**Contribution of RPAS in research and conservation in protected areas: present and future**

Jiménez López, Jesús; Mulero-Pázmány, Margarita

Department, University of Loja, Loja, Ecuador

Provide full correspondence details here including e-mail for the corresponding author

Provide short biographical notes on all contributors here if the journal requires them.

**Contribution of RPAS in research and conservation in protected areas: present and future**

During the past two decades, we have witnessed a growing interest in projects aimed to evaluate the feasibility of RPAS for conservation purposes, including environmental and wildlife monitoring or law enforcement. Beyond ethical and legal barriers impeding their integration in protected areas, it remains to be seen whether RPAS meet the requirements demanded by natural park managers. A bibliographic survey was carried out to search for potential RPAS applications supporting management and conservation actions aimed to reduce threats to biodiversity. We found that linking research investment with conservation priorities face technical and methodological challenges that could hinder the potential of RPAS to deliver a wide range of benefits to effective protected areas management.

Keywords: protected areas, RPAS, conservation

# Introduction

As defined by UICN, "a protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values" (Dudley 2008). Protected areas (PAs) have been declared under different reasons and circumstances but there is a consensus on its importance in safeguarding biodiversity, preserving ecosystem services and ensure persistence of the natural heritage (Watson et al. 2014; Chape, Spalding, and Jenkins 2008). Despite such praiseworthy intentions, PAs are subject to a wide variety of unforeseen challenges requiring rapid and effective solutions (Watson et al. 2014). Habitat change and fragmentation, pollution, overexploitation of natural resources, climate change and invasive species have been identified as the main global threats to biodiversity (Groom, Meffe, and Caroll 2006) . To curb the loss of biodiversity while attending other inherent activities, financial allocations have targeted, among others, staff recruitment and training, infrastructure and equipment, communication programs, tourism and recreational activities, law enforcement, support decision-making and disaster management, biodiversity monitoring, environmental assessment or actions aimed at strengthening educational and research programs.

Some aspects of above-mentioned conservation measurement have benefit from a wide range of technological advances, including remote sensors, field-based monitoring stations, manned surveys, camera traps, wildlife tracking devices, informatics and computing (Pimm et al. 2015). More recently, applications of remotely piloted aircraft systems (RPAS, also known as unmanned aerial systems, UAS, drones) have been the subject of a growing interest in both the civilian and scientific sphere (Rodríguez et al. 2012; Koh and Wich 2012; Anderson and Gaston 2013; Linchant et al. 2015a; Christie et al. 2016; Torresan et al. 2017). While obstacles remain, the use of RPAS for conservation purposes have receive a major emphasis and its feasibility reasonably proven. To date, however, it has not been adequately weighted whether RPAS meet the demands of decision-makers, which often face budgetary constraints and under-resourcing, limiting the accomplishment of management objectives (Watson et al. 2014). (Leverington et al. 2010) systematically reviewed outcomes from performance assessments of PAs across the world and revealed that “adequacy of infrastructure, equipment and facilities” was the closest management indicator related to overall effectiveness. Moreover, conservation practitioners identified a wide range of threats requiring appropriate management measurements. As a result, “biological resources use”, including hunting, logging and fishing, was pointed out as a major concern, scoring high globally. Nevertheless, RPAS for wildlife and habitat monitoring account for most of studies, while law enforcement of illegal activities has ostensibly received minor attention from the academia, despite the relevance. To bridge the gap between science and conservation priorities, we carried out an extensive literature revision to set the current state of RPAS for conservation purposes and rise knowledge to effectively mitigate threats and promote effective management to PAs from RPAS.

# Methods

A bibliographical review (see PRISMA Flowchart) of scientific articles, gray literature, postgraduate theses and websites was carried out, following a similar line to other related studies (Linchant et al. 2015b; Christie et al. 2016; Mulero-Pázmány et al. 2017). Last reference revised was published on X, 2017. The main tool for selecting bibliography was Google Scholar. Key search criteria, primarily in English, encompass RPAS in their various meanings and acronyms, reflecting the varied terminology used. Keywords were combined with terms referring to threats and common conservation measurements in PAs (see table 1) using logical disjunctions. A total of X search terms and X combinations were applied. A sweep of bibliographical citations and related articles was performed and further complemented with some other recent references found elsewhere (Research Gate, Mendeley Desktop, Review articles, Internet search engines). After removing duplicated results, more than 500 articles were collected. The remaining publications (x) were grouped according to the following categories: "wildlife monitoring and management", for feasibility studies facing alternative fauna population surveys and tracking methods; "monitoring and mapping of terrestrial and aquatic ecosystems", for habitat surveys; "Law enforcement" encompasses monitoring poaching, illegal logging and other illicit activities; "Ecotourism" is restricted to recreational activities and visitors management; "Environmental management and emergency response" span from environmental monitoring, risk assessment, disaster response to search and rescue activities. Common challenges to above categories are summarize within legal constraints and actions to minimize impact on fauna, while operational costs and technological advances are also considered, since all shape the feasibility of RPAS to approach conservation and environmental issues. Recent and representative examples in PAs are presented in tabular format (see table 2), identifying where the study was conducted, the expected accomplishments and technical specifications of the aerial platform. The guidelines for identifying management gaps were mainly based on the “Management effectiveness evaluation in protected areas – a global study” second edition (Leverington et al. 2010). As a result, possible scenarios for implementing RPAS as convenient tools to help achieve conservation goals in PAs are suggested, highlighting some trends and opportunities that apparently have not yet been adequately exploited.

# Results and discussion

## Wildlife Monitoring and Management

Wildlife surveys are considered essential for effective management of PAs. RPAS have mostly been applied for surveying large and medium size terrestrial mammals (Jain 2013; Barasona et al. 2014), birds (A. M. Wilson, Barr, and Zagorski 2017; J. C. Hodgson et al. 2016; Christie et al. 2016; Sardà-Palomera et al. 2012; Chabot and Bird 2012; Ratcliffe et al. 2015) , species relying on coastal and marine ecosystems (Colefax, Butcher, and Kelaher 2017; A. Hodgson, Peel, and Kelly 2017; W. R. Koski et al. 2015; Dulava, Bean, and Richmond 2015; Durban et al. 2015; W. R. Koski et al. 2009), to inspect breeding and nesting areas at inaccessible sites (Szantoi et al. 2017; Wich et al. 2016; Puttock et al. 2015; van Andel et al. 2015; Weissensteiner, Poelstra, and Wolf 2015) or as a complement for wildlife telemetry tracking methods (Christie et al. 2016; Bayram et al. 2016; Mulero-Pázmány et al. 2015; Körner et al. 2010; Cliff et al. 2015; Ordóñez-Delgado et al. 2016; Soriano, Caballero, and Ollero 2009). Summing up, authors mostly coincide on the broad potential of RPAS to complement census campaigns, traditionally carried out by ground-based crews, terrestrial vehicles, manned aircrafts or vessels. As becoming easier to operate, there are sufficient grounds to instruct rangers on the use of RPAS, who are often subject to time-consuming and often dangerous raids. If appropriate safety measures are taken, RPAS might be considered a less invasive, nonhazardous and reliable monitoring technique (Jewell 2013) compared with other methodologies requiring approaching, capturing or indirectly disturbing wildlife. Moreover, RPAS constitute a promising advance linking animal movement and remote sensing disciplines. For instance, wildlife and habitat interactions can be closely examine by having fine-scale and timely aerial images from places crossed by electronically tagged species.

## Monitoring and mapping of terrestrial and aquatic ecosystems

Operational deployment of RPAS to inform adaptive management has the potential to complement aerial remote sensing and earth observation (EO), surpassing spatio-temporal scale challenges at affordable cost and providing precise in-situ measurements (Gross, Goetz, and Cihlar 2009). Ecosystem mapping and monitoring projects using RPAS have increased notoriously both by governmental institutions (U.S. Geological Survey National 2017) and research groups. Studies on this topic range from quantifying the spread and detection rate of invasive species (Müllerová et al. 2016; Zaman, Jensen, and McKee 2011; Perroy, Sullivan, and Stephenson 2017; Müllerová et al. 2017; Michez et al. 2016), analyze the dynamic, structure and biophysical attributes of forest stands (Gini et al. 2012; Zahawi et al. 2015; Lisein et al. 2015; Kachamba et al. 2016; Gonzalez et al. 2016; Zhang et al. 2016; Getzin, Nuske, and Wiegand 2014; Getzin, Wiegand, and Schöning 2012; Ivosevic, Han, and Kwon 2017; Stark et al. 2017) or mapping sensitive shallow coastal habitats (Ventura et al. 2016; Casella et al. 2017) , wetlands (Chabot and Bird 2013) or riparian ecosystems (Husson 2016). RPAS has also been suggested as an appropriate tool for community-based forest monitoring (Paneque-Gálvez et al. 2014), encouraging engagement of local stakeholders. Performance in PAs is often compared to surroundings , where it is assume that higher rates of ecosystem degradation occur (Ewers and Rodrigues 2008). With reference to the above, efforts to design a standardized RPAS based surveying protocol remain fundamentally unexplored.

## Wildlife risk assessment and Management

RPAS constitute an attainable low-cost alternative to manually inspecting hazardous facilities and detecting ground nest or vulnerable species at agricultural fields where mechanical harvesting pose risk of death (Barasona et al. 2014; Lobermeier et al. 2015; Christiansen et al. 2014; Israel and Reinhard 2017; Mulero-Pázmány, Negro, and Ferrer 2013). A recent study registered wildlife night activity from a RPAS using a thermal camera to select suitable locations to install ecological corridors (Gülci and Akay 2016). Without going into discussion, some park managers may contemplate the use of RPAS for wildlife capture procedures, through devices adapted to release tranquilizing darts where otherwise manual approaching free-range animals is often considered ineffective, biased or dangerous. Caso elefante y jabali

## Law enforcement

RPAS have also relevance in the control and surveillance of PAs including poaching (Mulero-Pázmány et al. 2014; Franco et al. 2016; Olivares-Mendez et al. 2014) and other less contentious forbidden activities (Sabella et al. 2017). (Duffy 2014) analyzed the consequences of the militarization of conservation practices as an increasing trend in PAs around the world and illustrates the use of RPAS through several examples.

Nevertheless, effective implementation faces important technical and legal constraints that can explain the scarcity of scientific articles found. First, the reviewed literature mentions the need to design more efficient live vision systems. Low autonomy of RPAS is especially critical in large natural parks, limiting the area under surveillance, while issues concerning flying in bad weather conditions have not yet been completely resolved. (Banzi 2014) argues that RPAS fulfilling suitable specifications are costly, especially in developing countries. However, as technology increasingly becomes more accessible and sophisticated, it is expected that main barriers will appear in the legislative and social sphere. Often flying beyond the visual line of sight (BVLOS) and above a certain altitude is forbidden, limiting the effectiveness of the inspection. RPAS applied to surveillance of PAs is also questioned arguing human right breaching (Duffy 2014). Some detractors are skeptical about the ability of RPAS to persuade offenders, who in many cases go through a situation of great need. However, some studies have shown that the effectiveness of antipoaching depends to a large extent on a greater allocation of resources (Hilborn et al. 2006). Moreover, recording illegal activities within the limits of PAs can prove to be valid evidence against offenders. Probably the success of such initiatives requires a greater consensus among the parties involved and the development of strategies that seek to solve the causes of poaching.

## Ecotourism

Within the still scarce literature (King 2014) summarized possible recreational activities and formulas for granting RPAS flight permits in designated areas. (Hansen 2016; Park and Ewing 2017) valued the effectiveness of RPAS to monitor visitors activities in PAs and (Chamata and King 2017) proposed possible profitable concession scenarios. Stakeholders agreed on a set of policies to establish permitted activities with RPAS within tourist locations in Antarctica (Leary 2017). Other PAs opted for simpler rules (OEH 2017) or, not without valid reason, forbidden RPAS. A permissive use of RPAS for recreational purposes could result in visual and acoustic impact on the landscape, causing discomfort and risk to visitors and wildlife. It seems obvious that in hands of non-skilled operators, the risk of accidents and losses would increase. This can also lead to hazardous events, like water supply pollution or wildfires in sensitive areas due to the presence of flammable and toxic components, fueling the low popularity of RPAS in detriment of the benefits they bring. Even when the economic benefits and leisure possibilities are promising, it would be advisable to be cautious in the face of the demand of the ecotourism industry to incorporate RPAS in their activities.

# Environmental management and emergency response

RPAS has been adapted for sampling and remotely sensing pollution , biological and biochemical agents in water and air (Schwarzbach et al. 2014; Zang et al. 2012; Ore et al. 2015), mapping environmental risk factors for predicting zoonotic diseases (Fornace et al. 2014). but also coastal erosion dynamics (Casella et al. 2016, 2014), search and rescue missions (Van Tilburg et al. 2017), support eradication of feral species (McCaldin, Johnston, and Rieker 2015), and wildfires. Such applications have operational requirements which eventually are costly. For instance, sophisticated on-board instruments, gas powered engines for longer endurance and higher payloads or gear designed to assist sampling, hold cargo or deliver assistance.

Plausible scenarios include automate procedures to assess damage in trails and amenities after natural hazard events.

## Current Challenges

### Legal barriers and ethical constraints

RPAS operations faces important legal barriers that undermine their true potential in the civilian sphere (Stöcker et al. 2017). An overly restrictive regulatory framework is currently limiting the applications of RPAS in the field of conservation and their use has not been without problems, resulting in governments that have totally or partially prohibited RPAS operations in protected areas. This highlights the urgent need to seek consensus among countries and adapt legislation to distinguish amongst the purpose of leisure, research and management. Social and ethical

### Impact of RPAS on wildlife and ecosystems

Animal welfare and perturbation of sensitive habitat in wildlife management and ecological research is source of strong debate (F. Dormann et al. 2007; R. P. Wilson and McMahon 2006). RPAS are not exempt of discussion and consequently disturbance effects of RPAS on birds (Duriez et al. 2015; McEvoy, Hall, and McDonald 2016; Fletcher 2017; Scobie and Hugenholtz 2016; Weissensteiner, Poelstra, and Wolf 2015; Lyons et al. 2017) and mammals (Ditmer et al. 2015; Pomeroy, Connor, and Davies 2015) were documented. Despite a greater degree of awareness reflected in a emergent set of guidelines (J. C. Hodgson and Koh 2016; Mulero-Pázmány et al. 2017), most of studies marginally inform reactions and further trials aimed at quantifying changes in behavioral patterns and physiological effects targeting a broader group of wildlife is recommended. Also, we believe that development of RPAS platforms suited to wildlife projects remain fundamentally unexplored. Furthermore, an optimal trade-off between benefits and environmental costs should be weighted (Grémillet et al. 2012; Sepúlveda et al. 2010). By designing quieter, non-polluting and safer components, the impact on wildlife and ecosystems could be reduced and its objective observation facilitated (Jewell 2013; R. P. Wilson and McMahon 2006), reducing sources of bias. Nonetheless, RPAS has great potential to evolve, replacing more invasive monitoring techniques. This should be consciously considered by those reluctant to integrate RPAS in research and conservation activities. Step by step, a code of best practice and recommendations could be continuously updated based on lessons learned, forming the basis for the certified RPAS operators (McEvoy, Hall, and McDonald 2016).

### Costs of RPAS operation

From the economic point of view, expenses derived from the operation with RPAS are hardly quantifiable (AUVSI 2013) .While RPAS are relatively easy to operate, investment on technical and analytical expertise is not often adequately weighted. Computational requirements are also demanding, big data storage remains a challenge and certain phases of information processing requires the acquisition of pricey commercial software or alternatively the recruitment of high-level specialized services. Also, operations with RPAS are not exempt from accidents affecting both the structural components and captors, thus having a negative impact on the budget originally planned. Moreover, park rangers should be aware that there is no single solution covering all the conservation purposes (W. Koski 2010) and a trade-off analysis among available platforms should be pondered. While do-it-yourself (DIY) RPAS are often considered more versatile than commercial alternatives, time required for proper assembling and lack of experience could affect reliability. Suppliers often provide support, training and companion software, albeit services could be charged. Furthermore, coupled sensors are often the more expensive but also breakable parts of the platform. Despite these drawbacks, RPAS are increasingly being considered a cost-effective and safer alternative to manned aircraft and complement both ground surveys and satellite remote sensing.

### Technological advances

Massive amount of information is collected when remotely sensing ecosystems using ultra-high resolution sensors, resulting in storage, processing and methodological bottlenecks. When used for wildlife census, recurring to manual counting and identifying individuals is time consuming. Progress in computer vision and machine learning algorithms are intended to automate such procedures (Andrew and Shephard 2017; Chabot and Francis 2016; Gonzalez et al. 2016; Lhoest et al. 2015; van Gemert et al. 2015; Christiansen et al. 2014; Martin et al. 2012; Abd-Elrahman, Pearlstine, and Percival 2005; Longmore et al. 2017; Seymour et al. 2017). Despite encouraging results, these methods should be adapted to a broader range of species and probably implemented in more user-friendly packages. Also, further research should be encompassed to assess the overall performance of RPAS data collection techniques compared to more mature options where statistical and sampling methods to address the analysis and modeling of species distribution are available. On the contrary, the photogrammetric process is guaranteed from commercial software and emerging open source alternatives are promoted by institutions cita, at expense of major complexity. On the other hand, traditional pixel-based remote sensing classification algorithms are not suitable for fine-scale outcomes from RPAS cita, and further investment on machine learning techniques would be desirable (Piragnolo, Masiero, and Pirotti 2017). In general, we found that a solid technical and analytical background is required. This may could curb the applicability of RPAS in PAs, moreover when despite being strongly recognized to effective management, “adequacy of staff training” performs poorly overall.

# Conclusions

Park managers demands practical and cost-effective solutions to handle an overwhelming amount of environmental issues requiring appropriate decisions. Bridging the gap between science and conservation priorities require driving research to those critical aspects of management requiring realistic, cost-effective and innovative solutions. While RPAS have been called upon to revolutionize conservation, bottlenecks for integrating them into the PAs management toolset come from different fronts, ranging from social issues to operational challenges. However, being a relatively young discipline, conservation RPAS have gone far and have great potential to evolve and **inform design decision,** supporting a wide range of management measures to cope with underlying pressures protected areas face.

# References

Abd-Elrahman, Amr, Leonard Pearlstine, and Franklin Percival. 2005. “Development of Pattern Recognition Algorithm for Automatic Bird Detection from Unmanned Aerial Vehicle Imagery.” *Surveying and Land Information Science* 65 (1): 37.

Andel, Alexander C. van, Serge A. Wich, Christophe Boesch, Lian Pin Koh, Martha M. Robbins, Joseph Kelly, and Hjalmar S. Kuehl. 2015. “Locating Chimpanzee Nests and Identifying Fruiting Trees with an Unmanned Aerial Vehicle.” *American Journal of Primatology* 77 (10): 1122–34. doi:10.1002/ajp.22446.

Anderson, Karen, and Kevin J Gaston. 2013. “Lightweight Unmanned Aerial Vehicles Will Revolutionize Spatial Ecology.” *Frontiers in Ecology and the Environment* 11 (3): 138–46. doi:10.1890/120150.

Andrew, Margaret E, and Jill M Shephard. 2017. “Semi-Automated Detection of Eagle Nests: An Application of Very High-Resolution Image Data and Advanced Image Analyses to Wildlife Surveys.” doi:10.1002/rse2.38.

AUVSI. 2013. “Are UAS More Cost Effective than Manned Flights? | Association for Unmanned Vehicle Systems International.” *AUVSI*. http://www.auvsi.org/are-uas-more-cost-effective-manned-flights.

Banzi, Jamali Firmat. 2014. “A Sensor Based Anti-Poaching System in Tanzania.” *International Journal of Scientific and Research Publications* 4 (4): 1–7.

Barasona, José A., Margarita Mulero-Pázmány, Pelayo Acevedo, Juan J. Negro, María J. Torres, Christian Gortázar, and Joaquín Vicente. 2014. “Unmanned Aircraft Systems for Studying Spatial Abundance of Ungulates: Relevance to Spatial Epidemiology.” *PLoS ONE* 9 (12): 1–17. doi:10.1371/journal.pone.0115608.

Bayram, Haluk, Krishna Doddapaneni, Nikolaos Stefas, and Volkan Isler. 2016. “Active Localization of VHF Collared Animals with Aerial Robots,” no. 13: 74–75. doi:10.1109/COASE.2016.7743503.

Casella, Elisa, Antoine Collin, Daniel Harris, Sebastian Ferse, Sonia Bejarano, Valeriano Parravicini, James L. Hench, and Alessio Rovere. 2017. “Mapping Coral Reefs Using Consumer-Grade Drones and Structure from Motion Photogrammetry Techniques.” *Coral Reefs* 36 (1). Springer Berlin Heidelberg: 269–75. doi:10.1007/s00338-016-1522-0.

Casella, Elisa, Alessio Rovere, Andrea Pedroncini, Luigi Mucerino, Marco Casella, Luis Alberto Cusati, Matteo Vacchi, Marco Ferrari, and Marco Firpo. 2014. “Study of Wave Runup Using Numerical Models and Low-Altitude Aerial Photogrammetry: A Tool for Coastal Management.” *Estuarine, Coastal and Shelf Science* 149. Elsevier Ltd: 160–67. doi:10.1016/j.ecss.2014.08.012.

Casella, Elisa, Alessio Rovere, Andrea Pedroncini, Colin P. Stark, Marco Casella, Marco Ferrari, and Marco Firpo. 2016. “Drones as Tools for Monitoring Beach Topography Changes in the Ligurian Sea (NW Mediterranean).” *Geo-Marine Letters* 36 (2): 151–63. doi:10.1007/s00367-016-0435-9.

Chabot, Dominique, and David M Bird. 2012. “Evaluation of an off-the-Shelf Unmanned Aircraft System for Surveying Flocks of Geese.” *Waterbirds* 35 (1): 170–74. doi:10.1675/063.035.0119.

———. 2013. “Small Unmanned Aircraft: Precise and Convenient New Tools for Surveying Wetlands” 24 (June): 15–24.

Chabot, Dominique, and Charles M. Francis. 2016. “Computer-Automated Bird Detection and Counts in High-Resolution Aerial Images: A Review.” *Journal of Field Ornithology* 87 (4): 343–59. doi:10.1111/jofo.12171.

Chamata, Johnny Elie, and Lisa Marie King. 2017. “The Commercial Use of Drones in U.S. National Parks.” *The International Technology Management Review* 6 (4): 158–64.

Chape, Stuart, Mark Spalding, and Martin Jenkins. 2008. *The World’s Protected Areas: Status, Values and Prospects in the 21st Century*. *Prospects*. doi:10.1007/s10728-009-0140-1.

Christiansen, Peter, Kim A rild Steen, Rasmus N yholm Jørgensen, and Henrik Karstoft. 2014. “Automated Detection and Recognition of Wildlife Using Thermal Cameras.” *Sensors (Basel, Switzerland)* 14 (8): 13778–93. doi:10.3390/s140813778.

Christie, Katherine S., Sophie L. Gilbert, Casey L. Brown, Michael Hatfield, and Leanne Hanson. 2016. “Unmanned Aircraft Systems in Wildlife Research: Current and Future Applications of a Transformative Technology.” *Frontiers in Ecology and the Environment* 14 (5): 241–51. doi:10.1002/fee.1281.

Cliff, Oliver M, Robert Fitch, Salah Sukkarieh, Debra L Saunders, and Robert Heinsohn. 2015. “Online Localization of Radio-Tagged Wildlife with an Autonomous Aerial Robot System.” *Robotics Science and Systems*, no. November 2016: 1–9. doi:10.15607/RSS.2015.XI.042.

Colefax, Andrew P., Paul A. Butcher, and Brendan P. Kelaher. 2017. “The Potential for Unmanned Aerial Vehicles (UAVs) to Conduct Marine Fauna Surveys in Place of Manned Aircraft.” *ICES Journal of Marine Science*. doi:10.1093/icesjms/fsx100.

Ditmer, Mark A., John B. Vincent, Leland K. Werden, Jessie C. Tanner, Timothy G. Laske, Paul A. Iaizzo, David L. Garshelis, and John R. Fieberg. 2015. “Bears Show a Physiological but Limited Behavioral Response to Unmanned Aerial Vehicles.” *Current Biology* 25 (17). Elsevier Ltd: 2278–83. doi:10.1016/j.cub.2015.07.024.

Dudley, Nigel. 2008. *Guidelines for Protected Area Management Categories*. *System*. Vol. 3. doi:10.2305/IUCN.CH.2008.PAPS.2.en.

Duffy, Rosaleen. 2014. “Waging a War to Save Biodiversity: The Rise of Militarized Conservation.” *International Affairs* 90 (4): 819–34. doi:10.1111/1468-2346.12142.

Dulava, Sharon, William T. Bean, and Orien M. W. Richmond. 2015. “ENVIRONMENTAL REVIEWS AND CASE STUDIES: Applications of Unmanned Aircraft Systems (UAS) for Waterbird Surveys.” *Environmental Practice* 17 (3): 201–10. doi:10.1017/S1466046615000186.

Durban, J W, H Fearnbach, W L Perryman, and D J Leroi. 2015. “Photogrammetry of Killer Whales Using a Small Hexacopter Launched at Sea.” *Journal of Unmanned Vehicle Systems* 3 (June): 1–5. doi:dx.doi.org/10.1139/juvs-2015-0020.

Duriez, Olivier, Guillaume Boguszewski, Elisabeth Vas, and David Gre. 2015. “Approaching Birds with Drones: First Experiments and Ethical Guidelines ´,” 2015–18.

Ewers, Robert M., and Ana S.L. Rodrigues. 2008. “Estimates of Reserve Effectiveness Are Confounded by Leakage.” *Trends in Ecology and Evolution*. doi:10.1016/j.tree.2007.11.008.

F. Dormann, Carsten, Jana M. McPherson, Miguel B. Araújo, Roger Bivand, Janine Bolliger, Gudrun Carl, Richard G. Davies, et al. 2007. “Methods to Account for Spatial Autocorrelation in the Analysis of Species Distributional Data: A Review.” *Ecography* 30 (5): 609–28. doi:10.1111/j.2007.0906-7590.05171.x.

Fletcher, Stephanie B. Borrelle; Andrew T. 2017. “Will Drones Reduce Investigator Disturbance to Surface-Nesting Birds?” *Marine Ornithology* 45 (January): 89–94.

Fornace, Kimberly M., Chris J. Drakeley, Timothy William, Fe Espino, and Jonathan Cox. 2014. “Mapping Infectious Disease Landscapes: Unmanned Aerial Vehicles and Epidemiology.” *Trends in Parasitology*, October. Elsevier Ltd, 1–6. doi:10.1016/j.pt.2014.09.001.

Franco, Antonio Di, Pierre Thiriet, Giuseppe Di Carlo, Charalampos Dimitriadis, Patrice Francour, Nicolas L Gutiérrez, Alain Jeudy De Grissac, et al. 2016. “Five Key Attributes Can Increase Marine Protected Areas Performance for Small-Scale Fisheries Management.” *Nature Publishing Group*, no. November. Nature Publishing Group: 1–9. doi:10.1038/srep38135.

Gemert, Jan C van, Camiel R Verschoor, Pascal Mettes, Kitso Epema, Lian Pin Koh, and Serge Wich. 2015. “Nature Conservation Drones for Automatic Localization and Counting of Animals.” *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 8925: 255–70. doi:10.1007/978-3-319-16178-5\_17.

Getzin, Stephan, Robert S. Nuske, and Kerstin Wiegand. 2014. “Using Unmanned Aerial Vehicles (UAV) to Quantify Spatial Gap Patterns in Forests.” *Remote Sensing* 6 (8): 6988–7004. doi:10.3390/rs6086988.

Getzin, Stephan, Kerstin Wiegand, and Ingo Schöning. 2012. “Assessing Biodiversity in Forests Using Very High-Resolution Images and Unmanned Aerial Vehicles.” *Methods in Ecology and Evolution* 3 (2): 397–404. doi:10.1111/j.2041-210X.2011.00158.x.

Gini, R., D. Passoni, L. Pinto, and G. Sona. 2012. “Aerial Images From an Uav System: 3D Modeling and Tree Species Classification in a Park Area.” *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XXXIX-B1 (September): 361–66. doi:10.5194/isprsarchives-XXXIX-B1-361-2012.

Gonzalez, Luis F., Glen A. Montes, Eduard Puig, Sandra Johnson, Kerrie Mengersen, and Kevin J. Gaston. 2016. “Unmanned Aerial Vehicles (UAVs) and Artificial Intelligence Revolutionizing Wildlife Monitoring and Conservation.” *Sensors (Switzerland)* 16 (1). doi:10.3390/s16010097.

Grémillet, David, William Puech, Véronique Garçon, Thierry Boulinier, and Yvon Le Maho. 2012. “Robots in Ecology: Welcome to the Machine.” *Open Journal of Ecology* 2 (2): 49–57. doi:10.4236/oje.2012.22006.

Groom, Martha J, Gary Meffe, and C Ronald Caroll. 2006. “Principles of Conservation Biology” 3 (779): 63–109.

Gross, John E., Scott J. Goetz, and Josef Cihlar. 2009. “Application of Remote Sensing to Parks and Protected Area Monitoring: Introduction to the Special Issue.” *Remote Sensing of Environment* 113 (7). Elsevier B.V.: 1343–45. doi:10.1016/j.rse.2008.12.013.

Gülci, Sercan, and Abdullah Emin Akay. 2016. “Using Thermal Infrared Imagery Produced by Unmanned Air Vehicles to Evaluate Locations of Ecological Road Structures.” *Journal of the Faculty of Forestry Istambul University* 66 (2): 698–709. doi:10.17099/jffiu.76461.

Hansen, Andreas Skriver. 2016. “Applying Visitor Monitoring Methods in Coastal and Marine Areas – Some Learnings and Critical Reflections from Sweden.” *Scandinavian Journal of Hospitality and Tourism* 2250 (June): 1–18. doi:10.1080/15022250.2016.1155481.

Hilborn, Ray, Peter Arcese, Markus Borner, Justin Hando, Grant Hopcraft, Martin Loibooki, Simon Mduma, and Anthony R E Sinclair. 2006. “Effective Enforcement in a Conservation Area.” *Science* 314 (5803): 1266–1266. doi:10.1126/science.1132780.

Hodgson, Amanda, David Peel, and Natalie Kelly. 2017. “Unmanned Aerial Vehicles for Surveying Marine Fauna: Assessing Detection Probability.” *Ecological Applications* 27 (4): 1253–67. doi:10.1002/eap.1519.

Hodgson, Jarrod C., and Lian Pin Koh. 2016. “Best Practice for Minimising Unmanned Aerial Vehicle Disturbance to Wildlife in Biological Field Research.” *Current Biology* 26 (10). doi:10.1016/j.cub.2016.04.001.

Hodgson, Jarrod C, Shane M Baylis, Rowan Mott, Ashley Herrod, and Rohan H Clarke. 2016. “Precision Wildlife Monitoring Using Unmanned Aerial Vehicles.” *Scientific Reports* 6 (March). Nature Publishing Group: 22574. doi:10.1038/srep22574.

Husson, Eva. 2016. “Images from Unmanned Aircraft Systems for Surveying Aquatic and Riparian Vegetation.” Uppsala.

Israel, Martin, and Aline Reinhard. 2017. “Detecting Nests of Lapwing Birds with the Aid of a Small Unmanned Aerial Vehicle with Thermal Camera.” In *Unmanned Aircraft Systems (ICUAS), 2017 International Conference on*, 1199–1207.

Ivosevic, Bojana, Yong Gu Han, and Ohseok Kwon. 2017. “Calculating Coniferous Tree Coverage Using Unmanned Aerial Vehicle Photogrammetry.” *Journal of Ecology and Environment* 41 (1). Journal of Ecology and Environment: 4–11. doi:10.1186/s41610-017-0029-0.

Jain, Mukesh. 2013. “Unmanned Aerial Survey of Elephants.” *PLoS ONE*. doi:10.1371/ journal.pone.0054700.

Jewell, Zoe. 2013. “Effect of Monitoring Technique on Quality of Conservation Science.” *Conservation Biology* 27 (3): 501–8. doi:10.1111/cobi.12066.

Kachamba, Daud Jones, Hans Ole Ørka, Terje Gobakken, Tron Eid, and Weston Mwase. 2016. “Biomass Estimation Using 3D Data from Unmanned Aerial Vehicle Imagery in a Tropical Woodland.” *Remote Sensing* 8 (11): 1–18. doi:10.3390/rs8110968.

King, Lisa M. 2014. “Will Drones Revolutionise Ecotourism?” *Journal of Ecotourism* 13 (1): 85–92. doi:10.1080/14724049.2014.948448.

Koh, Lian Pin, and Serge A. Wich. 2012. “Dawn of Drone Ecology: Low-Cost Autonomous Aerial Vehicles for Conservation.” *Tropical Conservation Science* 5 (2): 121–32. doi:WOS:000310846600002.

Körner, Fabian, Raphael Speck, Ali Haydar, and Salah Sukkarieh. 2010. “Autonomous Airborne Wildlife Tracking Using Radio Signal Strength,” 107–12.

Koski, William. 2010. “An Inventory and Evaluation of Unmanned Aerial Systems for Offshore Surveys of Marine Mammals An Inventory and Evaluation of Unmanned Aerial Systems for Offshore Surveys of Marine Mammals,” no. March.

Koski, William R., Travis Allen, Darren Ireland, Greg Buck, Paul R. Smith, a. Michael Macrander, Melissa a. Halick, Chris Rushing, David J. Sliwa, and Trent L. McDonald. 2009. “Evaluation of an Unmanned Airborne System for Monitoring Marine Mammals.” *Aquatic Mammals* 35 (3): 347–57. doi:10.1578/AM.35.3.2009.347.

Koski, William R., Gayan Gamage, Andrew R. Davis, Tony Mathews, Bernard LeBlanc, and Steven H. Ferguson. 2015. “Evaluation of UAS for Photographic Re-Identification of Bowhead Whales, Balaena Mysticetus.” *Journal of Unmanned Vehicle Systems* 3 (1): 22–29. doi:10.1139/juvs-2014-0014.

Leary, David. 2017. “Drones on Ice: An Assessment of the Legal Implications of the Use of Unmanned Aerial Vehicles in Scientific Research and by the Tourist Industry in Antarctica.” *Polar Record*, no. May: 1–15. doi:10.1017/S0032247417000262.

Leverington, Fiona, Katia Lemos Costa, Jose Courrau, Helena Pavese, Christoph Nolte, Melitta Marr, Lauren Coad, et al. 2010. “Management Effectiveness Evaluation in Protected Areas – a Global Study. Second Edition 2010.” *Environmental Management* 46 (5): 685–98. doi:10.1007/s00267-010-9564-5.

Lhoest, S, J Linchant, S Quevauvillers, C Vermeulen, and P Lejeune. 2015. “How Many Hippos (Homhip): Algorithm for Automatic Counts of Animals with Infra-Red Thermal Imagery from UAV.” *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* 40 (3W3): 355–62. doi:10.5194/isprsarchives-XL-3-W3-355-2015.

Linchant, Julie, Jonathan Lisein, Jean Semeki, Philippe Lejeune, and Cédric Vermeulen. 2015a. “Are Unmanned Aircraft Systems (UASs) the Future of Wildlife Monitoring? A Review of Accomplishments and Challenges.” *Mammal Review* 45 (4): 239–52. doi:10.1111/mam.12046.

———. 2015b. “Are Unmanned Aircraft Systems (UASs) the Future of Wildlife Monitoring? A Review of Accomplishments and Challenges.” *Mammal Review* 45 (4): 239–52. doi:10.1111/mam.12046.

Lisein, Jonathan, Adrien Michez, Hugues Claessens, and Philippe Lejeune. 2015. “Discrimination of Deciduous Tree Species from Time Series of Unmanned Aerial System Imagery.” *PLoS ONE* 10 (11). doi:10.1371/journal.pone.0141006.

Lobermeier, Scott, Matthew Moldenhauer, Christopher Peter, Luke Slominski, Richard Tedesco, Marcus Meer, James Dwyer, Richard Harness, and Andrew Stewart. 2015. “Mitigating Avian Collision with Power Lines: A Proof of Concept for Installation of Line Markers via Unmanned Aerial Vehicle.” *Journal of Unmanned Vehicle Systems* 3 (4): 252–58. doi:10.1139/juvs-2015-0009.

Longmore, S. N., R. P. Collins, S. Pfeifer, S. E. Fox, M. Mulero-P??zm??ny, F. Bezombes, A. Goodwin, M. De Juan Ovelar, J. H. Knapen, and S. A. Wich. 2017. “Adapting Astronomical Source Detection Software to Help Detect Animals in Thermal Images Obtained by Unmanned Aerial Systems.” *International Journal of Remote Sensing* 38 (8–10): 2623–38. doi:10.1080/01431161.2017.1280639.

Lyons, Mitchell, Kate Brandis, Corey Callaghan, Justin Mccann, Charlotte Mills, Sharon Ryall, and Richard Kingsford. 2017. “Bird Interactions with Drones from Individuals to Large Colonies.” *bioRxiv*, 1–10. doi:10.1101/109926.

Martin, Julien, Holly H. Edwards, Matthew A. Burgess, H. Franklin Percival, Daniel E. Fagan, Beth E. Gardner, Joel G. Ortega-Ortiz, Peter G. Ifju, Brandon S. Evers, and Thomas J. Rambo. 2012. “Estimating Distribution of Hidden Objects with Drones: From Tennis Balls to Manatees.” *PLoS ONE* 7 (6): 1–8. doi:10.1371/journal.pone.0038882.

McCaldin, Guy, Michael Johnston, and Andrew Rieker. 2015. “Use of Unmanned Aircraft Systems to Assist with Decision Support for Land Managers on Christmas Island (Indian Ocean).” Australia.

McEvoy, John F., Graham P. Hall, and Paul G. McDonald. 2016. “Evaluation of Unmanned Aerial Vehicle Shape, Flight Path and Camera Type for Waterfowl Surveys: Disturbance Effects and Species Recognition.” *PeerJ* 4. doi:10.7717/peerj.1831.

Michez, Adrien, Hervé Piégay, Lisein Jonathan, Hugues Claessens, and Philippe Lejeune. 2016. “Mapping of Riparian Invasive Species with Supervised Classification of Unmanned Aerial System (UAS) Imagery.” *International Journal of Applied Earth Observation and Geoinformation* 44. Elsevier B.V.: 88–94. doi:10.1016/j.jag.2015.06.014.

Mulero-Pázmány, Margarita, Jose Ángel Barasona, Pelayo Acevedo, Joaquín Vicente, and Juan José Negro. 2015. “Unmanned Aircraft Systems Complement Biologging in Spatial Ecology Studies.” *Ecology and Evolution* 5 (21): 4808–18. doi:10.1002/ece3.1744.

Mulero-Pázmány, Margarita, Susanne Jenni-Eiermann, Nicolas Strebel, Thomas Sattler, Juan José Negro, and Zulima Tablado. 2017. “Unmanned Aircraft Systems as a New Source of Disturbance for Wildlife: A Systematic Review.” *PLoS ONE* 12 (6). doi:10.1371/journal.pone.0178448.

Mulero-Pázmány, Margarita, Juan José Negro, and Miguel Ferrer. 2013. “A Low Cost Way for Assessing Bird Risk Hazards in Power Lines: Fixed-Wing Small Unmanned Aircraft Systems.” *Journal of Unmanned Vehicle Systems* 2 (1). NRC Research Press: 5–15.

Mulero-Pázmány, Margarita, Roel Stolper, L. D. Van Essen, Juan J. Negro, and Tyrell Sassen. 2014. “Remotely Piloted Aircraft Systems as a Rhinoceros Anti-Poaching Tool in Africa.” *PLoS ONE* 9 (1): 1–10. doi:10.1371/journal.pone.0083873.

Müllerová, Jana, Josef Brůna, Tomáš Bartaloš, Petr Dvořák, Michaela Vítková, and Petr Pyšek. 2017. “Timing Is Important: Unmanned Aircraft vs. Satellite Imagery in Plant Invasion Monitoring.” *Frontiers in Plant Science* 8 (May). doi:10.3389/fpls.2017.00887.

Müllerová, Jana, Josef Brůna, Petr Dvořák, Tomáš Bartaloš, and Michaela Vítková. 2016. “Does the Data Resolution/origin Matter? Satellite, Airborne and UAV Imagery to Tackle Plant Invasions.” *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* 41 (July): 903–8. doi:10.5194/isprsarchives-XLI-B7-903-2016.

OEH. 2017. “Drones in Parks Policy.” *NSW Environment & Heritage*. Accessed October 19. http://www.environment.nsw.gov.au/topics/parks-reserves-and-protected-areas/park-policies/drones-in-parks.

Olivares-Mendez, Miguel A, Tegawendé F Bissyandé, Kannan Somasundar, Jacques Klein, Holger Voos, and Yves Le Traon. 2014. “The NOAH Project: Giving a Chance to Threatened Species in Africa with UAVs.” *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST* 135 LNICST: 198–208. doi:10.1007/978-3-319-08368-1\_24.

Ordóñez-Delgado, Leonardo, Gustavo Tomás, Diego Armijos-Ojeda, Andrea Jara-Guerrero, Rodrigo Cisneros, and Carlos Iván Espinosa. 2016. “New Contributions to the Knowledge of Birds in Tumbesian Region; Conservation Implications of the Dry Forest Biosphere Reserve, Zapotillo, Ecuador.” *Ecosistemas* 25 (2): 13–23. doi:10.7818/ECOS.2016.25-2.03.

Ore, John Paul, Sebastian Elbaum, Amy Burgin, and Carrick Detweiler. 2015. “Autonomous Aerial Water Sampling.” *Journal of Field Robotics* 32 (8): 1095–1113. doi:10.1002/rob.21591.

Paneque-Gálvez, Jaime, Michael K. McCall, Brian M. Napoletano, Serge A. Wich, and Lian Pin Koh. 2014. “Small Drones for Community-Based Forest Monitoring: An Assessment of Their Feasibility and Potential in Tropical Areas.” *Forests* 5 (6): 1481–1507. doi:10.3390/f5061481.

Park, Keunhyun, and Reid Ewing. 2017. “The Usability of Unmanned Aerial Vehicles (UAVs) for Measuring Park-Based Physical Activity.” *Landscape and Urban Planning* 167 (June). Elsevier: 157–64. doi:10.1016/j.landurbplan.2017.06.010.

Perroy, Ryan L., Timo Sullivan, and Nathan Stephenson. 2017. “Assessing the Impacts of Canopy Openness and Flight Parameters on Detecting a Sub-Canopy Tropical Invasive Plant Using a Small Unmanned Aerial System.” *ISPRS Journal of Photogrammetry and Remote Sensing* 125. International Society for Photogrammetry and Remote Sensing, Inc. (ISPRS): 174–83. doi:10.1016/j.isprsjprs.2017.01.018.

Pimm, Stuart L, Sky Alibhai, Richard Bergl, Alex Dehgan, Chandra Giri, Zoë Jewell, Lucas Joppa, Roland Kays, and Scott Loarie. 2015. “Emerging Technologies to Conserve Biodiversity.” *Trends in Ecology & Evolution* 30 (11). Elsevier Ltd: 685–96. doi:10.1016/j.tree.2015.08.008.

Piragnolo, Marco, Andrea Masiero, and Francesco Pirotti. 2017. “Open Source R for Applying Machine Learning to RPAS Remote Sensing Images.” *Open Geospatial Data, Software and Standards* 2 (1): 16. doi:10.1186/s40965-017-0033-4.

Pomeroy, P, L O Connor, and P Davies. 2015. “Assessing Use of and Reaction to Unmanned Aerial Systems in Gray and Harbor Seals during Breeding and Molt in the UK.” *Journal of Unmanned Vehicle Systems* 113 (September): 102–13.

Puttock, A.K., A.M. Cunliffe, K. Anderson, and R.E. Brazier. 2015. “Aerial Photography Collected with a Multirotor Drone Reveals Impact of Eurasian Beaver Reintroduction on Ecosystem Structure 1.” *Journal of Unmanned Vehicle Systems* 3 (3): 123–30. doi:10.1139/juvs-2015-0005.

Ratcliffe, Norman, Damien Guihen, Jeremy Robst, Sarah Crofts, Andrew Stanworth, and Peter Enderlein. 2015. “A Protocol for the Aerial Survey of Penguin Colonies Using UAVs.” *Journal of Unmanned Vehicle Systems* 3 (3): 95–101. doi:10.1139/juvs-2015-0006.

Rodríguez, Airam, Juan J. Negro, Mara Mulero, Carlos Rodríguez, Jesús Hernández-Pliego, and Javier Bustamante. 2012. “The Eye in the Sky: Combined Use of Unmanned Aerial Systems and GPS Data Loggers for Ecological Research and Conservation of Small Birds.” *PLoS ONE* 7 (12). doi:10.1371/journal.pone.0050336.

Sabella, Giorgio, Fabio Massimo Viglianisi, Sergio Rotondi, and Filadelfo Brogna. 2017. “Preliminary Observations on the Use of Drones in the Environmental Monitoring and in the Management of Protected Areas. The Case Study of ‘R.N.O. Vendicari’, Syracuse (Italy)” 8 (1): 79–86.

Sardà-Palomera, Francesc, Gerard Bota, Carlos Viñolo, Oriol Pallarés, Víctor Sazatornil, Lluís Brotons, Spartacus Gomáriz, and Francesc Sardà. 2012. “Fine-Scale Bird Monitoring from Light Unmanned Aircraft Systems.” *Ibis* 154 (1): 177–83. doi:10.1111/j.1474-919X.2011.01177.x.

Schwarzbach, Marc, Maximilian Laiacker, Margarita Mulero-Pazmany, and Konstantin Kondak. 2014. “Remote Water Sampling Using Flying Robots.” *2014 International Conference on Unmanned Aircraft Systems, ICUAS 2014 - Conference Proceedings*, 72–76. doi:10.1109/ICUAS.2014.6842240.

Scobie, Corey A., and Chris H. Hugenholtz. 2016. “Wildlife Monitoring with Unmanned Aerial Vehicles: Quantifying Distance to Auditory Detection.” *Wildlife Society Bulletin* 40 (4): 781–85. doi:10.1002/wsb.700.

Sepúlveda, Alejandra, Mathias Schluep, Fabrice G Renaud, Martin Streicher, Ruediger Kuehr, Christian Hagelüken, and Andreas C Gerecke. 2010. “A Review of the Environmental Fate and Effects of Hazardous Substances Released from Electrical and Electronic Equipments during Recycling: Examples from China and India.” *Environmental Impact Assessment Review* 30 (1). Elsevier Inc.: 28–41. doi:10.1016/j.eiar.2009.04.001.

Seymour, A. C., J. Dale, M. Hammill, P. N. Halpin, and D. W. Johnston. 2017. “Automated Detection and Enumeration of Marine Wildlife Using Unmanned Aircraft Systems (UAS) and Thermal Imagery.” *Scientific Reports* 7: 45127. doi:10.1038/srep45127.

Soriano, P, F Caballero, and A Ollero. 2009. “RF-Based Particle Filter Localization for Wildlife Tracking by Using an UAV.” *40 Th International Symposium of Robotics*, 239–44.

Stark, Danica J., Ian P. Vaughan, Luke J. Evans, Harjinder Kler, and Benoit Goossens. 2017. “Combining Drones and Satellite Tracking as an Effective Tool for Informing Policy Change in Riparian Habitats: A Proboscis Monkey Case Study.” *Remote Sensing in Ecology and Conservation*, no. Manyangadze 2009: 1–9. doi:10.1002/rse2.51.

Stöcker, Claudia, Rohan Bennett, Francesco Nex, Markus Gerke, and Jaap Zevenbergen. 2017. “Review of the Current State of UAV Regulations.” *Remote Sensing* 9 (5): 459. doi:10.3390/rs9050459.

Szantoi, Zoltan, Scot E. Smith, Giovanni Strona, Lian Pin Koh, and Serge A. Wich. 2017. “Mapping Orangutan Habitat and Agricultural Areas Using Landsat OLI Imagery Augmented with Unmanned Aircraft System Aerial Photography.” *International Journal of Remote Sensing* 38 (8–10). Taylor & Francis: 1–15. doi:10.1080/01431161.2017.1280638.

Tilburg, Christopher Van, S.T. Brown, M. Ferguson, and et al. 2017. “First Report of Using Portable Unmanned Aircraft Systems (Drones) for Search and Rescue.” *Wilderness & Environmental Medicine* 15 (0). Elsevier Inc.: 12. doi:10.1016/j.wem.2016.12.010.

Torresan, Chiara, Andrea Berton, Federico Carotenuto, Salvatore Filippo Di Gennaro, Beniamino Gioli, Alessandro Matese, Franco Miglietta, Carolina Vagnoli, Alessandro Zaldei, and Luke Wallace. 2017. “Forestry Applications of UAVs in Europe: A Review.” *International Journal of Remote Sensing* 38 (8–10). Taylor & Francis: 2427–47. doi:10.1080/01431161.2016.1252477.

U.S. Geological Survey National. 2017. “U.S. Geological Survey National Unmanned Aircraft Systems (UAS) Project.” Accessed September 20. https://uas.usgs.gov/.

Ventura, Daniele, Michele Bruno, Giovanna Jona Lasinio, Andrea Belluscio, and Giandomenico Ardizzone. 2016. “A Low-Cost Drone Based Application for Identifying and Mapping of Coastal Fish Nursery Grounds.” *Estuarine, Coastal and Shelf Science* 171. doi:10.1016/j.ecss.2016.01.030.

Watson, James E. M., Nigel Dudley, Daniel B. Segan, and Marc Hockings. 2014. “The Performance and Potential of Protected Areas.” *Nature* 515 (7525): 67–73. doi:10.1038/nature13947.

Weissensteiner, M H, J W Poelstra, and J B W Wolf. 2015. “Low-Budget Ready-to-Fly Unmanned Aerial Vehicles: An Effective Tool for Evaluating the Nesting Status of Canopy-Breeding Bird Species.” *Journal of Avian Biology* 46 (4): 425–30. doi:10.1111/jav.00619.

Wich, Serge, David Dellatore, Max Houghton, Rio Ardi, and Lian Pin Koh. 2016. “A Preliminary Assessment of Using Conservation Drones for Sumatran Orangutan (Pongo Abelii) Distribution and Density.” *Journal of Unmanned Vehicle Systems* 4 (1): 45–52. doi:10.1139/juvs-2015-0015.

Wilson, Andrew M, Janine Barr, and Megan Zagorski. 2017. “The Feasibility of Counting Songbirds Using Unmanned Aerial Vehicles.” *The Auk* 134 (2): 350–62. doi:10.1642/AUK-16-216.1.

Wilson, Rory P, and and Clive R McMahon. 2006. “Measuring Devices on Wild Animals: What Constitutes Acceptable Practice?” *Frontiers in Ecology and the Environment* 4 (3): 147–54. doi:10.1890/1540-9295(2006)004.

Zahawi, Rakan A, Jonathan P Dandois, Karen D Holl, Dana Nadwodny, J Leighton Reid, and Erle C Ellis. 2015. “Using Lightweight Unmanned Aerial Vehicles to Monitor Tropical Forest Recovery.” *Biological Conservation* 186 (June). Elsevier Ltd: 287–95. doi:10.1016/j.biocon.2015.03.031.

Zaman, Bushra, Austin M. Jensen, and Mac McKee. 2011. “Use of High-Resolution Multispectral Imagery Acquired with an Autonomous Unmanned Aerial Vehicle to Quantify the Spread of an Invasive Wetlands Species.” *International Geoscience and Remote Sensing Symposium (IGARSS)*, 803–6. doi:10.1109/IGARSS.2011.6049252.

Zang, Wenqian, Jiayuan Lin, Yangchun Wang, and Heping Tao. 2012. “Investigating Small-Scale Water Pollution with UAV Remote Sensing Technology.” *World Automation Congress*, no. Puerto Vallarta, Mexico, 2012: 1–4.

Zhang, Jian, Jianbo Hu, Juyu Lian, Zongji Fan, Xuejun Ouyang, and Wanhui Ye. 2016. “Seeing the Forest from Drones: Testing the Potential of Lightweight Drones as a Tool for Long-Term Forest Monitoring.” *Biological Conservation* 198: 60–69. doi:10.1016/j.biocon.2016.03.027.

Management effectiveness evaluation in protected areas – a global study. Second edition 2010

Table 1. Threats and pressures (Leverington et al. 2010)

|  |  |
| --- | --- |
| **Threats and pressures** | |
| **Pressures** | **Threats** |
| Demographic growths |  |
| Climate change | Agriculture |
| Natural resource consumption | Poaching, Encroachment, logging, hunting , grazing, harvesting, gathering non-timber products, |
| Mining |  |
|  |  |
|  |  |
|  | |

Table 2. Management measurements

Tablet 3. Recent examples of studies

Table 4. Factors accounting for cost