Lessons Learned While Establishing an Unmanned Aircraft Program at a State Natural Resource Management Agency

Anthony V. Fernando[1]**,** *Arkansas Game and Fish Commission, 1266 Lock and Dam Rd, Russellville, AR 72802*

Trey Reid, *Arkansas Game and Fish Commission, 2 Natural Resources Dr, Little Rock, AR 72205*

Scott A. Wyatt, *Arkansas Game and Fish Commission, 2 Natural Resources Dr, Little Rock, AR 72205*

Brian T. Aston, *Arkansas Game and Fish Commission, 2 Natural Resources Dr, Little Rock, AR 72205*

Abstract: The Arkansas Game and Fish Commission (AGFC) conducted 56 h of unmanned aircraft operations between February 2017 and April 2018. Operations involved video and still photography for both scientific and public outreach purposes, mapping, and live surveillance. Some operations were conducted under the small unmanned aircraft rule (Title 14 Code of Federal Regulations §107) established by the Federal Aviation Administration (FAA), while some were conducted under the terms of a Certificate of Authorization from the FAA. The initial training program consisted of a 32-h in-person class. After gaining operational experience, subsequent training expanded to a 112-h class with greater emphasis on hands-on flight experience. We also provide brief reports of four accidents involving small Unmanned Aerial Systems (sUAS), most of which occurred during training. Inexperienced pilots should be limited to low-risk projects until they gain operational experience.

Key words: sUAS, drone, accidents, training, operations

Journal of the Southeastern Association of Fish and Wildlife Agencies 6:100–106

Low-cost, small Unmanned Aerial Systems (sUAS) are readily available at many retailers. Numerous applications of sUAS have been demonstrated in natural resource management (Chabot and Bird 2015) such as habitat mapping (Birdsong et al. 2015), counting animals or breeding structures (Groves et al. 2016, Johnston et al. 2017), and estimating wildlife impacts on crops (Michez et al. 2016). However, relatively little information is available on training, agency policies, or standard operating procedures (SOPs) pertaining to use of sUAS. This creates difficulty for agencies intending to implement an sUAS program.

The Arkansas Game and Fish Commission (AGFC) began exploring the use of sUAS in 2013 to conduct mapping, search and rescue, and surveillance operations (AGFC 2013). Two Blade 350QX quadcopters were acquired by AGFC in 2013. At the time, AGFC personnel involved in the acquisition were unaware of any operating restrictions or licensing requirements for sUAS (AGFC 2013). The AGFC took delivery of the sUAS two days prior to the Federal Aviation Administration (FAA) issuing guidance on implementation of the unmanned aircraft portion of the 2012 FAA Modernization Act. This included the creation of the Certificate of Authorization (COA) and Section 333 exemption processes (described below) for commercial and government use of sUAS in the National Airspace System. The guidance included requirements for registration of sUAS as aircraft. Pilots of sUAS were also required to have a pilot certificate. The two sUAS were registered by AGFC in 2014, but no agency personnel working on the sUAS project had a pilot certificate, and an application for a COA by AGFC was rejected for lack of detail the same year. Guidance by the FAA was insufficient to allow AGFC employees without aviation experience to revise the COA application, and the program was allowed to languish.

At the end of 2016, a fisheries biologist was hired by AGFC who had experience as an airline pilot. This employee obtained a remote pilot certificate and revised AGFC's COA application, allowing sUAS operations to be conducted under both civil and public aircraft regulations. This paper offers a description of the regulatory environment encountered by AGFC for operating sUAS as it pertains to government agencies, a description of our training program, and an overview of specific sUAS applications by AGFC. We believe this information will be useful for other state agencies to consider as similar training and operating procedures are developed for sUAS.

1. Current address: Minnesota Department of Transportation, Office of Aeronautics, 222 E Plato Blvd MS 410, St. Paul, MN 55107

Current Regulatory Framework

The FAA and other agencies (FAA 2016a) regulate sUAS as aircraft. Government entities have the option of operating sUAS either under "public aircraft" or "civil aircraft" rules. Public aircraft rules require the operating agency to obtain a COA or waiver from the FAA to operate sUAS; however, agencies (e.g., U.S. National Aeronautics and Space Administration and U.S. Department of Defense) that had pre-existing memorandums of understanding or letters of agreement between themselves and the FAA were allowed to continue operating under the terms of those agreements (FAA 2016a). The COA specifies the terms and operating conditions the permitted agency must function within in order to operate sUAS, and can be unique to each operator based on the needs, experience, and training program of the applying agency. Importantly, pilots flying under public aircraft rules do not necessarily need to be certified by the FAA if the FAA has already approved the training and certification program of the government agency. This may allow greater flexibility to interested agencies for training and certifying sUAS pilots if sending employees through commercial remote pilot training and licensing programs is not feasible.

In the context of manned aviation, civil aircraft rules cover all aircraft operation not specified in advance to be public aircraft operations. The FAA Modernization Act of 2012 required the FAA to not increase regulation of model aircraft hobbyists (FAA 2016). As a result, two branches of civil aircraft rules exist for sUAS operation; Title 14 Code of Federal Regulations (CFR) §101 covers recreational use of model aircraft, which specifies that those rules only apply if "the aircraft is flown strictly for hobby or recreational use" (14 CFR §101.41[a]). Thus, the 14 CFR §101 framework does not apply to agency personnel in the context of agency operations. The other branch of civil aircraft regulation for sUAS is the small aircraft rule, which replaced the Section 333 exemption process (FAA 2016b). Section 333 exemptions were individually tailored by the FAA to each applicant and specified operational limitations and pilot certification requirements. On 29 August 2016, the small unmanned aircraft rule was implemented as 14 CFR §107 (FAA 2016a). Among other changes, this created the remote pilot certificate, required registration of sUAS, and allowed for within line-of-sight operations of sUAS during daylight hours only. Most provisions of 14 CFR §107 can be waived if an operator can provide assurances that they can otherwise safely complete their proposed sUAS flight operation.

The first AGFC pilot obtained a remote pilot certificate on 29 January 2017 which allowed us to conduct initial operations. The AGFC was issued a COA on 27 September 2017, giving us the ability to self-certify remote pilots and to establish pathways for obtaining short notice access to controlled airspace not readily available to operations under 14 CFR §107. In practice, we did not need short notice access, and, in fact, the need for a COA to do so has been eliminated by introduction of the Low Altitude Authorization Notification Capability (LAANC, FAA 2018b).

The operating conditions and limitations imposed by the COA were similar to the operating conditions and limitations for civil manned aircraft under the small aircraft rule (Table 1); however, there were a few differences. Under the COA, AGFC sUAS pilots were required to file a Notice to Airmen (NOTAM) at least 24 h prior to each flight, which, in effect, notifies manned aircraft pilots of the sUAS operation. Operators flying under 14 CFR §107, however, were unable to file NOTAMS. With the COA, AGFC had permission to fly at night with anti-collision lighting visible for at least three statute miles. Additionally, AGFC pilots under the COA were required to remain two to five nautical miles from airports; however, pilots under 14 CFR §107 had no such restrictions. There were also minor differences in the timeframe for reporting accidents; under the COA, accidents needed to be reported to the FAA within 24 h, while under 14 CFR §107 a pilot had up to 10 days to report the accident. In both cases, accidents had to be reported if damage to property exceeded $500 or if serious injury occurred.

Table 1. Comparison of selected flight limitations between Title 14 Code of Federal Regulations §107 (Small Unmanned Aircraft Systems) and Certificate of Authorization (COA) issued to the Arkansas Game and Fish Commission (2017-CSA-142-COA). AGL = above ground level, NOTAM = Notice to Airmen. Waiverable indicates that the Federal Aviation Administration may issue a waiver allowing operation outside this limitation.

Topic		§107	COA
Aircraft	Weight	Less than 24.9 kg	Less than 24.9 kg
	Maximum speed	160 kph	160 kph
	Registration	Required	Required
	Maximum altitude	121 m AGL	121 m AGL
Operation	Airspace	Class G, other airspace with waiver	Class G, no mechanism for other airspace classes
	Distance from airport	No specific distance, may not interfere with traffic pattern at an airport or heliport	Operation must exceed: 9.3 km from airport with operating control tower, 5.6 km from airport having a published instrument flight procedure 3.7 km airport not having an instrument flight procedure or control tower 3.7km from a heliport
	Night	Not permitted (waiverable)	Permitted with appropriate lighting
	NOTAM	Not required	Required to be filed at least 24-h in advance of operation
Reporting/ Certification	Routine	None	Monthly
	Accident/incident reporting	10 calendar days after incident or accident	Within 24 hours of accident or incident meeting criteria
	Pilot certificate	Remote pilot	None (agency certifies)

Currently, only the Fisheries Division SOP has been approved by appropriate AGFC authorities (Fernando and Olive 2017). This SOP provides that employees holding a remote pilot certificate can operate an sUAS within the operating limitations of 14 CFR §107, and that the employee acting as remote pilot in command (RPIC) is designated as responsible for ensuring those limitations are observed. The SOP requires approval from an assistant chief of fisheries prior to applying for a waiver to 14 CFR §107 operating limitations. The SOP also requires the RPIC to obtain permission from partner agencies before operating over land owned by those partner agencies, and explicitly allows for exchange of sUAS-acquired data with partner agencies and universities. Finally, the SOP specifies that an employee acting as a flight crewmember (RPIC or observer) cannot simultaneously drive a vehicle. These limitations beyond the basic regulations were intended to aid safety, accountability, and professional relationships with partner organizations.

Certification and Training

At present, AGFC employees intending to operate under 14 CFR §107 are expected to obtain a remote pilot certificate on their own. Generally these employees study for the written exam required by 14 CFR §107.63a(1) using commercially available training materials. Each AGFC operating division has its own policies on whether or not the employee can use work time and computers to study for and take this exam. Manned aircraft pilots that qualify under 14 CFR §107.63a(2), which is a separate certification pathway, do not have to take the written exam.

In the COA application, AGFC presented plans for a training syllabus for prospective new sUAS pilots adapted from that already being used by the police department in Rogers, Arkansas, one of the first government entities in Arkansas to be issued a COA for sUAS operation. Training topics included safety, theory of radio-controlled flight, systems training, hands-on operational training, and ethics and legal considerations. These topics were presented in an inaugural 32-h in-person AGFC class that also included external speakers from the Arkansas Agricultural Aviation Association, U.S. Forest Service, and Arkansas Tech University. Seats in the class were allocated among the AGFC's operating divisions by the informally constituted AGFC Drone Working Group. Each division was allowed to decide independently as to which employees would be sent to class. The class was held at the AGFC Enforcement Training Center in Mayflower, Arkansas. Thirteen sAUS pilots were trained in the initial class (one allocated sAUS pilot candidate became unable to attend on the first day), all of whom passed a written exam with a minimum score of at least 80%. Although the original intention was to offer the class on a semi-annual basis, personnel changes have put future classes on hold.

Operational Experience and Discussion

From February 2017 until April 2018 AGFC conducted 56.65 h of sUAS operations. Of these, 28.10 h were conducted under civil aircraft rules and the remainder were under public aircraft rules. All flights have been conducted by the Fisheries, Wildlife, Communications, or Enforcement divisions of AGFC, although other divisions sent pilot candidates to the training course and are likely to begin operations in the near future. As of 30 April 2018, the AGFC sUAS fleet consisted of two Blade 350QXs (Horizon Hobby LLC, Champaign, Illinois), one each of Phantom 4 Pro (Dá-Jiāng Innovations (DJI), Shenzen, China), Phantom 2 Vision+ (DJI), Mavic Pro (DJI), Matrice 600 (DJI), JJRC H37 (Jianjian Technology Co., Shenzen, China), and JJRC H47 (Jianjian Technology Co.). All models were multicopter-type sUAS.

Photographic or video inspection is perhaps the most straightforward task that can be completed using sUAS: maintaining a clear line of sight with the pilot, the sUAS is flown to photograph an area of interest. For example, a Phantom 4 Pro was used to capture 4k video and still photos of the shoreline of Lake Monticello located near Monticello, Arkansas. After the first set of flights, a second set of flights was made after an unplanned drawdown of the lake. Pairing of the videos and stills allowed qualitative comparison and understanding of shoreline habitat in Lake Monticello (Figure 1). This illustrates one flexibility of having an sUAS in inventory: obtaining aerial photographs on an opportunistic basis with manned or unmanned flight is difficult in many state procurement systems.

Photogrammetry is the art and science of taking real-world measurements from photographs (Colomina and Molina 2014, Nex and Remondino 2014). Computer software is used to stich overlapping photographs together and calculate a point-cloud representing the underlying topography. The photographs are then overlaid on the point cloud to create distortion free imagery. When using sUAS to obtain the photographs, automated flight control software can ensure that the photographs have optimal overlap. AGFC Biologists have used several photogrammetric software packages [e.g., Photoscan (Agisoft LLC, St. Petersburg, Russia), OpenDroneMap (Cleveland Metroparks, Ohio), MapsMadeEasy (Drones Made Easy, San Diego, California)] and autopilot software [e.g., MapPilot (Drones Made Easy), SkyCatch (Skycatch Inc, San Francisco, California)] to produce maps of areas up to 280 ha. In addition to corrected imagery, the underlying point cloud can be expressed as a Digital Elevation Model, which can then be analyzed using GIS software. These maps have been used to determine available habitat for king rails (*Rallus elegans*) and plan renovations to water control structures.

For small areas, producing aerial maps using sUAS can be an improvement over satellite imagery. The resolution of maps pro-

Figure 1. Vegetation exclusion pen at Lake Monticello, Arkansas, image taken by sUAS from approximately overhead. Left: 14 November 2017, Right: 1 September 2017.

duced by sUAS can be on the order of 1 cm pixel^{-1} in comparison to the 4- to 30-m resolution available from civilian satellites (Sawaya et al. 2003, Nex and Remondino 2014). Additionally, using an sUAS allows capturing imagery inexpensively and on-demand. Satellite imagery is commercially available on-demand at 3- to 5-m resolution, but can be extremely expensive. In our experience, however, current generation sUAS photogrammetry software does not handle open areas of water or moving leaves very well because of difficulty in establishing tie points between photographs. In comparison, satellite photographs generally have identifiable tie points because of the larger field of view from space. This limitation of the sUAS software affected attempts to assess the spread of nuisance aquatic vegetation on Bragg Lake, Arkansas (Figure 2). Further, sUAS photogrammetry is computationally intensive: with small areas imaged by 100–250 photographs, locally processed maps require several hours to complete, during which time the computer doing the processing is unusable. In practice, our maps were generated by setting up the processing job and allowing a computer to run overnight or over a weekend. Creation of large area photogrammetric maps with existing software outstripped the computational capacity readily available at local AGFC field offices, and they were generally processed using cloud services. The software itself is also expensive, with single-seat licenses for commercial software costing up to US$3500. Cloud-based processing systems are currently too uncertain in pricing for division budget planning.

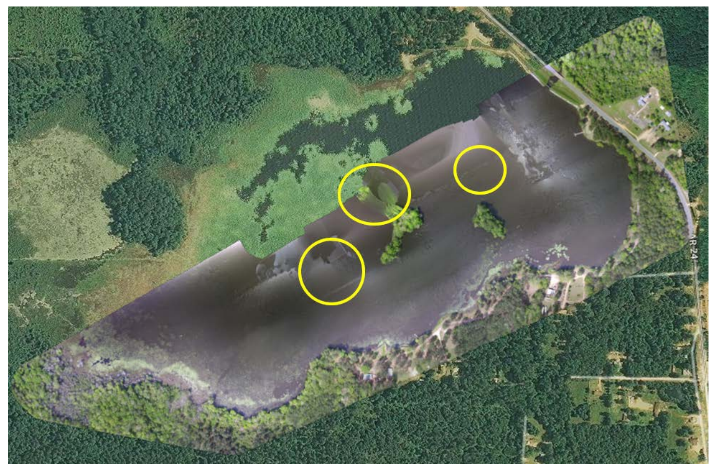

Figure 2. Bragg Lake, Ouachita County, Arkansas. Photogrammetric map from photos taken in April 2017 overlaid on Google Earth imagery from August 2014. Artifacts of poor photo alignment visible, such as smearing around the central island and banding on the lake surface identified by circle.

Table 2. Activities the Arkansas Game and Fish Commission has performed with small unmanned aircraft systems by operating division. X = activities performed.

Division	Video production	Still photography	Photogrammetric mapping	Live surveillance
Fisheries	X	X	X	–
Wildlife	–	–	X	–
Communications	X	X	–	–
Enforcement	–	X	–	X

AGFC has employed sUAS for fisheries and wildlife management (Table 2) in a variety of ways. For outreach and communications, the AGFC has primarily used sUAS for video projects (including segments broadcast on the weekly "Arkansas Wildlife TV" television program). The AGFC has also used sUAS for law enforcement activities; for example, enforcement officers successfully used an sUAS to perform post-flood inspections at the request of the city of Humnoke, Arkansas, and have trained to use sUAS for surveillance and detection of wild turkey (*Meleagris gallopavo)* bait sites. Tasks contemplated for the future include radio telemetry, water sampling, and the harassment of avian predators at fish hatcheries.

Accidents

The AGFC sUAS program experienced four accidents over the course of 56.6 flight h, representing an accident rate of 70.6 accidents 1000 h^{-1}. Three accidents occurred during initial or proficiency training, and only one occurred during an operational mission. Two met regulatory reporting requirements, and incident reports were filed with the FAA.

The first accident occurred during initial training when a remote pilot rolled the sUAS during landing. The pilot noted that he had used an engine shutdown for a different model sUAS that the pilot had been flying recreationally prior to the training class. This procedure caused the sUAS being flown to fly laterally and downward, resulting in a crash. Damage to the sUAS was minor (although it was unflyable until repaired) and this accident was not reported to the FAA.

The second accident also occurred during initial training, when a pilot of a fixed-wing sUAS misjudged a landing approach and struck a power line. The instructor attempted to take control of the aircraft, but was unable to prevent the sUAS from lodging in a tree. Although the aircraft was likely undamaged at that point, the nosecone was cracked while retrieving the aircraft from the tree. Overall damage to the aircraft was minor, the power line was undamaged, and this accident was not reported to the FAA. Similarly, another sUAS struck a tree during proficiency training. In this case, the sUAS suffered damage to motor supports, fuselage, and the thermal camera. Estimated damage exceeded $600 and the incident was reported to the FAA.

The final accident involved an sUAS that was being used to inspect a water control structure. During the operation, the sUAS struck a small tree growing from the water, sunk in about 4 m of water, and was not able to be retrieved. At the time of the accident, the aircraft was about 180 m away from the pilot and 3–5 m over the water. The pilot, who was making his second flight after initial training, reported that late afternoon light conditions caused patterns on the water that obscured the tree. Because the crash resulted in the total loss of an aircraft, the incident was reported to the FAA.

The Enforcement Division reviewed the training program after the second accident involving an enforcement division pilot, determined that operator training was inadequate, and ceased flight operations. A new training program was developed in conjunction with Arkansas Tech University which comprised a 112-h training curriculum. Topics covered in the new curriculum included: development of sUAS technologies, general operations, filing of NOTAMs, camera settings, scenario-based training, sUAS applications, policy relating to privacy, civil rights and civil liberties, assessing and analyzing sUAS platform capabilities, FAA regulations, weather, and airspace classification. The program also included an additional 40 h of remote flight time supervised by an instructor and required Enforcement Division remote operators to obtain a remote pilot certificate. Two sUAS pilots who had attended the initial training program were selected for the second training program. Both passed the remote pilot exam after completing the classroom portion of the training, and Enforcement Division remote flight operations resumed in June 2018.

Future Outlook and Lessons Learned

The FAA forecasts the overall non-model sUAS fleet to increase from 110,000 aircraft in 2017 to as many as 717,000 aircraft by 2022 (FAA 2018a). This increase will likely include aircraft used by natural resource agencies. The obvious potential for the technology has been adequately demonstrated (e.g., Birdsong et al. 2015, Marcaccio et al. 2016, Fernando et al. 2019). How an agency might implement an sUAS program for day-to-day operations has been less clear. The single most important lesson AGFC has learned is that prospective pilots who do not already operate sUAS recreationally need a substantial amount of hands-on training to be able to fly operational missions safely. Agencies should implement extensive training programs for prospective sUAS pilots that involve 30–40 h of hands-on flight experience in low-risk areas prior to larger scale use of sUAS to support an agency's mission.

Data handling has been a challenge. High resolution video creates large data files; a 16- GB memory card can be filled in as little as 20 min. Still photographs take less space, but the hundreds of photographs generated by autopilot controlled mapping flights can still take up 40 GB for moderately sized projects. The most active fisheries pilot generated around 1 TB of video and still imagery over the course of a year. This strained AGFC network resources, and much of the data was ultimately stored on external USB hard-drives. An agency creating a program should have a designated plan to store and retrieve these files.

Anecdotally, raptors have followed or acted as if interested in AGFC sUAS, causing pilots to land the craft in order not to interfere with bird behavior. However, flying over a large flock of geese (~5000 birds) at 100 m above ground level did not result in the birds flushing as we have observed with larger and louder manned aircraft. Research has suggested that there is a great deal of variation in avian response to sUAS (Vas et al. 2015, McEvoy et al. 2016, Holldorf 2018). Developing procedural responses to disturbance of birds by sUAS and establishing offset distances for different types of birds and other animals is important future work (Mulero-Pazmany et al. 2017, Holldorf 2018).

With the exception of one sUAS which is capable of flying longer, 20 min is the approximate maximum operations time for our aircraft. Weather conditions and flight activities can alter this, as flying at high speed or in cold weather greatly reduces battery life. The Enforcement Division made extensive modifications (including installation of high capacity inverters for charging batteries) to the work vehicle of one of its remote pilots to permit sustained operations of the one much larger sUAS. Also, an sUAS typically requires a large rigid box to protect it during transportation, which can be a challenge. The AGFC Communications Division found that using small foldable sUAS made it easy to have an sUAS available with little extra planning. Finally, we found that using inexpensive neutral density filters on camera lenses greatly improves the quality of video, especially during periods of intense sunlight and glare (e.g., the middle of the day or operations over water).

Limited prior studies have suggested that pilot error is the most important cause of sUAS accidents, in contrast to hardware failure which is the leading cause of accidents involving larger unmanned aerial vehicles (Joslin 2015, Fernando 2017). Pilot error was a contributing cause in all accidents involving AGFC sUAS. In 2 of 4 accidents, pilots were operating too low for prevailing conditions. Future training courses will increase hands-on training, emphasize spatial judgement, and guidelines will be developed for minimum altitudes at varying distances from the controller. The Enforcement Division has implemented a minimum operating altitude of 46 m AGL for all future sUAS projects. Future training courses will also emphasize that pilots who are flying more than one make and model of sUAS must be aware of control differences.

Despite this, it must be recognized that early in the development of an sUAS program, some accidents must be expected. Spatial judgement as related to aviation appears to be a learned skill, rather than an innate one (e.g., Stanton et al. 2001, Taylor et al. 2008). Experience with military aircraft suggested that all programs initially have a high accident rate, which decreases over time as operational experience is developed (Office of the Secretary of Defense 2002). Therefore, the early stages of an agency's sUAS program should have procedural safeguards to ensure minimal risk of injury to people or damage to property. In the context of a natural resource agency, this initially can be accomplished by limiting areas of operation to low-risk locations, such as at training centers, over water, and in wildlife management areas which have controlled access. Such restrictions could be loosened as pilots gain experience.

Very recent programs (such as LAANC) have greatly improved the utility of 14 CFR §107. In most cases, it should not be necessary for a natural resource agency to obtain a COA. Exceptions include situations where it is necessary to routinely fly in restricted airspace, or when it is impractical for administrative reasons to have employees operating sUAS to obtain remote pilot certificates. There is however, no excuse for state agency personnel to operate sUAS without complying with the regulatory frameworks established by the FAA.

We wanted to share our experience with accidents here because almost no data are available on the rate of occurrence or nature of sUAS accidents, especially in the context of sUAS operated by state agencies. Newly-created programs should give serious consideration to both the hands-on training their pilot candidates will receive, as well as what missions will be allowed before the pilot corps has significant operational experience. We anticipate a general loosening of some sUAS regulations, which will permit new activities such as "beyond visual line of sight" flight. This will create opportunities for new applications, especially related to mapping and surveillance of large and inaccessible areas. However, the need for flight crews to build experience through small, low-risk projects will remain unchanged.

Acknowledgments

Discussion of commercial products does not constitute endorsement by the Arkansas Game and Fish Commission. Wilson Short (Arkansas Tech University) has been instrumental in developing sUAS training programs for AGFC. Wes Cleland (AGFC) provided historical context for the 2014 acquisition program. The authors would also like to thank the editor and three anonymous reviewers for constructive commentary on this manuscript.

Literature Cited

Arkansas Game and Fish Commission (AGFC). 2013. AGFC aerial imaging device acquisition. Report. Arkansas Game and Fish Commission, Little Rock.

Birdsong, T.W., M. Bean, T.B. Grabowski, T.B. Hardy, T. Heard, D. Holdstock, K. Kollaus, S. Magnelia, and K. Tolman. 2014. Application and utility of a low-cost unmanned aerial system to manage and conserve aquatic resources in four Texas rivers. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:80–85.

Chabot, D. and D.M. Bird. 2015. Wildlife research and management methods in the 21st century: Where do unmanned aircraft fit in? Journal of Unmanned Vehicle Systems 3:137–155.

Colomina, I. and P. Molina. 2014. Unmanned aerial systems for photogrammetry and remote sensing: a review. ISPRS Journal of Photogrammetry and Remote Sensing 92:79–97. Office of the Secretary of Defense. 2002. Unmanned aerial vehicles roadmap 2002–2027. Department of Defense, Washington, D.C.

Federal Aviation Administration (FAA). 2016a. Operation and certification of small unmanned aircraft systems. Federal Register 81(124):42064–42214.

———. 2016b. Small unmanned aircraft systems. Advisory Circular AC 107-2, Washington, D.C.

———. 2018a. FAA aerospace forecast Fiscal Years 2018–2038. FAA Report, Washington, D.C.

———. 2018b. Low Altitude Authorization Notification Capability—LAANC. Air Traffic Organization Policy Notice JO 7210.909. Washington, D.C.

Fernando, A.V. 2017. Survey of sUAS unintended flight termination as depicted in internet video. Journal of Unmanned Vehicle Systems 5:109–114.

——— and J. A. Olive. 2017. Use of unmanned aerial systems. Standard Operating Procedure. Arkansas Game and Fish Commission, Little Rock.

———, W. C. Short, and K. N. Nault. 2019. Comparison of angler pressure counts by manned and unmanned aircraft on an Arkansas Tailwater Fishery. Journal of the Southeastern Association of Fish and Wildlife Agencies 6:94–99.

Groves, P. A., B. Alcorn, M. M. Wiest, J. M. Maselko, and W. P. Connor. 2016. Testing unmanned aircraft systems for salmon spawning surveys. FACETS 1:187–204.

Holldorf, E. 2018. Avifauna ethological response to unmanned aircraft systems. Thesis, University of San Francisco, San Francisco, California.

Johnston, D. W., J. Dale, K. T. Murray, E. Josephson, E. Newton, and S. Wood. 2017. Comparing occupied and unoccupied aircraft surveys of wildlife populations: Assessing the gray seal (*Haichoerus grypus*) breeding colony on Muskeget Island, USA. Journal of Unmanned Vehicle Systems 5:178–191.

Joslin, R. 2015. Synthesis of unmanned aircraft system safety reports. Journal of Aviation Technology and Engineering 5:2–6.

Marcaccio, J. V., C. E. Markle, and P. C. Chow-Fraser. 2016. Use of fixed-wing and multirotor unmanned aerial vehicles to map dynamic changes in a freshwater marsh. Journal of Unmanned Vehicle Systems 4:193–202.

McEvoy, J. F., G. P. Hall, P. G. McDonald. 2016. Evaluation of unmanned aerial vehicle shape, flight path, and camera type for waterfowl surveys: disturbance effects and species recognition. PeerJ 4:e1831.

Michez, A., K. Morelle, F. Lehaire, J. Widar, M. Authelet, C. Vermeulen, and P. Lejune. 2016. Use of unmanned aerial system to assess wildlife (*Sus scrofa*) damage to crops (*Zea mays*). Journal of Unmanned Vehicle Systems 4:266–275.

Mulero-Pazmany, M., S. Jenni-Eiermann, N. Strebel, T. Satiter, J. J. Negro, and Z. Tablado. 2017. Unmanned aircraft systems as a new source of disturbance for wildlife: a systematic review. PLoS ONE 12(6): e0178448.

Nex, F. and F. Remondino. 2014. UAV for 3D mapping applications: a review. Applied Geomatics 6:1–15.

Sawaya, K. E., L. G. Olmanson, N. J. Heinert, P. L. Brezonik, and M. E. Bauer. 2003. Extending satellite remote sensing to local scales: land and water resource monitoring using high resolution imagery. Remote Sensing of the Environment 88:144–156.

Stanton, N. A., P. R. G. Chambers, and J. Piggott. 2001. Situational awareness and safety. Safety Science 39:189–204.

Taylor, H. A., T. T. Brunye, and S. T. Taylor. 2008. Spatial mental representation: Implications for navigation system design. Reviews of Human Factors and Ergonomics 4:1–40.

Vas, E., A. Lescroel, O. Duriez, G. Boguszewski, and D. Gremillet. 2015 Approaching birds with drones: first experiments and ethical guidelines. Biology Letters 11(2):20140754.