A LITERATURE REVIEW

OF THE EFFECTS OF UNMANNED AIRCRAFT SYSTEMS ON SEABIRDS AND MARINE MAMMALS

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TABLE OF CONTENTS

I. DESCRIPTION **1**
II. INTRODUCTION AND BACKGROUND **1**
III. RESTRICTIONS ON USE OF UAS **1**
INTERNATIONAL 1
FEDERAL 2
STATE AND LOCAL 3
IV. TECHNOLOGY **4**
VERTICAL TAKE-OFF AND LANDING 4
FIXED-WING 4
ELECTRIC UAS 4
GAS-POWERED UAS 5
LIMITATIONS ON COMPARISON OF TECHNOLOGY 5
V. TYPES OF DISTURBANCES **5**
VI. EFFECTS OF UAS ON SEABIRDS **5**
ACOUSTIC EFFECTS 6
VISUAL EFFECTS 6
MULTIPLE EFFECTS 7
VII. EFFECTS OF UAS ON MARINE MAMMALS **7**
ACOUSTIC EFFECTS 7
VISUAL EFFECTS 7
MULTIPLE EFFECTS 8
VIII. DISCUSSION **8**
IX. POTENTIAL BIASES AND DATA GAPS **9**
EMPIRICAL EVIDENCE 9
CONFOUNDING VARIABLES 9
X. CONCLUSION **9**
REFERENCES **11**

List of Acronyms

AGL	Above Ground Level
AHA	Airborne Hunting Act
FAA	Federal Aviation Administration
ESA	Endangered Species Act
FWS	Fish and Wildlife Service
FW	Fixed-Wing
GCS	Ground Control Station
ICAO	International Civil Aviation Organization
LALE	Low Altitude Long Endurance
LASE	Low Altitude Short Endurance
MMPA	Marine Mammal Protection Act
NFZ	No Fly Zone
NMFS	National Marine Fisheries Service
NPS	National Park Service
RPA	Remote Piloted Aircraft
UAS	Unmanned Aircraft System
UAV	Unmanned Aircraft Vehicle
VTOL	Vertical Take-Off and Landing

I. DESCRIPTION

Unmanned Aircraft Systems (UAS) have become increasingly prevalent in the last decade. The combined total hobbyist and commercial UAS sales are expected to rise from 2.5 million in 2016 to 7 million in 2020 (FAA, 2017). However, despite this rapid growth in UAS deployment, knowledge of the effects of UAS on wildlife is very limited to date. Additionally, there have been a limited number of studies examining the effects of UAS operations on either seabirds or marine mammals, particularly when flown at lower altitudes. More extensive research is needed to assist in shaping guidelines for the safe use of UAS. Here, we describe some frequently used UAS flown in close proximity to wildlife, provide a review of studies that have addressed behavioral impacts to date, and offer several recommendations for ways in which to minimize the impacts of UAS usage on seabirds and marine mammals.

II. INTRODUCTION AND BACKGROUND

Unmanned Aircraft Systems (UAS) – also commonly known and referred to as "Unmanned Aerial Vehicles (UAV)," "Remotely Piloted Aircraft (RPA)," or "drones" - promise to transform the way we interact with our environment. For the purpose of this literature review, we will be using UAS to refer to all of these.

While UAS use is becoming more popular, legislation in public areas is sparse, although recently some changes in regulations have taken place. As discussed in more detail in *Section III*, the Federal Aviation Administration (FAA) is the federal body that governs the usage of commercial UAS in the United States. Unlike commercial operations however, on May 19, 2017, the DC Circuit Court of Appeals held that the FAA does not have the authority to regulate the use of UAS "strictly for hobby or recreational use".[1] However, due to the petitioner missing a filing deadline, the end result of the lawsuit is that the FAA registration rule was vacated. As a result, private citizens are piloting most of the UAS today.

The FAA Modernization and Reform Act's safety guidelines include a restriction that to operate UAS one must be "in accordance with a community-based set of safety guidelines." The Act lacks more comprehensive rules establishing clear boundaries for when, where, and how UAS are to be operated, which has raised multiple concerns (FAA, Modernization and Reform Act, 2012). Indeed, a recent poll shows just how far this concern has permeated into the general public. According to Reuters, "[s]ome 73 percent of respondents to [an online poll] said they want regulations for the lightweight, remote-control planes," and "forty-two percent went as far as to oppose private ownership of drones, suggesting they prefer restricting them to officials or experts trained in safe operation" (Scott, 2015). Title 14 of the Code of Federal Regulations (14 CFR Part 107) Part 107 does have specific guidance on aircraft operations that can apply to recreational or hobby craft. Details can be found in Section III.

III. RESTRICTIONS ON USE OF UAS

There is a plethora of regulatory bodies that oversee different aspects of guidelines and procedures as they relate to UAS deployment. Here we describe selected predominant entities that have laws, regulations and/or restrictions that can apply to UAS and marine wildlife interactions, although this is by no means an exhaustive list.

International

[1] *See* United States Court of Appeals for the DC Circuit 15-1459, available at https://www.cadc.uscourts.gov/internet/opinions.nsf/FA6F27FFAA83E20585258125004FBC13/$file/15-1495-1675918.pdf

International Civil Aviation Organization (ICAO): In 2011, the ICAO issued a circular (CIRC328) serving as a first look at potential guidelines to standardize UAS use globally. While no mandatory regulation exists at the international scale, the ICAO has developed a toolkit for best practices to follow, which is available at https://www4.icao.int/uastoolkit/home/about.

Federal

Federal Aviation Administration (FAA): As of 2017, the rules for operating UAS are listed in the table below (modified from FAA regulations, https://www.faa.gov/uas/). For further information on where hobbyists can fly their UAS, the FAA has developed a website with additional guidance, available at https://www.faa.gov/uas/where_to_fly/b4ufly/. There are two ways for recreational or hobby UAS fliers to operate in the National Airspace System in accordance with the law and/or FAA regulations. Each of the two options has specific requirements that the UAS operator must follow. The decision as to which option to follow is up to the individual operator. Option #1. Fly in accordance with the Special Rule for Model Aircraft (Public Law 112-95 Section 336) or Option #2. Fly under the FAA's Small UAS Rule (14 CFR part 107). In order to fly a UAS for work, business, or non-recreationally, operator MUST follow the requirements in the Small UAS rule (14 CFR Part 107).[2]

	Hobbyist Requirements (Model Aircraft Rules)	**Fly for Work/Business Requirements, Recreational or Hobby if so chose (Part 107)**
Pilot Requirements	No pilot requirements.	Must have Remote Pilot Airman Certificate. Must be 16 years old. Must pass TSA vetting.
Aircraft Requirements	Unless exclusively operated in compliance with Section 336 of Public Law 112-95 (*Special Rule for Model Aircraft*), the aircraft must be registered if over 0.55 lbs.	Must be less than 55 lbs. Must be registered if over 0.55 lbs. Must undergo pre-flight check to ensure UAS is in condition for safe operation.
Location Requirements	5 miles from airports without prior notification to airport and air traffic control.	Class G airspace. (Subject to waiver)
Operating Rules	Must yield right of way to manned aircraft. Must keep the aircraft in sight (visual line-of-sight). UAS must be under 55 lbs. Strongly encouraged to follow community-based safety guidelines listed below Must notify airport and air traffic control tower before flying within 5 miles of an airport.	Must keep the aircraft in sight (visual line-of-sight). Must fly under 400ft (122m). Must fly during the day. Must fly at or below 100 mph. Must yield right of way to manned aircraft. Must not fly over people. Must not fly from a moving vehicle. (All of these rules subject to waiver)
Example Applications	Educational or recreational flying only.	Flying for commercial use (e.g. providing aerial surveying or photography services).
Legal or Regulatory Basis	Public Law 112-95, Section 336 – *Special Rule for Model Aircraft.* *FAA Interpretation of the Special Rule for Model Aircraft.*	Title 14 of the Code of Federal Regulation (14 CFR Part 107).

Community Based Safety Guidelines
Individuals flying for hobby or recreation are strongly encouraged to follow safety guidelines, which include:

[2] For more information, see https://www.faa.gov/uas/getting_started/fly_for_work_business/ (accessed July 31, 2017). Summary of FAA Part 107 (pdf), see https://www.faa.gov/uas/media/part_107_summary.pdf

- Fly at or below 400 feet and stay away from surrounding obstacles
- Keep your UAS within sight
- Never fly near other aircraft, especially near airports
- Never fly over groups of people
- Never fly over stadiums or sports events
- Never fly near emergency response efforts such as fires
- Never fly under the influence of drugs or alcohol

Understand airspace restrictions and requirements

National Park Service (NPS): In 2014, the NPS provisionally banned all UAS due to safety and noise concerns, with a maximum penalty of $5,000 fine and six months in jail. Specifically, 36 C.F.R 2.17(a)(3) states, "delivering or retrieving a person or object by parachute, helicopter, or other airborne means, except in emergencies involving public safety or serious property loss, or pursuant to the terms and conditions of a permit" is illegal.

Marine Mammal Protection Act (MMPA): The MMPA safeguards seals from harassment by changing their behavior and requires beachgoers to stay at least 150ft (45.7m) away from them (Hoshaw, 2017). Harassment is defined under the MMPA as an act that has the potential to injure or disturb a marine mammal or marine mammal stock through a disruption of behavioral patterns (16 U.S.C. §1362). The Endangered Species Act (ESA) further provides protections for species that are listed as either endangered or threatened (16 U.S.C. §1531).

Airborne Hunting Act (AHA): The AHA, managed by the Department of the Interior states that it is illegal to use aircraft to harass any bird, fish, or other animal (16 U.S.C. §742j-1). Harassment is defined as: disturb, worry, molest, rally, concentrate, harry, chase, drive, herd or torment the animal (50 C.F.R. 19.4).

Fish and Wildlife Service (FWS): The FWS has suggestions on appropriate UAS usage which includes: (1) launch the UAS more than 328ft (100m) from wildlife, and (2) never approach animals or birds vertically with the UAS.

State and Local

In addition to federal UAS regulations, states and local governments have also passed laws regulating the use of UAS by individuals, businesses, law enforcement, and other interests throughout the country. While not an exhaustive list, this review looks at some of the areas adjacent to or abutting California Sanctuaries to illustrate the types of activities that may restrict UAS use.

CA Legislation: While other states have enacted legislation to address UAS operation, no such legislation has been enacted in California. Governor Jerry Brown has vetoed several attempted bills.

SB 347, introduced by Hannah-Beth Jackson, would limit disruptive UAS use near private property and prohibit the weaponization and reckless operation of the unmanned aerial vehicles. Violations would be punishable by a fine of up to $250 or a misdemeanor, and the California Department of Transportation would be tasked with developing liability insurance requirements. The bill moved out of the Senate to the Assembly on 5/31/17 with a 26-12 vote.[3] This is the 3rd bill on UAS proposed by Hannah-Beth Jackson. Her first piece of UAS legislature, SB 142 (2015), made it through both houses, but was later vetoed. The subsequent legislative session, Hannah-Beth Jackson introduced SB 868, which encompassed a number of

[3] For updates on the progress of the SB 347, see CA Legislative Information, available at http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB347 (accessed June 30, 2017).

components including banning UAS in state parks without a permit. The bill died in the Assembly Committee on Privacy.

California State Parks Regulations: Administered by the State of California Department of Parks and Recreation, states that prohibited activities include molesting, hunting, disturbing, harming, feeding, touching, teasing, or spotlighting any kind of animal or fish or attempting to do so unless specifically authorized by individual park regulations (14 CCR 4305).

Northern California, adjacent to Monterey Bay National Marine Sanctuary: The Golden Gate Bridge, Highway and Transportation District has banned UAS from flying over or near the bridge or on any other District property.[4]

Northern California, abutting Monterey Bay National Marine Sanctuary: San Mateo County Parks prohibits the use of UAS on the Devils Slide trail, which is adjacent to a significant seabird breeding colony.[5]

IV. TECHNOLOGY

A UAS consists of multiple parts depending on the type of unit being used, and can include the unmanned aerial vehicle (UAV), the sensor, and/or the ground control station (GCS). UAS classification is derived solely from existing military descriptions (Fiori, et. at., 2017). The two most common types of UAS used are fixed-wing (FW) systems and vertical takeoff and landing (VTOL) systems, described briefly in the following sections.

Vertical Take-off and Landing

These types of UAS have the ability to take-off and land vertically. VTOL class ranges from nano-aircraft to larger unmanned helicopters. They generally have from three to eight propellers.

Fixed-Wing

These types of UAS are usually larger in size than a VTOL unit, and they have the ability to fly higher and faster than VTOL systems. The two major types of FW systems are:

a. *Low altitude long endurance (LALE):* This type of UAS lasts generally longer than 4 hours. LALE are smaller than LASE at normally less than 13ft wingspan.
b. *Low altitude short endurance (LASE):* This type of UAS is proficient at shorter travel times (approximately 1–2 hours). Generally, these aircraft are smaller than LALE at usually <8ft wingspan.

In addition to the way a device is launched, a UAS can also be categorized according to whether it is electric or gas powered. Examples of popular brands used in UAS studies include (*see Appendix A* for more comprehensive list of units used in wildlife research):

Examples of Electric UAS

[4] See the following for more information: http://goldengate.org/news/bridge/drones-prohibited-on-golden-gate-bridge.php, or call (415) 921-5858.
[5] See the following for more information: http://parks.smcgov.org/devils-slide-trail-regulations, or call (650) 363-4020.

- CropCam (Chabot and Bird, 2012)
- Multiplex Twin Star II (Sarda-Palomera et al., 2012)
- Phantom (Vas et al., 2015)

Examples of Gas-Powered UAS

- FoldBat (Jones et al., 2006)
- T-Hawk (Dulava et al., 2015)

A relevant distinction between these types of UAS is that gas-powered devices are normally noisier than their electric counterparts, which has potentially substantial implications for wildlife disturbances, discussed in more detail in *Section VIII*. In Mulero-Pazmany et al.'s review, gas-powered engines produced more wildlife reactions, which suggests the significance of noise as a potentially important cause of disturbance (Mulero-Pazmany et al., 2016).

Limitations on Comparison of Technology

In the studies published to date, researchers have often relied on one brand of UAS rather than comparing the results of the different types of UAS units. It is hard to extrapolate or conclude a precise response of wildlife to particular models of UAS given how different the noises, sizes, and flight patterns are of all of the devices currently for sale. Wildlife may react very differently to certain types of devices.

V. TYPES OF DISTURBANCES

A disturbance generally is a change in environmental conditions. Acute or chronic disturbance of wildlife has the potential to significantly impact an individual, population, and/or species (Christiansen et al., 2016).

A UAS can cause disturbance in multiple, significant ways. Potential methods of disturbances to wildlife include the size, shape, noise, and/or flight pattern of a UAS. The reactions of wildlife may be more or less significant under various circumstances and cause different reactions in species. As seen in *Appendix A*, it appears that two general categories that disturbances fall in to are: (1) noise (such as the buzzing sound of a UAS), and (2) visual (such as the appearance of or shadow produced by a UAS), which are discussed in detail below as they relate to both seabirds and marine mammals (Smith et al., 2016). Likewise, studies to date have also identified that the distance and approach angle of the UAS are significant factors influencing the response of animals (Goebel et al., 2015; Pomeroy et al., 2015; Vas et al., 2015; Smith et al., 2016; Christiansen, et al., 2016).

VI. EFFECTS OF UAS ON SEABIRDS

Seabirds are known to be sensitive to disturbances, however limited studies have measured the disturbance effects explicitly of UAS on seabirds. Studies conducted on flocks of Canada and Snow Geese (Chabot & Bird, 2012), and semi-wild mallards (Vas et al., 2015) documented that a nominal amount of disturbance occurred. Drever et al. (2015) also noted that disturbance appeared to be minimal when researching certain shorebirds and waterfowl including Dunlins, Mallards, American Green-winged Teals, American Wigeons, and Northern Pintails.

Disturbances can range from minor actions to extreme events, such as a flushing event of seabird colony or marine mammal pupping area (Christiansen et al., 2016). For example, flushing of seabirds can result in nest abandonment and/or the loss of eggs or chicks. Flushing of marine mammals can result in pups being crushed. While this paper is focused on the effects of UAS on marine mammal and seabirds, there is a substantial number of peer-reviewed reports that document reactions of wildlife as a result of flushing. This literature review however is focused on UAS and marine wildlife interactions, and not on the effects of a population or species of wildlife from exposure to various types of disturbance.

<u>Acoustic Effects</u>

Gas-powered UAS are louder and may increase disturbance of seabirds when flown at lower altitudes. Specifically, Dulava noted that the gas-powered UAS that was used in their research on non-nesting waterbirds may increase flushing behavior. This is potentially due to the buzzing noise emitted while the UAS was in flight (Dulava, 2015). The study concluded that if gas-powered UAS are selected for use, the UAS should maintain an altitude of at least 98ft (30m) or higher near waterbirds during the nonbreeding season in order to reduce the possibility of flushing behavior. They further suggest that this threshold should likely be modified both by species and by season (noting that colonial nesting waterbirds may be more sensitive to disturbance during the breeding season) (Dulava, 2015).

<u>Visual Effects</u>

Both the flight pattern and shape of a UAS has been shown to influence the level of disturbance to birds. A recent study by McEvoy et al. examined different UAS and their disturbance effects on large mixed flocks of species (McEvoy et al., 2016). The authors looked at the shape and wing profile of UAS and found multirotor UAS and FW UAS had minimal disturbance effects (McEvoy et al., 2016). The delta-wing design (Topodrone-100) shown in *Figure 1*, combined with flight patterns that were similar to a known predator at the study sites, elicited the greatest level of disturbance as birds flew from the shore to open water. It should be noted that the arrival of an actual predator was observed and resulted in a mass takeoff, a stronger reaction than the UAS-evoked responses. The closer that a UAS resembles a potential predator, the more disturbances occurred (McEvoy et al., 2016).

Figure 1. Response of mixed flocks of waterfowl to UAS of flying overhead at various altitudes

UAV	Shape	Altitude Above Water						
		100 m	90 m	80 m	70 m	60 m	50 m	15 m (take-off)
UAVER Avian-P		NR	NR	NR	NR	V	N/A	F
Skylark II		NR	NR	NR	NR	V	NA	F
Drone Metrex Topodrone-100		NR	NR	F	F	F	N/A	F
DJI Phantom		N/A	N/A	N/A	N/A	N/A	V	V
FoxTech Kraken-130		NR	NR	NR	NR	NR	V	N/A

NR (green squares) = No discernible response; V (yellow squares) = Vigilance response detected; F (red squares) = Flight Response; N/A = UAS did not fly over birds at that altitude

Multiple Effects

Vas et al.'s study specifically addresses the significance of both proximity and color to three different types of waterfowl - mallards, flamingo, and common greenshanks. The researchers found that while the color of the UAS and approach frequency had no impact on bird response, the birds responded strongly to a vertical approach angle (Vas et al., 2015). Furthermore, while flying the UAS at lower altitudes (lower than 98ft (30m) AGL) produces clearer imagery, this results in increased risk of potential wildlife disturbance.

VII. EFFECTS OF UAS ON MARINE MAMMALS

While the use of UAS in ecological studies is growing, there has been a limited number of studies that have been targeted to explicitly document the effects on marine mammals. As an example, NOAA has been using VTOL UAS for several marine mammal surveys since 2014 (Marine Mammal Commission, 2016).

Acoustic Effects

Cetaceans and sirenians spend most of their time underwater and therefore are not as directly disturbed acoustically as other wildlife. Pinnipeds, however, are more sensitive to acoustic harassment because they haul out on rocks, beaches, estuaries, and other shorelines (Christiansen et al., 2016; Smith et al., 2016; Whitehouse et al., 2010). Laura Chapman, a research coordinator at the Marine Mammal Center, further noted that the buzzing noise produced can interrupt the sleep cycle of seals, who normally sleep at haul out sites during the day. A UAS flying above the beach can cause the animals to alter their behavior during reproductive and pupping season, when mother seals need to bond with their young (Hoshaw, 2017). UAS can also cause a mother to abandon a pup (Hoshaw, 2017).

Moreover, disturbance has been documented as minimal for whales. Specifically, researchers recorded disturbances observed at 42.5ft (13m) AGL for blue, gray, humpback, and sperm whales (Acevedo-Whitehouse et al., 2010), and about 98ft (30m) AGL for killer whales (Durban et al., 2015). Scientists report that toothed and baleen whales hear the noise when a UAS is flying at 33ft (10m) AGL, but the effect is likely small, even when animals are close to the surface (Christiansen et al., 2016).

No disturbance was documented for Florida manatees when UAS were flown at 328ft (100m) (Jones et al., 2006). Furthermore, researchers posit that dugongs (and other marine fauna) would not be disturbed by the acoustic effects of a fixed-wing UAS being flown at 1,000ft (305m) AGL (Hodgson et al., 2013).

Visual Effects

It seems that cetaceans are more sensitive to behavioral disturbances as the flight altitude of a UAS drops (Smith et al., 2016). Smith et al. discuss their communication with R. Cassoff on October 29, 2014, which provides a relevant example. Bottlenose dolphins were seen following the shadows of a VTOL UAS unit at about 65.5ft (20m) AGL, but were also shown to intermittently avoid the shadows from a tethered airship that floated over focal animals (the altitude of the airship was not stated) (Smith et al., 2016).

Multiple pinniped species have been observed flushing into the water as a result of UAS, especially when a UAS is flying at lower altitudes. Gray seals have shown disturbance behavior - specifically looking in the direction of the UAS - at 164ft (50m), and started moving towards the water (Pomeroy et al., 2015). The hovering behavior of a VTOL was shown to prompt flushing behavior in harbor seals who potentially perceived the UAS device as a predator overhead (Olson, 2013; Pomeroy et al., 2015). However, Pomeroy, et al. observe that behavioral responses to avian predators varies according to how frequently wildlife have previously been exposed to human activities (Pomeroy et al., 2015).

Multiple Effects

Marine mammals that spend considerable amounts of time on land may be especially sensitive to both visual and acoustic effects stemming from use of a UAS (Christiansen et. al., 2016; Smith et al., 2016; Whitehouse et al., 2010). However, to date, there is little evidence that they disturb large whales, but more evidence exists that a UAS can cause pinnipeds to have dangerous reactions on land if flown too low. However, no reaction has been observed for most research assignments (Marine Mammal Commission, 2016).

VIII. DISCUSSION

With there has been an increase in the number of articles assessing the potential for harassment from UAS devices (Ditmer et al., 2015; Dulava, Bean & Richmond, 2015; Pomeroy et al., 2015; Vas et al., 2015), the information overall is still relatively limited to date. For the most part, the literature about potential disturbance behavior has either described unique instances (*i.e.,* Ditmer et al., 2015; Vas et al., 2015), or the literature is of a narrative nature and includes illustrative reports (*i.e.,* Smith et al., 2016; Hodgson et al., 2016).

However, certain conclusions regarding the harassment of wildlife from UAS can still be reached. Reactions are dependent on the type of UAS used and different species react differently. Many studies have concluded that UAS elicited substantially less disturbance behavior when flown at the equivalent heights of a manned aircraft (Acevedo-Whitehouse et al., 2010; Moreland et al., 2015). Therefore, we can conclude that behavioral responses are more significant from flight altitude as compared to other UAS disturbances. This seems likely given that noise levels are significantly less than from a manned aircraft, and are often reduced by ambient noise intensities (Jones et al., 2006; Hodgson et al., 2013; Goebel et al., 2015; Pomeroy et al., 2015; Smith et al., 2016). Results of the Marine Mammal and NMFS UAS Symposium and McEvoy et al. (2016) further emphasize these distinctions. UAS devices (and especially electric units) are quieter than manned aircrafts and can therefore be flown substantially lower without causing the same level of harassment (Marine Mammal Commission, 2016; McEvoy et al., 2016).

Additionally, the literature reviewed suggests an overall absence of a wildlife response when a UAS is above certain altitudes, which, to emphasize again, is dependent on the type of species and the type of interaction (also *see Section IX* for further limitations in the literature). The size of the UAS seems to affect animal reactions, with larger UAS producing responses at higher AGL than small ones (Mulero-Pazmany et al., 2016; Smith et al., 2016). As some of the authors have noted, this is seemingly because the size of the threat increases the perceived risk and a potential predator approach as a reason for disturbance (Pomeroy et al., 2015; Vas et al., 2015). For species that exhibit (congregate) dense populations - such as seabird breeding or roosting sites and pinniped haul-out sites - a flushing event can escalate into a charge, and cause injury or mortality (Christiansen et. al., 2016).

When comparing the different studies, birds appear to be more sensitive to UAS (*see Appendix A*). Both flightless and large birds seem to show more of a reaction to UAS presence, although this could be because of a greater detection range when a UAS is flown (Mulero-Pazmany et al., 2016). Furthermore, the literature reviewed on whales seem to show that they are the least affected by UAS flights (Mulero-Pazmany et al., 2016; Smith et al., 2016). However, there has not been a substantial number of studies to conclude this with certainty, further discussed in *Section IX*. A vertical approach and the hovering behavior of a UAS in flight also appeared to cause an increased level of disturbance, which reports have noted could be potentially associated with a predator attack (Vas et al., 2015; Olson, 2013). In certain circumstances, it may be in a researcher's best interest to modify the UAS to look like non-threatening wildlife when getting near to an animal. For example, a UAS could be modified to look like a bird that is not a predator of the species that is being studied (Hodgson & Koh, 2016; McEvoy et al., 2016). This could be especially beneficial for research activities conducted by UAS.

As discussed in *Section IV*, gas-powered engines (which are generally noisier than electric engines) produced an increase in the amount of animal reactions (Mulero-Pazmany et al., 2016). Additionally, animal reactions are not only influenced by the volume of the noise a UAS creates, but are also influenced by changes in the intensity of the noise produced (Mulero-Pazmany et al., 2016; Ditmer et al., 2015). It should further be noted that the background levels of noise (the ambient surrounding environments) influence the acoustic outcomes as well.

IX. POTENTIAL BIASES AND DATA GAPS

Empirical Evidence

In many cases where information on UAS is available, the information seems to stem from largely descriptive observations mentioned solely in the context of other research which was not focused on studying the impacts of UAS on the species itself (Smith et al., 2016). More specifically, most of the relevant research that was examined for this literature review looked at the usefulness of a UAS in research, rather than empirical data on the behavioral responses of wildlife explicitly (Perryman et al., 2014; Kosti et al., 2013). Due to this information deficit, the available research to date on wildlife behaviors appears to be potentially skewed, subjective, and biased. Information is only reported when an observed behavioral reaction occurs rather than in situations where no outward behavioral responses were elicited (Smith et al., 2016).

To further emphasize this point, a lack of an observed behavioral response does not necessarily mean that a disturbance did not occur. Ditmer et. al. found that black bears had increased heart rates by as much as 400% when a UAS was hovering above them, even though they appeared calm and laidback on the surface which would indicate initially that no harassment has occurred (Ditmer et al., 2015). While numerous studies have documented and discussed the physiological reactions of wildlife, analyzing and discussing these responses is outside the scope of this literature review.

Confounding Variables

Moreover, based on the material studied for this literature review, a significant reason affecting potential disturbances to wildlife is the altitude of a UAS in flight (as discussed in *Section VIII*). When looking at the impacts to wildlife from different flight altitudes, the literature reviewed does not offer any definite or explicit evidence to distinguish between the different types of disturbances (for example, no evidence is given for disturbances that occur from acoustic effects versus disturbances that occur from visual effects). For example, while generally it appears pinnipeds react to a UAS flying overhead, there is no specific evidence that the disturbance occurs from acoustic, visual, or multiple effects, and some pinniped species may not react at all when a UAS is flying low (Goebel et al., 2015; Perryman et al., 2014). Rather, this information is generally observed and anecdotal.

X. CONCLUSION

Despite their value for ecological research, multiple concerns have been raised about the risk of harassment on wildlife (Smith et al., 2016; Pomerey et al., 2015; Ditmer et al., 2015). Based on the existing literature, larger UAS sizes, and the noisier, gas-powered units evoked the greatest reactions in wildlife. When conducting research, a UAS should be selected in order to minimize the potential for both visual and acoustic effects, looking at the shape, size, noise, and color of the different types of UAS.

Further, based on the literature reviewed, general recommendations to minimize the potential for disturbance of marine mammals and seabirds include: avoid UAS profiles that resemble predator species; avoid areas with congregating wildlife; avoid maneuvers directly above the wildlife; and favor low-noise or small UAS when comparing to noisier or larger units (Mulero-Pazmany et al., 2016). Additionally, in order to minimize disturbance a UAS should be flown at the highest altitude possible.. As seen in *Appendix A*, disturbances appear to be minimal around 328ft (100m), species reactions generally start to occur more frequently at around 164ft (50m), and disturbances increase more substantially around 115ft (35m). Both Dulava and Vas et al. noted that significant disturbances occurred at 98ft (30m). While more research is needed looking at the effects specifically of UAS, general recommendations would be to fly and launch a UAS at or above 328ft (100m) from the species in order to minimize the potential for disturbances. These recommendations are further supported with FWS suggestions for UAS management, as discussed in *Section III* above.

Lastly, almost all authors and researchers recommend adopting some form of the precautionary principle in the absence of evidence of clear thresholds for disturbance (Hodgson & Koh, 2016; Vas et al., 2015; Christiansen et al., 2016). For recreational use in areas with marine wildlife, UAS use should be prohibited in areas known to have congregating wildlife, a seabird colony, a marine mammal pupping area, and/or nesting grounds of the animals. Further, as described above, hobbyists should be restricted from piloting UAS maneuvers directly overhead of an animal.

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Acevedo-Whitehouse, K.; Rocha-Gosselin, A.; Gendron, D. A novel non-invasive tool for disease surveillance of free-ranging whales and its relevance to conservation programs. Anim. Conserv. 2010, 13, 217–225

The authors collected exhaled breath condensate from 8 different cetacean species. Large whales showed no additional avoidance behaviors when approached by UAS than observed during vessel-based activities. However, both species of dolphins frequently swam away from the bow of the boat once the pole was extended over the front of the boat for sampling and returned to bowride the boat when the pole was out of the plane of sight.

Adame, K., Pardo, M. A., Salvadeo, C., Beier, E., & Elorriaga-Verplancken, F. R. (2017). Detectability and categorization of California sea lions using an unmanned aerial vehicle. *Marine Mammal Science*. https://doi.org/10.1111/mms.12403

This study used UAS-based counts of California sea lions to estimate colony fitness. This method reduces counting errors and disturbance to animals, when compared with counts from boats or land. Concluding results from the study indicate that UAS provided for more accurate counts. Issues with existing methods used for sea lion counts include:

- Counts from boats: can miss some that are hidden and it is hard to estimate size which leads to higher categorization error when compared to UAS-based counts
- Counts from land: can disturb, not always accessible.
- Counts from manned aircraft: costly, putting humans at risk. UAS more convenient than manned aerial surveys in terms of costs and of flexibility of visual angles, although in very large and remote colonies, manned aerial surveys may be more practical

The study observed that when the UAS was flown at 49ft (15m) altitude, there was no pinniped species disturbance observed and did not elicit visible reaction. The study tested different heights to analyze when UAS' elicited visible reactions. When the UAS was flown at 33ft (10m) altitude, sea lions were observed looking up towards the UAS and some even jumped into the water. Further, the study showed that the UAS sometimes disrupted yellow-footed gulls (Larus livens), which in turn scattered more sea lions into the water.

Christiansen, F., Rojano-Doñate, L., Madsen, P. T., & Bejder, L. (2016). Noise Levels of Multi-Rotor Unmanned Aerial Vehicles with Implications for Potential Underwater Impacts on Marine Mammals. *Frontiers in Marine Science, 3*. https://doi.org/10.3389/fmars.2016.00277

Acute or chronic disturbance of wildlife can significantly impact individual, population, and species health. This study presents findings on UAS noise impacting marine mammals underwater concluding that while noise may be heard by some marine mammals under water, it is implied that the underwater noise effect is small, even for animals close to the water surface. UAS can elicit behavioral responses in pinnipeds on land, ranging from elevated alertness levels to animals fleeing into the water. The authors find that effects of disturbance may be due visual cues, including the shadow or noise of a UAS. Cetaceans and sirenians spend most time underwater and therefore are not disturbed much acoustically, but pinnipeds hauling out are more sensitive. Flushing events can also lead to stampedes, which can cause mortality. Furthermore, flight altitude is an important factor in disturbance potential. Authors conclude that in lieu of more robust evidence of disturbances, the precautionary principle should be adopted.

Ditmer, M. A., Vincent, J. B., Werden, L. K., Tanner, J. C., Laske, T. G., Iaizzo, P. A., … Fieberg, J. R. (2015). Bears Show a Physiological but Limited Behavioral Response to Unmanned Aerial Vehicles. *Current Biology, 25(17), 2278–2283.* https://doi.org/10.1016/j.cub.2015.07.024

Bears can exhibit cardiac stress in the presence of UAS even when no behavioral responses are observed. The authors support the NPS decision to ban all public use of UAS within NPS boundaries.

Drever, M. C., Chabot, D., O'Hara, P. D., Thomas, J. D., Breault, A., & Millikin, R. L. (2015). Evaluation of an unmanned rotorcraft to monitor wintering waterbirds and coastal habitats in British Columbia, Canada [1]. *Journal of Unmanned Vehicle Systems*, *3*(4), 256–267. https://doi.org/10.1139/juvs-2015-0019

This study evaluates the use of UAS to identify and count wintering waterbirds in British Columbia, Canada. During each UAS flight, the researchers noted disturbance behavior, specifically flushing, and if/when the birds returned to their original places. The authors find that waterbird disturbance responses are species-specific. Ducks did not react when the UAS hovered 20m directly above. Dunlin tended to flush as the UAS flew overhead but quickly returned within 1 or 2 min to continue feeding or roosting. Gulls were the most likely to flush as the UAS approached, and on some occasions did not return to the site. Consecutive flights over the same groups of ducks and shorebirds resulted in a decrease in response to the UAS, indicating that birds may habituate to the UAS. The authors conclude that while they witnessed some disturbance at all altitudes flown, most birds appeared undisturbed by the presence of the UAS when flown ≥200ft (≥61 m).

Dulava, S., Bean, W. T., & Richmond, O. M. W. (2015). ENVIRONMENTAL REVIEWS AND CASE STUDIES: Applications of Unmanned Aircraft Systems (UAS) for Waterbird Surveys. *Environmental Practice*, *17*(3), 201–210. https://doi.org/10.1017/S1466046615000186

This study was conducted to assess the benefits of UAS technology on estimating the distribution and abundance of waterbirds. The size of UAS will depend on the payload necessary to gather target data. Tomales Bay, one of the locations in the study, is a long, narrow inlet of the Pacific Ocean, is part of the Greater Farallones National Marine Sanctuary, and is utilized by a wide array of bird species, including grebes, gulls, cormorants, pelicans, and waterfowl. Results of the study posit that UAS caused more flushing of birds at altitudes of 52.5-88.5ft (16-27m) and less at altitudes of 108-259ft (33-79m). One of the conclusions gathered is that gas powered UAS are louder and caused flushing below 98ft (30m) (by comparison, winged planes tend to cause disturbance below 984ft (300m) and helicopters below 1,476ft (450m)), and that vertical approach caused increased disturbance.

Durban, J.; Fearnbach, H.; Barrett-Lennard, L.; Perryman, W.; LeRoi, D. Photogrammetry of killer whales using a small hexacopter launched at sea. J. Unmanned Veh. Syst. 2015, 3, 131–135.

The authors report findings on photogrammetry and photo-identification of killer whales using a VTOL UAS. The study posits that because these devices are quiet and stable in flight they can therefore be flown at relatively low altitudes without disturbing the whales. They obtained almost 19,000 images of the whales flying the UAS at an altitude of 115-131ft (35-40m) AGL and report that no behavioral responses from the whales was observed during any of the flights. The further argue that the whales were likely not aware of the UAS at these altitudes.

FAA. (2017). *FAA Aerospace Forecast: Fiscal Years 2017-2037*. Retrieved from https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2017-37_FAA_Aerospace_Forecast.pdf

The FAA annual forecast finds a sustained increase in overall air travel and the use of UAS. The combined total hobbyist and commercial UAS sales are expected to rise from 2.5 million in 2016 to 7 million in 2020.

Fiori, L., Doshi, A., Martinez, E., Orams, M. B., & Bollard-Breen, B. (2017). The Use of Unmanned Aerial Systems in Marine Mammal Research. *Remote Sensing*, *9*(6), 543. https://doi.org/10.3390/rs9060543

This report describes some of the recent developments and differences between the two main types of UAS, FW and VTOL. They argue that the systematic use of UAS is still relatively far-off due to low altitude, long endurance systems which are still sold at relatively high prices. They then present an overview of the use of UAS as a survey tool for marine mammal studies.

Goebel, M.E.; Perryman, W.L.; Hinke, J.T.; Krause, D.J.; Hann, N.A.; Gardner, S.; LeRoi, D.J. A small unmanned aerial system for estimating abundance and size of antarctic predators. Polar Biol. 2015, 38, 619–630.

The authors use VTOLs for estimating abundance, colony area, and density of krill dependent predators in Antarctica. Focusing on the noise impact, no reaction of pinnipeds - fur seal, Weddell seal, and leopard seal colonies - was observed while flying at 75.5ft (23m) AGL. They further report that VTOL's are more useful than other UAS for ecological research because of their portability, stability in flight, limited launch area requirements, safety, and limited sound when compared to FW aircrafts.

Greenfieldboyce, N. (2015, August 13). Drones Increase Heart Rates of Wild Bears. Too Much Stress? NPR.

This article reports on study by Ditmer, et. al., described above, which concludes that UAS significantly changed the heart rates of the bears, even while in hibernation.

Hayden, T. (2015, September 6). Press Photographers Oppose Jackson Drone Bill. Say Proposed Law Would Prevent Honest News-Gathering.

This article reports on how proposed bill SB 142 (2015), in California, is intended to ban UAS use below 350ft over private property. A letter sent to Brown and signed by more than 30 news organizations argues that the proposed law unfairly hamstring photographer's responsibilities. It is difficult to assess exact height of a UAS from the ground and therefore with overburden the court system with erroneous complaints filed by homeowners.

Hodgson, A.; Peel, D.; Kelly, N. Unmanned aerial vehicles for surveying marine fauna: Assessing detection probability. Ecol. Appl. 2017.

This study measures abundance surveys of humpback whales in Australia using UAS. The authors then looked at potential bias from using UAS for population estimates. The study further emphasizes that UAS are an effective alternative to traditional methods.

Hodgson, J., & Koh, L. P. (2016). *Best practice for minimizing unmanned aerial vehicle disturbance to wildlife in biological field research* (pp. R404–R405). Current Biology Magazine.

There are benefits and risks to the use of UAS in field research, and a growing need for best practices. The disturbance potential depends on the species, the environmental and historical context, the type of UAS and its type of movement. The authors advocate the precautionary principle in the absence of extensive information. There is a need for studies specific that specifically look at impact of UAS on wildlife (as opposed to providing information about impact on wildlife incidental to other research).

Hodgson, J., Shane M. Baylis, Rowan Mott, Ashley Herrod & Rohan H. Clarke (2016). Precision wildlife monitoring using unmanned aerial vehicles.

The authors study the potential use of UAS for more precise wildlife monitoring, comparing retrospective counting from images taken with UAS with ground counters for colonies of seabirds. The study found UAS derived estimates had overall smaller variance than ground-based monitoring and could be a powerful tool for wildlife monitoring.

Hodgson, A.; Kelly, N.; Peel, D. Unmanned aerial vehicles (UAVS) for surveying marine fauna: A dugong case study. PLoS ONE 2013, 8, e79556.

This report presents the findings of UAS used for abundance surveys of dugongs in western Australia. The authors find that the UAS uses substantially less fuel and potential reductions in noise disturbance. When flown at 1,000ft (305m), it is unlikely that noise from the ScanEagle would be audible to marine fauna underwater.

Hoshaw, L. (2017, March 27). Drones on Monterey beaches frighten seals during mating season.

The Marine Mammal Center in Sausalito, CA has received complaints about amateur UAS "harassing" seals. The article posits that the buzzing noise produced by a UAS can interrupt the sleep cycle of seals, who normally sleep during the day. The Marine Mammal Center argues that if the animal is looking at the UAS, it is being harassed. Furthermore, UAS can also cause a mother to abandon a pup. The Monterey Bay National Marine Sanctuary docents say that such harassment is against the law. Finally, the article notes that FAA bans UAS flights within 5 miles of all airports without prior approval.

Ivosevic, B., Han, Y.-G., Cho, Y., & Kwon, O. (2015). The use of conservation drones in ecology and wildlife research. Journal of Ecology and Environment, 38(1), 113–118. https://doi.org/10.5141/ecoenv.2015.012

UAS are used by environmental managers for monitoring as a low impact and low cost tool. Ivosevic, et al., argues that UAS are effective tool for census of animals due to their agility and image quality abilities. UAS can be sent to previously inaccessible areas to create a map and monitor the wildlife that lives there. The paper highlights that a key consideration in further development of conservation UAS is in their ease of use for non-specialists.

King, B. (2015). A love-hate relationship with drones. NPR.

This NPR article reports on instance where chimpanzees in a zoo seemed to purposely "attack" a news agency UAS in their enclosure with sticks, inferring that they did not like it.

Landsberg, Bruce (2014). The UAS conundrum. AOPA Pilot.

This article discussing the difficult task the FAA faces in regulating UAS. The author calls for basic regulations to be published, asserting that current guidelines are not sufficient for UAS.

Development and Use of UASs by the National Marine Fisheries Service for Surveying Marine Mammals; Marine Mammal Commission: Bethesda, MD, USA, 2016.

This document is a write-up of the Marine Mammal Commission and NMFS sponsored workshop to assess the development and use of UAS within NMFS. Based on the conference, VTOL UAS have been proven to be superior platforms compared to FW. Researchers posit that to minimize disturbance, UAS are flown relatively high.

McEvoy, J. F., Hall, G. P., & McDonald, P. G. (2016). Evaluation of unmanned aerial vehicle shape, flight path and camera type for waterfowl surveys: disturbance effects and species recognition. *PeerJ*, *4*, e1831. https://doi.org/10.7717/peerj.1831

This study was designed to assess disturbance effects on waterfowl in Australia from various UAS models that may render a survey invalid, and to assess whether an airborne digital imaging system could provide adequate resolution for unambiguous identification of small bodied waterfowl.

The authors found little or no obvious disturbance effects on wild, mixed-species flocks of waterfowl when UAS were flown at least 197ft (60m) AGL (fixed wing models) or 131ft (40m) above individuals (multirotor models). Disturbance in the form of swimming away from the UAS through to leaving the water surface and flying away from the UAS was visible at lower altitudes and when fixed-wing UAS either approached subjects directly or rapidly changed altitude and/or direction near animals. Using tangential approach flight paths that did not cause disturbance, commercially available onboard optical equipment was able to capture images of sufficient quality to identify waterfowl and even much smaller taxa such as swallows.

Moreland, E.E.; Cameron, M.F.; Angliss, R.P.; Boveng, P.L. Evaluation of a ship-based unoccupied aircraft system (uas) for surveys of spotted and ribbon seals in the bering sea pack ice. J. Unmanned Veh. Syst. 2015, 3, 114–122.

This study used UAS to fly over the Bering Sea to determine whether advances in UAS technology can enable effective, large-scale, systematic ship-based surveys for seals. When comparing their results with manned surveys, we can see a marked reduction in disturbance during UAS operations. Seals hauled out on ice floes were reported to not be disturbed by a UAS flying overheat, even for animals flown over repeatedly. With improvements in technology, reduced operational costs, and the establishment of inclusive airspace regulations, the authors suggest large-scale UAS surveys will be possible in the arctic and subarctic habitat of the US.

Mulero-Pázmány, M., Jenni-Eiermann, S., Strebel, N., Sattler, T., Negro, J.J., & Tablado, Z. (2017). Unmanned aircraft systems as a new source of disturbance for wildlife: A systematic review.

The authors of this study reviewed 36 publications and 17 unpublished documents about UAS and their effect on wildlife and identified the different factors influencing the probability and magnitude of wildlife disturbances due to UAS. The study found UAS responses differ depending on flight patterns, engine type, and characteristics of the animal. Birds had the highest sensitivity to disturbance in comparison to terrestrial animals and aquatic animals. The authors recommend favoring low-noise or small UAS and short missions.

Perlman, D. (2014, June 23). Illegal drone flights over Monterey Bay sanctuary draw warning.

This news article reports that officials from the Monterey Bay National Marine Sanctuary are reminding the public that flying UAS in NOAA Regulated Overflight Zones is prohibited. It also notes that FAA bans

UAS from flying above 400ft (122m) anywhere, and the NPS banned UAS from national parks in 2014 because of noise and safety concerns.

Perryman, W.L.; Goebel, M.E.; Ash, N.; LeRoi, D.J.; Gardner, S. Small Unmanned Aerial Systems for Estimating Abundance of Krill-Dependent Predators: A Feasibility Study with Preliminary Results; National Oceanic and Atmospheric Administration; Southwest Fisheries Science Center: La Jolla, CA, USA, 2014; pp. 64–72.

This report provides the technical specifications and a detailed review of the experience with the types of platforms used by Goebel et al. in the 2015 study on the abundance of krill-dependent predators.

Pomeroy, 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.

This article assesses abundance surveys, photogrammetry, and photo-identification of seals in UK using three different types of UAS units.

1. VTOL/Cinestar 6: Little to no behavioral reactions at 98ft (30m) altitude on frequently disturbed haulout. Seals on more remote hallout site observed flushing with UAS at 164ft (50m)
2. VTOL/Cinestar and VTOL/Skijib: For breeding seals: Animals were alert, lifted heads with UAS at 98ft (30m); shuffling and changes in position were observed when UAS at 49ft (15m).
    a. For molting seals: Animals were alert, lifted heads with UAS at 98ft (30m); shuffling and changes in position were observed when UAS at 98ft (30m); seals observed to flee from UAS at 16.5ft (5m).
3. VTOL/Vulcan 8: For breeding seals: Animals were alert, lifted heads with UAS at 164ft (50m); locomotion of seals was observed when UAS was at 98ft (30m);
    a. For molting seals: Animals were alert, lifted heads with UAS at 164ft (50m); shuffling, changes in position, and fleeing were observed when UAS at 164ft (50m).

Scott, Alwynn (2015). Americans OK With Police Drones - Private Ownership, Not So Much: Poll. http://news.yahoo.com/americans-ok-police-drones-private-ownership-not-much-120553042.html

This article from Reuters reports on American beliefs regarding UAS policy.

Seymour, A.C.; Dale, J.; Hammill, M.; Halpin, P.N.; Johnston, D.W. Automated detection and enumeration of marine wildlife using unmanned aircraft systems (UAS) and thermal imagery. Sci. Rep. 2017, 7, 45127.

The authors use UAS, along with thermal imagery and computer vision to improve on traditional wildlife survey methods. They used a FW UAS imaging 2 grey-seal breeding colonies in eastern Canada. While the authors made no mention of whether disturbances occurred, they mention that it is important to consider seal haul-out behavior when planning studies. They finally note that a UAS can produce more precise species counts with substantially reduced costs and has the potential to reduce risk.

Smith, C. E., Sykora-Bodie, S. T., Bloodworth, B., Pack, S. M., Spradlin, T. R., and Leboeuf, N. R. (2016). Assessment of known impacts of unmanned aerial systems (UAS) on marine mammals: data gaps and recommendations for researchers in the United States. *J.Unmanned Veh. Syst.* 4,1–14. doi:10.1139/juvs-2015-0017

Smith et al. provides a review of measured effects of UAS on marine mammals and identified that the two potential sources of disturbance are the visual cues from the UAS (including its shadow) and the noise emitted by the UAS.

Sweeney, K.L.; Helker, V.T.; Perryman, W.L.; LeRoi, D.J.; Fritz, L.W.; Gelatt, T.S.; Angliss, R.P. Flying beneath the clouds at the edge of the world: Using a hexacopter to supplement abundance surveys of steller sea lions (Eumetopias jubatus) in Alaska. J. Unmanned Veh. Syst. 2015, 4, 1–12.

This study is an earlier write-up of Sweeney et al.'s presentation at the UAS symposium.[6] Using an APH-22 (which is a 6-motor rotor craft), the researchers have been surveying pinniped populations since 2014. The APH-22 provides researchers substantial benefits due to its ability to hover over animals and carry heavy payloads. In comparison to manned aircraft survey images, the UAS can provide high resolution images, but has reduced efficiency over large geographic area.

Vas, E., Lescroel, A., Duriez, O., Boguszewski, G., & Gremillet, D. (2015). Approaching birds with drones: first experiments and ethical guidelines. Biology Letters, 11(2), 20140754–20140754. https://doi.org/10.1098/rsbl.2014.0754

This study tested the disturbance to birds with different approach speed, color, and frequency of flights – these showed no difference in effect, approaching within 13ft (4m). The results show that during 80% of all cases the Phantom, which is an electric UAS, could fly within 13ft (4m) of semi-captive mallards, wild flamingos, and greenshanks without visibly modifying their behavior (although Phantom UAS approaching a bird vertically usually caused increased disturbance). Vas, et. al. recommends launching at least 328ft (100m) from the bird species that were studied.

[6] Presentation available at https://swfsc.noaa.gov/uploadedFiles/Events/Meetings/UAS_2016/Presentation/Sweeney.pdf.

UAS Use for Seabird and Marine Mammal Research *(adapted and modified from Smith et al., 2016)*			
Objective of Study	**UAS Class/Model**	**Behavioral response details**	**Source**
Fin whale (Balaenoptera physalus), sperm whale (Physeter macrocephalus), humpback whale (Megaptera novaeangliae), and gray whale (Eschrichtius robustus)	VTOL/Aquacopter	Large whales showed no additional avoidance behaviors when approached by UAS than observed during vessel-based activities, however dolphins were observed actively moving away.	Acevedo-Whitehouse, et. al, 2013
California sea lions (Zalophus californianus)	DJI Phantom 3 Advanced	15m: there was no pinniped species disturbance observed and did not elicit visible reaction; 10m: sea lions were observed looking up and some flushing behavior. UAS sometimes disrupted yellow-footed gulls (Larus livens), which in turn scattered more sea lions into the water.	Adame, et al., 2017
Humpback whales (Megaptera novaeangliae)	VTOL/Splashdrone	noise may be heard underwater by toothed and baleen whales when flying at 10m AGL or lower, but the effect is likely to be small, even for animals close to the surface	Christiansen, et.al, 2016
American black bears	VTOL/3D Robotics	Flights rarely induced a measurable change in movement behavior but heart rates indicated a stressed response during all flights	Ditmer, et al., 2015
Shorebirds and waterfowl including Dunlin (Calidris alpina), Mallard (Anas platyrhynchos), American Green-winged Teal (Anas crecca), American Wigeon (Anas Americana), and Northern Pintail (Anas acuta)	VTOL/Responder UAS	Some disturbance at all altitudes flown, but most birds appeared undisturbed by the presence of the UAS when flown >61m altitude, where disturbance appears to be minimal.	Drever et al., 2015
Non-nesting waterbirds	VTOL/Honeywell RQ-16 T-Hawk FW/AeroVironment RQ-IIA	May increase flushing behavior of waterbirds when flown at altitudes below 30m	Dulava, 2015
Killer whales (Orcinus orca)	VTOL/APH-22	No behavioral responses observed during any flights at an altitude of 35-40m	Durban, et. al., 2015
Blue whales (Balaenoptera musculus)	VTOL/APH-22	35–40 m above the surface level allows the gathering of important information about size, health, and behavior, while reducing disturbance levels and increasing the measurement precision if compared with manned aircraft	Durban, et. al., 2016
Fur seals, leopard seals, and Weddell seals (Leptonychotes weddellii)	VTOL/APH-22	Focusing on the noise impact, no reaction of pinnipeds - fur seal, Weddell seal, and leopard seal colonies - was observed while flying at 23m AGL	Goebel, et. al., 2015 Perryman, et. al., 2014
Dugongs (Dugong dugon)	FW/ScanEagle	When flown at 1,000ft, it is unlikely that noise from the ScanEagle would be audible to maine fauna underwater	Hodgson, et al., 2013

Lesser Frigatebirds (Fregata ariel), Crested Tern (Thalasseus bergii), and Royal Penguins (Eudyptes schlegeli)	VTOL/3D Robotics	No behaviorial responses mentioned	Hodgson, et al., 2016
Humpback whales (Megaptera novaeanlgiae)	FW/ScanEagle	Unlikely to have behavioral responses when flown at 300m	Hodgson, et al.,
Manatees (Trichechus manatus latirostris)	FW/Foldbat	No disturbance observed while flying at 100m AGL	Jones, et. al., 2006
Ibis, egrets, and wood storks	FW/Foldbat	No behavioral reactions at flight altitudes of 100 to 150m	Jones, et. al., 2006
Bowhead whales (Balaena mysticetus)	FW/TD100-E	No behavioral responses recorded	Koski, et. al., 2015
Mixed-species flocks of waterfowl in Australia (most common waterfowl observed included Eurasian coot (Fulica atra), Pacific black duck (Anas superciliosa), grey teal (Anas gracilis), hardhead (Aythya australis), Australasian shoveler (Anas rhynchotis), pink-eared duck (Malacorhynchus membranaceus), musk duck (Biziura lobata), blue billed duck (Oxyura australis), and black swan (Cygnus atratus))	FW/UAVER Avian-P FW/Skylark II FW/Drone Metrex Topodrone-100 VTOL/DJI Phantom VTOL/FoxTech Kraken-130	little or no obvious disturbance effects on wild, mixed-species flocks of waterfowl when UAVs were flown at least 60m above the water level (fixed wing models) or 40m above individuals (multirotor models). Disturbance in the form of swimming away from the UAV through to leaving the water surface and flying away from the UAV was visible at lower altitudes and when fixed-wing UAVs either approached subjects directly or rapidly changed altitude and/or direction near animals.	McEvoy, et al., 2016
Spotted and ribbon seals	FW/ScanEagle	Comparison with manned aircraft surveys showed marked reduction in disturbance during UAS operations. Showed no or little apparent response at 120 AGL.	Moreland, et. al., 2015
Harbor seal (Phoca vitulina) (30-50m)	VTOL/Cinestar 6	Little to no behavioral reactions at 30m altitude on frequently disturbed haulout. Seals on more remote hallout site observed flushing with UAS at 50m	Pomeroy, et. al., 2015
Gray seal (Halichoerus grypus) (5-30m)	VTOL/Cinestar 6 VTOL/Skijib	For breeding seals: Animals were alert, lifted heads with UAS at 30m; shuffling and changes in position were observed when UAS at 15m. For molting seals: Animals were alert, lifted heads with UAS at 30m; shuffling and changes in position were observed when UAS at 30m; seals observed to flee from UAS at 5m	Pomeroy, et. al., 2015
Gray seal (Halichoerus grypus) (30 - 50m)	VTOL/Vulcan 8	For breeding seals: Animals were alert, lifted heads with UAS at 50m; locomotion of seals was observed when UAS was at 30m; For molting seals: Animals were alert, lifted heads with UAS at 50m; shuffling, changes in position, and fleeing were observed when UAS at 50m	Pomeroy, et. al., 2015
Grey seals (Halichoerus grypus)	FW/eBee	No behaviorial responses mentioned	Seymour, et. al.,
Steller sea lions (Eumetopias jubatus)	VTOL/APH-22 Hexacopter	Over 4 hours of flight time, only one instance of disturbance, 5 animals flushed into the water (0.3% disturbance rate, as compared to 5% disturbance rates from amanned aircraft)	Sweeney, et. al., 2015
Semi-wild mallard (Anas platyrhynchos), wild flamingos (Phoenicopterus roseus), and common greenshanks (Tringa nebularia)	VTOL/Phantom	80% of all UAS flights could fly within 4m without visibly modifying their behavior	Vas, et. al., 2015