthropogenic pressures, including changes in climate and land cover are
72 affecting natural systems at a planetary scale (Steffen et al. 2015). Solutions are required at a global
73 scale. Rapid advances in technology have transformed agriculture, mining and other industries
74 (REF). Similarly, a considered approach to technological advances in support of nature
75 conservation is integral to enhancing our global capacity to halt the wave of environmental
76 degradation and species extinction, and to documenting that progress (Snaddon et al. 2013, Pimm et
77 al. 2015). But technology is not a silver bullet and must be nurtured and carefully targeted to ensure

78 it meets its potential. Here we discuss the reasons why to date conservation innovation has not lived
79 up to these expectations and describe key enabling *services* essential for technology development to
80 scale up for global impact. These services are not currently available to support individual efforts to
81 develop conservation-targeted technology. We propose the establishment of an international entity
82 to provides global leadership and coordinate such service provision, promoting, supporting and
83 helping finance the development of technologies instrumental to addressing conservation
84 challenges.

86 **Conservation technology**

87 We are unlikely to meet global conservation and sustainability goals without significantly
88 improving the capacity to (i) monitor natural systems and wildlife populations, and (ii) avoid and
89 mitigate threats to biodiversity. Innovations in, and adoption of conservation technology will be
90 central to meeting these challenges over the next decade. We use the term *conservation technology*
91 to refer to devices, software platforms, computing resources, algorithms and biotechnology methods
92 that can cater for the needs of the conservation community (Pearce 2012, Greenville and Emery
93 2016). Despite its shortcomings this term is becoming the standard description for technological
94 solutions in this context. Conservation technologies can enhance our ability to collect and analyze
95 data on wildlife species, ecosystems and processes, helping us understand their status and trends,
96 identify drivers of extinction and degradation, and monitor the efficacy and efficiency of
97 conservation actions at a global scale (Joppa et al. 2016). They can also support conservation action
98 on the ground, detecting and fighting illegal activities (e.g. remotely-sensed logging or fishing;
99 Dunn et al. 2018), mitigating threats to biodiversity (e.g. biological invasions; Dejean et al. 2012),
100 and restoring habitats (e.g. coral reefs; Anthony et al. 2017) at unprecedented scales.

101 The conservation community has a long history of applying technology for monitoring and
102 management (Cooke et al. 2004, Pettorelli et al. 2014, Burton et al. 2015). New technologies are
103 starting to address previously intractable conservation challenges, for example, discovering critical
104 migratory routes with miniaturized trackers, monitoring remote seabird colonies by satellite, global

105 platforms to monitor wildlife populations (wildlifeinsights.org), controlling the spread of invasive
106 species with robots, tracking illegal forest clearing, and rediscovering species from trace DNA in
107 the environment (Bridge et al. 2011, Groom et al. 2013, Schwaller et al. 2013, Hussey et al. 2015).
108 Emerging technologies, like synthetic biology (Piaggio et al. 2017), advanced Artificial Intelligence
109 (Berger-Wolf et al. 2017), bio-batteries or the Internet of Things, promise increasingly powerful
110 methods in coming decades for tackling conservation issues at global scales (Allan et al. 2018).
111 However, while there are encouraging initiatives in conservation technology, and promising signs,
112 there is currently a lack of leadership, coordination and support to maximize the positive impacts of
113 conservation technology at the scale required to address global conservation challenges.

114 By enhancing on-ground management, research, monitoring, and policy, improved
115 conservation technology, coupled with wider availability and uptake of technology, will contribute
116 to fulfilling obligations under international policy such as the Strategic Plan for Biodiversity 2011-
117 2020 (Convention on Biological Diversity 2010), the United Nation's Sustainable Development
118 Goals (UN 2015), the Convention on International Trade in Endangered Species of Wild Fauna and
119 Flora, and the Ramsar Convention on Wetlands. Improved uptake of technology will enhance
120 knowledge and reporting and use of findings, enabling open tracking of progress toward
121 internationally agreed targets (Snaddon et al. 2013). Capacity is currently lacking to monitor
122 progress toward the achievement of agreed international biodiversity targets, diminishing their
123 impact and social legitimacy, and limiting their power to halt environmental degradation and
124 species extinction (IEAG 2015).

125

126 **Opportunities and challenges**

127 Since the Industrial Revolution, technology development has largely been driven by big industries
128 like consumer electronics, infrastructure, biomedical and the military (Berger-Tal and Lahoz-
129 Monfort 2018). With a few but notable exceptions (e.g. telemetry; Kays et al. 2015), the
130 conservation community has traditionally appropriated technologies developed for other purposes.
131 But the technology landscape has massively changed in the last decade. Current trends see

132 accelerating engineering achievements matched by low production costs, rapid prototyping, high
133 computational power and widespread access to the internet. Novel approaches to product
134 development and the dawn of a new industrial revolution, with more agile design and production
135 cycles, open the window to cheaper, more targeted technology. Some collaborative approaches,
136 such as open-source hardware (Gibb 2014, Pearce 2017, Hill et al. 2018) and *Do-It-Yourself* or
137 *Maker* communities (Cressey 2017), are starting to harness collective know-how thanks to near-
138 global connectivity, supported by emerging online platforms (and associated communities) for
139 sharing and collaboration (e.g. www.instructables.com for electronics or www.thingiverse.com for
140 digital designs including 3D-printing).

141 A growing international movement proposes that the time is ripe for the conservation
142 community to move to the driver's seat, becoming innovation leaders, actively seeking to design
143 novel technologies and devices to suit the specific needs of the conservation community (Joppa
144 2015, Allan et al. 2018, Berger-Tal and Lahoz-Monfort 2018). Such a new paradigm could provide
145 cheaper, targeted and modular tools, but is unprecedented and faces many technical, human and
146 organizational challenges. Within the last decade, similar calls to collaborative innovation "for
147 good" have been made for accelerating discovery (e.g. open source scientific instrumentation;
148 Pearce 2012, GOSH 2018) and contributing to sustainable development (Zelenika and Pearce
149 2014). Coupled with Distributed Manufacturing (Lowe 2019), open innovation has potential to
150 produce technologies appropriate for local economic, political and social conditions, sourced locally
151 by communities to meet their needs, reducing the traditional dependency from foreign aid, large
152 industries in developed nations and traditional distribution channels (Zelenika and Pearce 2014).
153 These arguments strongly resonate with the conservation community.

154 Some conservation organizations and research groups have already delved into small-scale
155 development of conservation technology, either customizing off-the-shelf devices or even
156 developing their own products (e.g. the Zoological Society of London's *Instant Detect* camera-trap
157 system), often in partnership with technologists. These technologies are sometimes disseminated as
158 open-source (Hill et al. 2018) or intended as commercial products (Mennill et al. 2012, Kwok

2017). Despite some successes, conservation technology has only progressed in an ad-hoc manner, largely based on individual uncoordinated initiatives. Overall, the potential of technology to assist on-the-ground conservation at global scales is not materializing well and fast enough. Project failure or lack of scaling are not typically reported or published, for obvious reasons. Based on the collective experience of the authors, of being involved with different conservation technologies while working in academia, conservation organizations and technology companies, we distinguish here two fundamental groups of reasons for this failure. (1) Firstly, the problem can be at the developer's end, either due to failed technical development, or the technology not scaling up for impact. The latter could be due to lack of incentives: promising technology prototypes may be produced as part of research projects or within conservation organizations, but the interest to turn them into finalized products that are available for others to use (either commercially or as open source) is often missing. Even when the drive to expand exists, commercial and non-commercial attempts to scale up technology may prove non-viable over the longer-term, for a variety of reasons including lack of existing valid business models, scarce funding for maintenance and customer support, or overestimating the size of the customer base or community of open-source contributors. Technology development itself may also fail if conservation organizations not familiar with engineering design and manufacturing processes underestimate the skills and resources required to custom-build (or even customize) technology, particularly for use under the typically demanding field conditions. (2) Failure may also happen at the user's end. Inappropriate choices of technology, over-confidence and over-reliance in technological solutions (the technology 'hype') or misplaced motivations to use them (e.g. quest for novelty or media attention) may lead to failed field deployment, or deployment of technologies that are not fit-for-purpose and hence do not help address conservation problems in practice, particularly considering a given ecological, social and political context (McGowan et al. 2017).

Most of the reasons listed above reflect structural deficiencies in the way technology is developed, produced, distributed and supported, rather than poor technologies, with organizations and individuals involved often lacking the business-oriented mindset that underpins general

186 technology development (Iacona et al. accepted). This situation must change if technology is to play
187 the transformative role necessary for global sustainability.

188

189 **Provision of key services for implementation**

190 Most of the individual ingredients for conservation technology to shift gears are already in place,
191 including ingenuity, human and financial resources, connectivity and data platforms. What is
192 lacking is a series of key support functions, which we call here enabling *services*, that ensure the
193 translation from innovation and development to sustained, effective application of technology at the
194 scale needed for global conservation solutions. Such services would help support the full life-cycle
195 of a technology product, from materials to ongoing service, maintenance and recycling. These
196 services would also help scale-up solutions for global impact, from drawing board to manufacturing
197 and distribution of thousands of units. Other services like capacity building and best practice
198 guidelines would also support uptake of appropriate technology by the conservation community.
199 We identify three primary types of services (Fig.1); the relevance of specific services will depend
200 on the type of technology being developed (e.g. an electronic device vs a computer software).

201 *Guidance and technical support.* Consumer-level technology often does not deliver exactly
202 what conservation projects need. For example, an off-the-shelf drone may be ineffective for a
203 specific biodiversity monitoring task without substantial customization (Pirodda et al. 2017).
204 Conservation organizations are typically not familiar with or well equipped to manage engineering
205 design and product manufacture processes. Such organizations are likely to underestimate the skills
206 and resources required to customize fit-for-purpose technology. More broadly, technical support,
207 product maintenance and user training (e.g. field deployment techniques and/or data management
208 and analysis) are also essential to ensure a sustained and efficient use of technology. In the open-
209 source arena, needed services also include supporting the transition from prototypes (created by
210 small-scale developers such as university researchers or individual innovators) to ready-to-use
211 products by: purchasing batches; customizing the technology in-house to fit the needs of the
212 conservation clients; and, if required, pooling designs from the wider open-source technology

213 community, allowing for agile manufacturing. These services could support the development of
214 customized conservation technology products at a reduced cost compared to generic commercially-
215 developed ones.

216 *Financial support.* Conservation projects and funding cycles are often not naturally matched
217 to the requirements of technology design, development, iterative trialing, and the necessary failures
218 associated with testing new technology in early stages. Short-term development is substantially
219 easier to fund than the longer-term stages of the technology cycle, such as continued maintenance
220 and support, or upgrades as technology matures. Moreover, some organizations may not have
221 appropriate facilities to handle product commercialization. A financial *buffer* between technology
222 developers and users is needed to minimize the impact of these issues. The human and financial
223 resources required to sustain all the proposed services could be financed at least partly by
224 reinvesting part of the income generated from providing technological solutions to the conservation
225 community; this requires coordination when in a distributed collaborative open source setting.
226 Recent experiences (conservation technology initiatives that directly include revenue streams in
227 their plans since ideation; e.g. AudioMoth, Box 1) indicate there is a willingness to pay that
228 premium. Freelance developers could also be employed when needed to fill development gaps,
229 sustainably engaging with the wider open-source technology community. Furthermore, business-
230 oriented planning and evaluation practices that have not been part of the traditional conservation
231 community toolbox, but are essential for developing and producing technology (Iacona et al. in
232 accepted), could be provided.

233 *Knowledge clearing house.* Objective, transparent appraisals of any technology are required
234 to maximize trust with consumers and investors to expedite growth in development and uptake. A
235 neutral entity is needed to collate and analyze feedback from field trials (failures and successes),
236 synthesizing and providing independent advice (free of commercial interests) and honest appraisals
237 of the limitations of technology. Understandably, it is unlikely that commercial companies would
238 openly provide this kind of information. Best practice guidelines could be developed progressively,
239 ensuring that the drive for developing or commissioning conservation technologies are aligned with

240 conservation objectives and expectations, avoiding toxic motivations like the quest for novelty,
241 seeking media attention or the appeal to “play” with new gadgets. Ultimately, a broad
242 understanding of technology and conservation, coupled with recognized leadership, could lead to
243 conservation technology roadmaps being developed to help focus future development efforts into
244 those technologies of greater impact.

245 Many of the services above represent familiar concepts in the industry sector. Commercial
246 technology businesses have traditionally taken care of the complete *product pipeline* from ideation
247 to deployment and after-sales. But these services are currently either incomplete or non-existent in
248 the emerging approaches to developing technology for conservation (Box 2). Critical gaps in
249 essential services can break this pipeline and compromise the long-term viability of products by
250 disconnecting great conservation technology ideas and prototypes, from their potential users at a
251 global scale, driving the failure of many promising technology projects to deliver on-ground
252 benefits.

253 254 **The way forward: international leadership and service coordination**

255 We propose the establishment of an international entity that promotes the development and uptake
256 of conservation technology for global impact, ensuring the continuity and sustainability of the
257 conservation technology pipeline, from needs to support (Box 2). This entity would achieve its
258 mission by: (i) providing international leadership and coordinating conservation technology
259 development, within the broader technological landscape; (ii) coordinating the delivery of the
260 aforementioned key services to cover identified needs in a systematic way, with a business-oriented
261 mindset; and (iii) developing institutional links with global policy institutions (e.g. Convention on
262 Biological Diversity) and providing strategic advice regarding conservation technology.
263 Importantly, the conservation community should trust that this leadership, advice and services are
264 provided with independence and transparency, free of commercial interests.

265 We believe the combination of leadership, service provision and linkage to policy and
266 international institutions would provide solid grounds to progress conservation technology for

267 impact. The entity would be well placed to address the reasons behind the current lack of significant
268 progress, through several channels. (1) A globally-recognized and legitimized entity would have
269 strong leverage to attract the attention of a broad range of technologists (from individual *Makers* to
270 industrial companies) and connect them to the conservation community. (2) It could incentivize
271 small teams of developers to scale up their ideas and prototypes of technologies identified of high
272 impact for conservation and (3) support this scaling process to deliver mature products that are
273 either widely available or can be locally sourced, and that are viable over the longer-term, including
274 all steps in the technology pipeline. (4) It could also assist users (conservation researchers,
275 practitioners and policy makers) in their choice of appropriate technology and its effective and
276 efficient field deployment and use, in collaboration with other existing players in this field (e.g.
277 conservation technology online platforms and communities, conservation NGOs interested in
278 guidelines for technology use)

279 By working at the interface between developers and users of conservation technologies
280 (Fig.1), the conservation technology entity would act as a buffer that decouples the respective risks
281 and challenges of developers and users. It would *free small-scale developers* from the burden of
282 providing services like customer support, marketing and training, that may limit their capacity to
283 scale up and evolve their technology. This would allow them to concentrate their resources on their
284 core interest of developing technology for good. The services provided would also *shield the users*
285 from potential risks of working with non-commercial developers. For example, open-source designs
286 could safeguard users from a specific developer moving on to other ventures, providing continuity.
287 The global nature of this entity would also help connect the learnings from early technology
288 adopters who will risk failing at times (as part of their role) with late adopters that only use mature
289 technology for critical conservation projects that cannot afford failure.

290 Regardless of the exact nature of the proposed entity, we believe there are benefits in a two-
291 pronged approach (Fig 2). Our suggestion is inspired by the structure of the *Technology Mechanism*
292 of the United Nations Framework Convention on Climate Change (described in more detail in Box
293 3), created to enhance climate technology development and transfer to developing countries. On one

294 hand, the *policy arm* of the entity (akin to the Technology Executive Committee of the UNFCCC
295 Technology Mechanism) would provide leadership, strategic vision (e.g. identifying what
296 technologies to concentrate on), oversee technology development, and provide policy advice and
297 cross-institutional links with other intergovernmental entities regarding the use of conservation
298 technology. On the other hand, the *implementation arm* (akin to the Climate Technology Centre and
299 Network of the UNFCCC Technology Mechanism) would provide the key technical, financial and
300 knowledge support services discussed in the previous section. This could be a mixture of direct
301 provision and by nurturing and coordinating an international network of independent service
302 providers to fill critical gaps in the technology development pipeline (Box 2). This implementation
303 arm would function to identify and evaluate candidate technologies from developers, whether
304 individual innovators, research labs, conservation organizations, or private sector companies. These
305 processes would be informed by feedback from the conservation community.

306 **Exploring organizational models**

307 A range of organizational models could accommodate the roles we envisage for the proposed
308 conservation technology entity; we sketch here several options. On one end of the spectrum, it
309 could be loosely defined and consist of *open partnerships* between existing individual organizations
310 and foundations (e.g. conservation NGOs), collaborating to offer leadership and key
311 implementation services. Leading conservation organizations, private sector and research
312 universities could partner to deliver services that are available to all. Examples include computer
313 vision models and training datasets for camera trap data made available through specific multi-
314 institutional initiatives (e.g. <http://www.wildlifeinsights.org>), software tools for law enforcement
315 (SMART; <http://smartconservationtools.org>) or the Application Programming Interfaces (API)
316 approach deployed by Microsoft's *AI for Earth* program to provide machine-learning based
317 building blocks of new software services dedicated to biodiversity conservation. Other examples
318 include *NetHope* (<http://nethope.org>) that bring organizations together for a common purpose; or
319 online platforms specific to biodiversity, including *wildlabs.net*, a community of practice
320 encompassing conservationists and technologists, or Conservation X Labs' *Digital Makerspace*

321 (conservationxlabs.com/digital-makerspace), which allows conservation technology projects to
322 actively seek collaboration from technologists. Additionally, open committees could be formed to
323 service some of the needs regarding standards, guidance and knowledge (e.g. around new data
324 streams, modelling approaches or sensors). The main advantage of this pragmatic approach with a
325 loosely-defined distributed entity is that it would provide an agile and flexible starting point to “get
326 the ball rolling” based on existing organizations, in a way that is relatively easy to scale. To address
327 the much-needed financial resources gap, resource allocation could be spread across participating
328 organizations or a ‘conservation technology fund’ could back some or all of the services. As a start,
329 different components of this distributed entity might develop around specific types of technologies
330 (e.g. acoustic monitoring) in a more organic way. In contrast, a more mature version of this entity
331 would not be technology-specific but should be able to service a range of conservation
332 technologies, depending on identified priorities and gaps, with the type of services provided
333 matched to the needs of each type of technology. This higher level of coordination and global
334 leadership could be achieved if these distributed partnerships coalesced into a single entity through
335 a *global alliance* of conservation and technology stakeholders, who could collectively fund its
336 activities.

337 At the other end of the spectrum, the entity could be a formal institution, as a long-term
338 centralized solution with a broader technology scope. We suggest that this institution could be
339 intergovernmental. For instance, it could be shared among the United Nations Environment
340 Program (UNEP) and the United Nations Development Program (UNDP), which have the mandate
341 and capacity to establish links between countries, businesses and communities globally. While the
342 intergovernmental option would certainly take longer to establish and be more bureaucratic, we
343 believe it could provide stronger legitimacy for interacting with international policy, other
344 international organizations (e.g. in sustainable development), individual governments and the
345 industry. A UN-mandated institution could have leverage to attract technologists to contribute to
346 nature conservation, and generate interest and momentum for collaborative innovation. It would
347 keep a strong and explicit link to global biodiversity targets and agreements, including Article 16 of

348 the Convention on Biological Diversity which explicitly calls for a transfer of technology to
349 developing countries (Convention on Biological Diversity 1994). The *policy arm* of the institution
350 could be involved in exploring how technology can support the discussions under the
351 *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES), an
352 intergovernmental body created to strengthen the science-policy interface for biodiversity and
353 ecosystem services. Perhaps one of the strongest arguments for an intergovernmental institution is
354 that of funding and social justice. It could provide funding mechanisms not available through other
355 organizational structures, including formal instruments for nations to support economically the
356 global effort to scale up innovation for conservation of biodiversity and ecosystem services; and
357 opportunities for developed countries to contribute funds, know-how and technology to developing
358 countries. The challenge is to do so while avoiding creating new forms of technological and
359 economic dependency; open innovation might be key to achieve this. The financial commitment
360 from UN members to set up and fund the proposed institution can be at least partly offset by the
361 overall savings through efficiency in delivering on biodiversity commitments already made, as such
362 savings would derive from the institution's role as conservation technology catalyst. The arguments
363 outlined here to support the option an UN-based institution resonate with the mandates of the
364 abovementioned Technology Mechanism of the UNFCCC, within the context of climate change and
365 associated technologies.

366

367 **Conclusions**

368 Technology by itself will not solve our conservation problems. Economics, politics, culture, and
369 ethical, equity and welfare considerations will determine the success of conservation actions and
370 technology deployments therein (Sandbrook 2015, Driscoll et al. 2018). We also acknowledge the
371 significant institutional, logistical and political challenges to overcome for such an entity to be
372 created and become effective in realizing the potential of conservation technology – particularly if
373 intergovernmental. However, time is too short and resources too thin to achieve critical
374 conservation outcomes and halt degradation and species extinction without taking full advantage of

375 the power of modern technology. Tapping targeted and well-developed technological solutions is a
376 key part of the support needed for conservation to be effective in saving species and habitats. Thus,
377 it is time to coordinate efforts to overcome the challenges and impediments. The long-term viability
378 and growth of appropriate technology development, its uptake and use, can only be achieved
379 collectively, with some degree of coordination and institutional support.

380 A coordinated approach to provision of key services, global leadership and linkages to
381 global biodiversity policy would contribute to scaling up conservation efforts for global impact. The
382 entity we propose would connect conservationists, academia, industry and policy makers, anticipate
383 future technology changes, mobilize capacity by connecting key stakeholders in the innovation
384 chain, mitigate risks, and streamline the development pipeline for conservation technology. It would
385 ensure the long-term viability of useful conservation technology products, sustainably growing a
386 community of developers and users, and delivering benefits to both (Fig.1). The promotion and
387 support of open-source innovation could contribute to democratizing the development and use of
388 conservation technology, providing more equitable opportunities for individuals, small
389 organizations and developing countries (Convention on Biological Diversity 1994, Baden et al.
390 2015). With conservation technology coming out of age, and similar collaborations emerging for
391 developing scientific instrumentation and technology for sustainable development, now is the time
392 to establish the much-needed leadership, coordination and services that will deliver tangible results
393 for biodiversity conservation at global scales.

394

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498



500

501 Box 1: The recently developed *AudioMoth* acoustic device (<http://www.openacousticdevices.info>)

502 is one of the best existing examples of how technologist talent in a small independent team can

503 achieve global scale, supported by service provision within the context of open innovation.

504 *AudioMoth* was developed by Open Acoustic Devices, a team of university researchers, as open-

505 source technology; in a couple of years, it has become a popular device to assist monitoring for

506 conservation. It can be assembled for significantly lower cost than the purchase of commercially-

507 available units, and performs well in field conditions (Hill et al. 2018). Unlike commercial

508 alternatives, its processor can be programmed to run acoustic detection in-device. Both hardware

509 (electronic board) and software designs are freely available online, with electronic schematics in

510 CircuitHub (<http://circuitHub.com/projects/OpenAcoustics/AudioMoth>), who can also manufacture

511 it, and code in GitHub (<http://github.com/OpenAcousticDevices/AudioMoth-Project>). The hardware

512 and software can be modified by anyone with the appropriate skills. Pictures from field tests of

513 *AudioMoth* in New Forest (UK) in search of the rare New Forest cicada *Cicadetta montana* (A) and

514 in Belize's tropical forests to detect gunshots (B). In (C), testing variability between devices during

515 deployment in Belize.

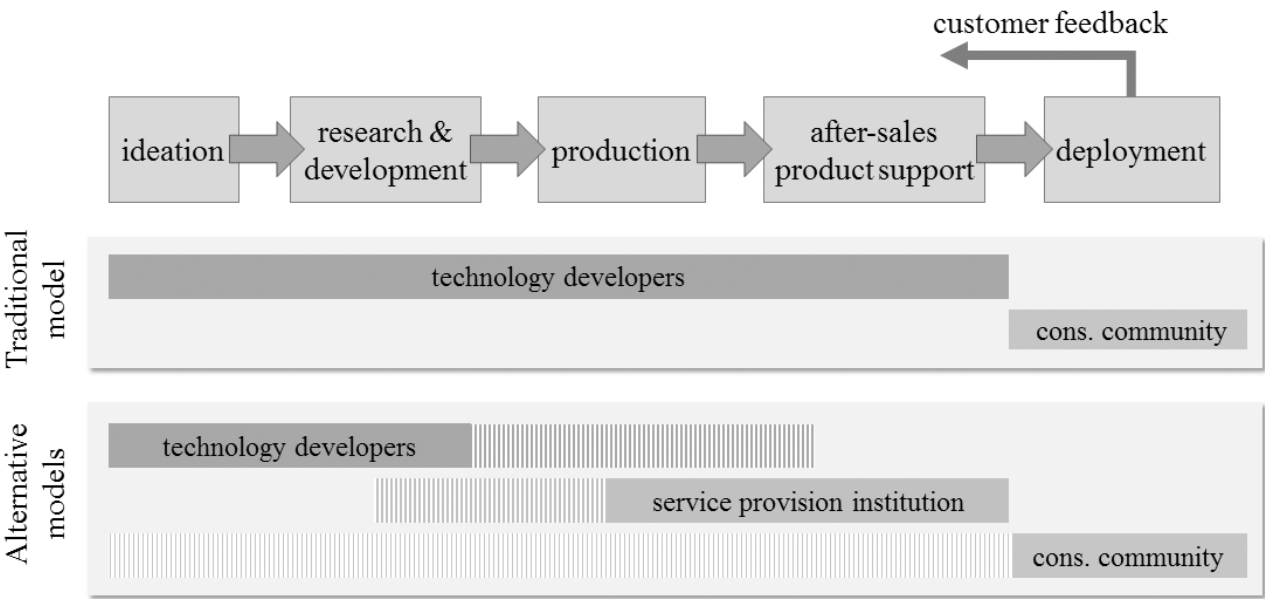
516 *AudioMoth* represents a rare example of service provision that supports conservation

517 technology development. Open Acoustics Devices designed the device but does not manufacture

518 nor sells it. The *Arribada Initiative* (<http://arribada.org>), a British-based conservation NGO
519 established by a Shuttleworth Foundation Fellow
520 (<https://www.shuttleworthfoundation.org/fellows/aldasair-davies>) has developed a group purchase
521 model in unison with Open Acoustic Devices in order to aggregate demand from those around the
522 world wishing to acquire *AudioMoth* units, and managing the shipping of the product. Pooling a
523 large order reduces the cost of manufacturing, hence driving down the overall cost of a single
524 device. Furthermore, any profits generated from the sale of devices are reinvested and made
525 available to Open Acoustic Devices as a funding source to develop future versions of this device,
526 fix bugs, or to cover support costs. This new approach ensures that the *AudioMoth* has a sustainable
527 development pipeline and that the original developers of open source conservation technologies are
528 supported and financed appropriately, while avoiding the hassle of dealing with ordering and
529 shipping.

530 *AudioMoth* and *Arribada Initiative* represent an example of ad hoc service provision.
531 The proposed conservation technology entity would have a greater capacity to provide or coordinate
532 similar services that could help many projects from small-scale teams to scale up their products for
533 global impact. In fact, organizations like *Arribada Initiative* could be part of the network of service
534 providers coordinated and supported by the *implementation arm* of the entity. Other small-scale
535 developments that could benefit from support and service provision include the open-source
536 *FieldKit* environmental sensing platform (by Conservify.org; [http://conservify.org/core-](http://conservify.org/core-projects/fieldkit)
537 [projects/fieldkit](http://conservify.org/core-projects/fieldkit)) or the *OpenCollar* initiative (<http://opencollar.io>) to develop a radio-collar platform
538 for tracking, as collaborative open innovation.

539



541

542 Box 2: The conservation technology *pipeline* represents the steps from idea (motivated by the

543 needs of the conservation community) to product deployment (by the conservation community).

544 Traditionally, commercial companies (developing either conservation-specific or consumer market

545 technology) develop an idea into a manufactured product and provide after-sales product support

546 (including services like warranty and repairs, training, updates). This approach works well for high-

547 volume consumer market products (e.g. a hand-held GPS unit) which are not specific for

548 conservation use; conservation-focused technology solutions tend to become expensive due to the

549 smaller target market. Newly emerging models of technology development (e.g. collaborative open-

550 source innovation) represent a big opportunity for conservation. In these, a developer designs a

551 product prototype but often does not manufacture it, and typically provides little or no after-sales

552 services (the varying degree of involvement in those steps is indicated by the greyed lined area).

553 Although some examples exist of conservation organizations taking ownership of the complete

554 pipeline (i.e. acting as technology developers), typically they remain technology users (indicated by

555 the greyed lined areas in other steps of the pipeline) and, of course, instigators of product ideas. We

556 propose that an international institution or alliance should take ownership of providing the missing

557 services, traditionally delivered by commercial companies, to cover the “new” gaps created between

558 developers and users, ensuring the flow of the conservation technology pipeline. Depending on the
559 case, provided services may extend into the research & development stages (greyed lined areas).
560

561 **Box 3 [text only]**

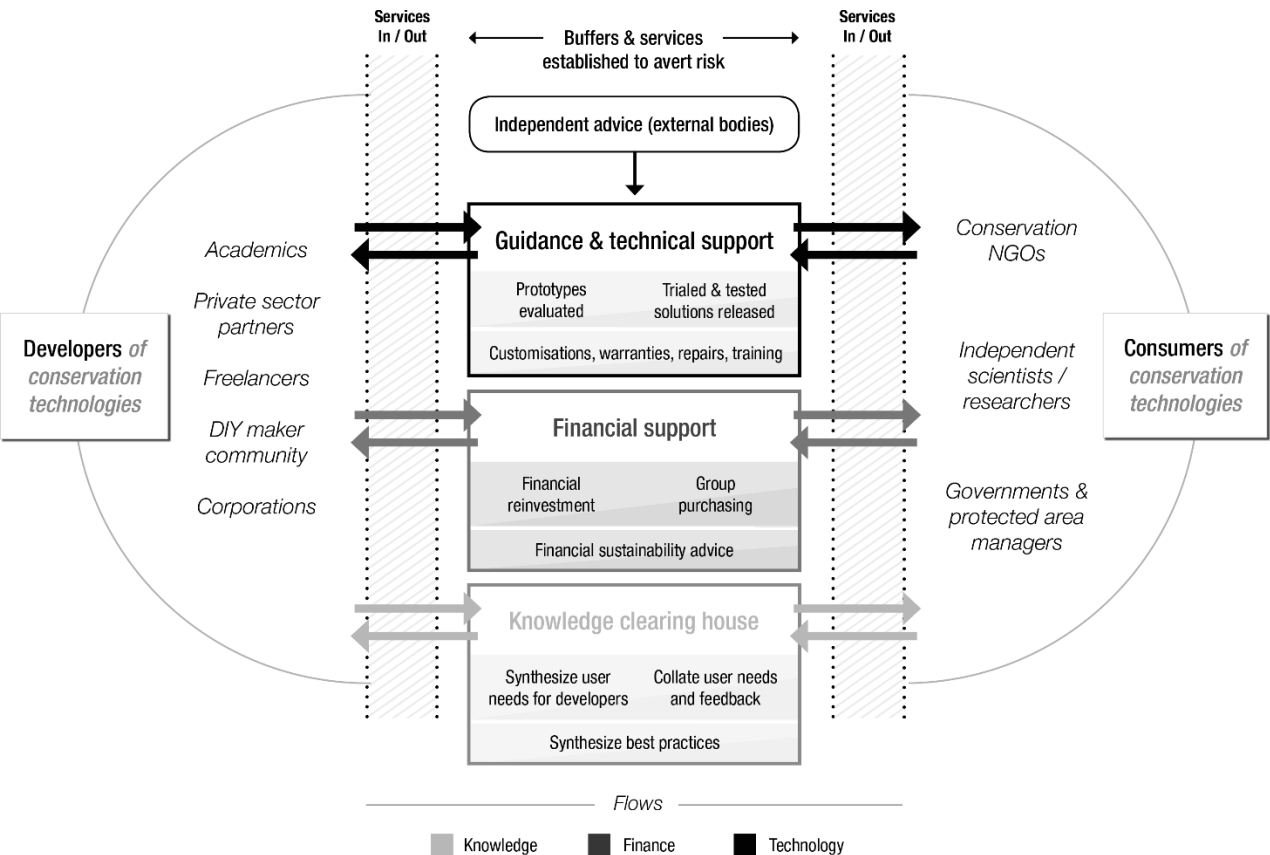
562

563 Box 3: Established in 2010, the *Technology Mechanism* of the United Nations Framework
564 Convention on Climate Change (UNFCCC) is dedicated to helping countries “to develop and
565 transfer climate technologies so that they can effectively reduce greenhouse gas emissions and
566 adapt to the adverse effects of the changing climate”. The UNFCCC’s Technology Mechanism
567 consists of two bodies, the *Technology Executive Committee* (TEC), and the *Climate Technology*
568 *Centre and Network* (CTCN).

569 The TEC provides high-level leadership and policy advice on linking climate technologies
570 with government policy, and identifies technology gaps and opportunities for member parties. It is
571 also charged with maintaining effective cross-institutional policy links with other intergovernmental
572 entities, such as the Global Environment Facility and Green Climate Fund. The CTCN, on the other
573 hand, is focused on providing technical assistance to its members, and enhancing the rate at which
574 technology is deployed on-ground through building networks between policy makers, technology
575 providers, and crucially, financiers. Together, these two arms of the Technology Mechanism assist
576 parties to the UNFCCC to develop climate-focused technology policies, foster collaborative
577 networks and access financing to fulfil their obligations and emissions reduction targets under the
578 Paris Agreement.

579 The critical nature of service provisioning is demonstrated by the CTCN, which includes a
580 coordinating center but also a large worldwide network of organizations (from academia, civil
581 society, research and the finance, private and public sectors) that deliver complementary services.
582 There is a demonstrable demand for the CTCN’s services, with a membership base that doubled
583 between 2015 to 2017, a concomitant 440% increase in requests for technical assistance and 350
584 projects registered for financial support.

585 **Figure 1**

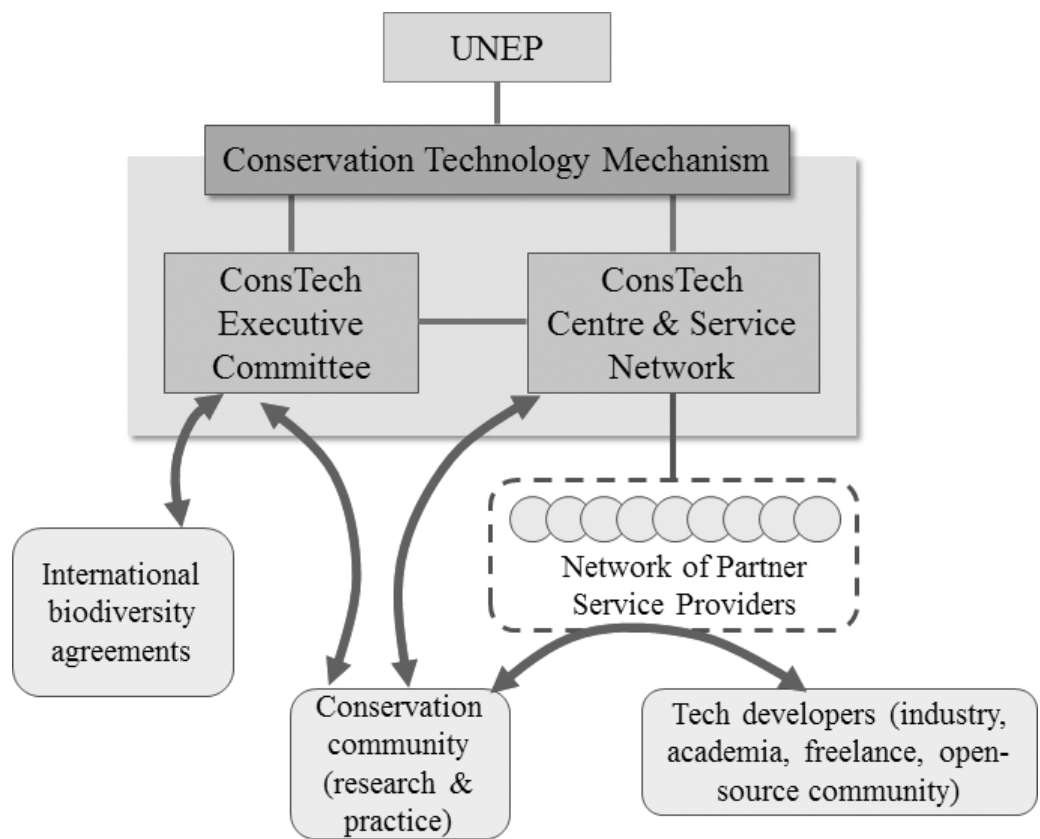


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587

588 Figure 1: Provision of critical services by the implementation arm of the proposed conservation
589 technology institution. We identify three critical types of services (technical, financial and
590 knowledge-related), tailored to address specific issues/concerns about how conservation
591 technologies are developed and used (see main text). These could be provided by a network of
592 independent third parties coordinated by the implementation arm. Such service provision would
593 help (i) free developers from some burdens that may limit their capacity to scale-up (from idea to
594 large-scale production and distribution) and evolve their technology, including customer support,
595 commercialization and marketing; and (ii) buffer some risks (e.g. investment) associated with
596 product commercialization. It would also shield the conservation community (the consumers) from
597 potential risks of working with non-commercial developers, ensuring technical support and training,
598 and safeguarding from the possibility of a specific developer moving on to other enterprises.

599 **Figure 2**



600

601

602 Figure 2: A potential organizational structure for a two-pronged formal intergovernmental
603 conservation technology institution, under the United Nations (e.g. UNEP). This vision is inspired
604 by the UNFCCC’s *Technology Mechanism* (Box 3). An *Executive Committee* would provide high-
605 level leadership and the policy connection to international biodiversity agreements. Service
606 provision would be secured by a *Centre & Service Network*, possibly as a mix of in-house services
607 and coordination of a *network of external service providers*. Together, they would fulfil the needs
608 highlighted in Fig.1, acting as interface between the conservation community and technology
609 developers in the industry, academia and open-source community. Alternatively, similar services
610 and leadership could be provided by an international alliance of conservation and technology
611 stakeholders, possibly emerging by coalescing a more loosely-defined distributed collaboration
612 between existing conservation organizations e.g. NGO, research and intergovernmental (see main
613 text).

614