A LITERATURE REVIEW ON THE EFFECTS OF UNCREWED AIRCRAFT SYSTEMS ON BIRDS, MARINE MAMMALS, AND SEA TURTLES


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FINAL REPORT
DECEMBER 15, 2021

A LITERATURE REVIEW ON THE EFFECTS OF UNCREWED AIRCRAFT SYSTEMS ON BIRDS, MARINE MAMMALS, AND SEA TURTLES

Final Report

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Greater Farallones National Marine Sanctuary
991 Marine Drive,
San Francisco, CA 94129

Prepared By:
Rachel Rhodes[1] and Matt Pickett[2]

[1]Independent Contractor (MESM 2021)
[2]Oceans Unmanned Inc.

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I. INTRODUCTION

Uncrewed Aircraft Systems (UAS), commonly referred to as drones, have become increasingly prevalent in ecological science and wildlife management in the last decade. UAS can gather high resolution aerial data that provide more affordable, efficient, and less disruptive options for wildlife management and monitoring compared to ground counts, aerial photographic surveys via crewed aerial platforms, as well as provide monitoring options in remote areas that were previously inaccessible or too large to cover on foot (Chabot & Bird, 2012; Chabot et al., 2015; McEvoy et al., 2016; Mustafa et al., 2017). UAS are also being used more frequently by both the film industry and other organizations as a safer, lower cost alternative to fixed-wing aircraft to capture high-resolution aerial imagery of the marine environment for both commercial and education purposes. However, UAS also have the potential to disturb wildlife and may evoke vigilant, aggressive, or escape behavior depending on the species, characteristics of the UAS, and flight operation. As seen in a recent event at a nesting site for Elegant Terns in Southern California in 2021, flight operations gone awry can result in nest abandonment for an entire colony, underpinning the need to develop guidelines for the use of UAS in sensitive wildlife areas (Levenson, 2021). Federal and state agencies recognize the need to manage the use of UAS near wildlife, but creating appropriate guidance can be challenging. Understanding wildlife disturbance from UAS is in its infancy with few published studies quantifying the impact on wildlife, and for only a handful of specific species. Broader, more extensive research is needed to quantify and understand the impacts on a wider range of taxa to assist in advancing guidelines for the safe use of UAS. Though current research is limited, it's important to understand the extant body of knowledge regarding UAS and wildlife to address the rapidly expanding use of this technology for research, commercial, and recreational use. This report provides Office of National Marine Sanctuaries (ONMS) with an overview of existing regulations governing the use of UAS, a brief description of the technology, a review of forty peer-reviewed studies that document avian, marine mammal, and sea turtle responses to UAS, and a review of fifty-three NOAA ONMS permits that have permitted UAS use in NOAA regulated overflight zones (NROZ). The report also offers recommendations for ways in which to minimize the impacts of UAS usage on birds, marine mammals, and sea turtles.

II. RESTRICTIONS ON USE OF UAS

Federal Requirements

The Federal Aviation Administration (FAA) is the sole federal body that governs the airspace and licenses usage of UAS in the United States today. Specifically, the FAA has the exclusive authority to regulate civilian aviation safety, the efficiency of the navigable airspace, and air traffic control. The expansion of UAS by both the military and civil sectors prompted discussion and review of how UAS are regulated and whether current FAA regulations apply. As of 2007, the FAA clarified that UAS are by definition an aircraft and thus falls under FAA jurisdiction (Public Law 112-95, Section 331(8)). In 2012 Congress tasked the FAA with developing a comprehensive plan to safely accelerate the integration of civil unmanned aircraft systems into the national airspace system. Subsequently, the FAA issued a series of regulations governing civilian UAS operations. These regulations depend on whether the flight is recreational or commercial as outlined below.

Recreational

Recreational operators of small UAS must follow a basic set of requirements that applies to flights purely for fun or personal enjoyment. These requirements include registering UAS with the FAA, taking a safety test, following the safety guidelines of a FAA-recognized Community Based Organization, keeping the aircraft within visual line of sight, flying at or below 400 ft above ground level (AGL) in Class G (uncontrolled) airspace, and staying clear of surrounding obstacles (49 USC § 44809). Additional safety guidelines include avoiding flying near other aircraft–especially near airports, over groups of people, over stadiums or sports events, near emergency response efforts such as fires, and never flying under the influence of drugs or alcohol.

Commercial

Commercial flyers with small UAS must follow rules outlined in 14 CFR Part 107. According to these rules, commercial flyers must be a FAA-Certified UAS pilot, register UAS with the FAA, keep the aircraft within visual line of sight, and fly below 400 ft AGL. As of April 21, 2021, pilots may now fly at night, and over people and moving vehicles as long as they meet specific requirements (86 FR 4382; 14 CFR § 107.29). The rules for operating UAS are summarized in the table below (Table 1).

Table 1. Summary of Requirements for Small UAS Flyers According to FAA Laws Regulations

	Recreational Requirements (Hobbyist Requirements)	**Commercial Requirements (Fly for Work/Business, or Recreational if so chose in accordance with 14 CFR Part 107)**
Pilot Requirements	• Must pass aeronautical knowledge and safety test and carry proof of passage	• Must pass aeronautical knowledge and safety test and have a Remote Pilot Certificate (must be 16 years or older) and carry proof of certificate.
Aircraft Requirements	• Not required to register UAS unless it is greater than 0.55 pounds	• Must register any UAS regardless of weight
Operating Rules	• Fly only for recreational purposes • Follow community-based safety guidelines • Keep the aircraft in visual line of sight • Yield the right of way to manned aircraft • Fly at or below 400 ft in uncontrolled airspace (Class G) • Need prior authorization to fly in controlled airspace (Class B, C, D, and E)	• Perform a pre-flight check to ensure UAS is in condition for safe operation and assess the operating environment • Keep the aircraft in visual line-of-sight • Fly at or below 400 ft • Groundspeed may not exceed 87 knots • May now fly over people, over moving vehicles, and at night without a waiver under certain conditions (86 FR 4382) • Yield the right of way to all aircraft, and airborne vehicles

Operating Rules (cont.)		• Need prior authorization to fly in controlled airspace (Class B, C, D, parts of E) • Fly at least 500 ft below a cloud or 2,000 ft horizontally from a cloud
Legal or Regulatory Basis	• Exception for limited recreational operations of unmanned aircraft (49 USC § 44809)	• Title 14 of the Code of Federal Regulation (14 CFR Part 107)

Although the FAA has sole jurisdiction of airspace as described above, there are several agencies within the Department of Interior and the Department of Commerce that have prohibited or restricted the operation of UAS in certain areas under their respective statutory authorities. Specifically, in 2014 the National Park Service provisionally banned the operation of all UAS in National Parks in order to protect public health and safety and to protect park resources and values (36 CFR § 1.5). U.S. Fish and Wildlife Service has interpreted its general aircraft regulations to prohibit launching, landing, or operating UAS in a national wildlife refuge (50 CFR § 27.34). Within NOAA, several national marine sanctuaries on the west coast require a permit to fly UAS in NOAA Regulated Overflight Zones (NROZ) (15 CFR Part 922). NROZ are specific zones in each sanctuary that have a designated minimum altitude for overflights of motorized aircraft to protect marine mammal and bird communities. If a pilot is observed flying below these minimum thresholds in these zones, it is presumed that a wildlife disturbance has occurred unless sufficiently proven otherwise and that the pilot is in violation of sanctuary regulations. Several national marine sanctuaries prohibit "take" of any marine mammal, sea turtle, or bird within or above the sanctuary. "Take" includes harassment or to attempt to engage in any such conduct and includes operation of an aircraft that results in the disturbance or molestation of any marine mammal, sea turtle or seabird (15 CFR § 922.3). Likewise, NOAA requires researchers to obtain a permit under the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) to use UAS at an altitude below 400 feet to research marine mammals, and in some cases, sea turtles. An MMPA permit is also required to use UAS for commercial and educational photography of non-ESA listed marine mammals.

State & Local Requirements

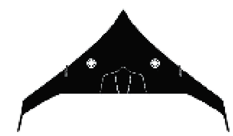
In addition to federal UAS regulations, states, local governments, and tribal governments have also passed laws and ordinances regulating the operation of UAS by individuals, businesses, law enforcement, and other interests throughout the country. Overall, 44 states have enacted laws pertaining to UAS including prohibiting UAS flights over specific property types, protecting privacy, allocating funds for industry certifications, and creating procedures and standards for law enforcement's use of UAS ("National Conference of State Legislatures," 2021). Specifically on the west coast, California has passed legislation that make it a misdemeanor to use UAS to invade the privacy of a person (AB 1129), prohibits the use above correctional facilities (SB 1355), makes it a misdemeanor to use UAS to interfere with activities of first responders and emergency personnel (AB 1680), provides immunity to emergency personnel that damage UAS that are interfering at the scene of an emergency (SB 807), and prohibits the use in any state wilderness, cultural preserve, or natural preserve (Cal. Code Regs. tit. 14, § 4351). In Washington, there is only one state law regulating the operation of UAS and it requires operators to obtain a permit to fly in state parks (WAC 352-32-130). There are also several local UAS restrictions, including some areas adjacent to national marine sanctuaries. A few examples of these areas include the Golden Gate Bridge in San Francisco (Golden Gate Bridge Highway & Transportation District), Pacific Grove, California Department of Fish and Wildlife's Sea Otter Game Refuge offshore of Big Sur, and an area near a breeding seabird colony at Devil's Slide (County of San Mateo Parks Department). Lastly, some tribal governments may prohibit UAS takeoff and/or landing in specific areas or require operators submit an application that includes proof of insurance, proof of FAA Drone Registration, flight plan(s), etc. (see e.g., https://navajodot.org/drone). Given that these restrictions can vary, it is best practice for operators to contact the local tribal government to ask for local protocols or permission to fly on tribal lands.

III. TECHNOLOGY

This report uses the term "Uncrewed Aircraft Systems (UAS)" to refer to unmanned aircrafts and their operating equipment, but there are a number of other terms used by different agencies and publications including "drones," "Unmanned Aerial Vehicles (UAV)," "Remotely Piloted Aircraft System (RPAS)," "Unoccupied Aircraft Systems (UAS)", and as the FAA refers to them, "Unmanned Aircraft Systems (UAS)." UAS come in a variety of shapes and sizes, but generally consists of three components, including the platform (flying vehicle), the payload (camera or other sensor), and ground control station (remote controller or computer). The most common type of UAS currently being used for both recreation and research are multirotor systems that operate and hover like a small helicopter. Two other types of UAS that are being increasingly used in research are fixed-wing systems and vertical takeoff and landing (VTOL) systems; all are described briefly below (Table 2).

Table 2. Summary of types of UAS

Type	Description	Example Silhouettes
Multirotor	The quadcopter is the most common of these systems which land and takeoff vertically like helicopters and can hover as required. Other multirotor include hexacopters and octocopters.	
Fixed-wing	These UAS are launched either by catapult or being hand thrown and fly like an airplane versus a helicopter. Fixed-wing flights require less power, thereby increasing range and duration of these systems.	

Vertical Take-off and Landing	These systems are a hybrid between multirotor and fixed-wing that takeoff vertically and then transition to forward fixed-wing flight to increase endurance and range.	

In addition to the way a system is launched and flown, UAS can also be categorized according to whether it is electric-powered, gas-powered, or a hybrid model that has both power sources. A relevant distinction between these types of UAS is that gas-powered devices are generally louder than their electric counterparts, which has potentially substantial implications for wildlife disturbances, discussed in more detail in *Section V* and *VI*. Examples of popular UAS type and models used in published studies can be found in *Appendix A, B*, and *C* and models of UAS permitted by NOAA ONMS can be found in *Appendix D*. As UAS technology continues to evolve, it is difficult to extrapolate or conclude a precise response of wildlife to specific models of UAS given that noise profiles, sizes, shapes, flight speeds vary between models and in-flight maneuvers and flight patterns can vary by operators. In addition, most of the published studies and permit reports only used one model rather than comparing the results of the different types of UAS. Further, wildlife reactions are highly situational depending on the species, time of year (e.g., nesting, breeding, or pupping season), and other environmental variables as well as how a UAS is operated (e.g., altitude, angle of approach, speed, duration of flying time, etc.). Section IV provided a more detailed discussion of all these factors.

IV. REVIEW OF WILDLIFE DISTURBANCE

A disturbance is the response of wildlife to the presence of a stimulus which may result in the animal undergoing behavioral and or physiological changes (Weston et al., 2020). Acute or chronic disturbances can significantly impact an animal's energy budget, reproductive success, and long-term survival (Tablado & Jenni, 2017). UAS are novel stimulus and a new potential source of disturbance for wildlife. Both the sounds and visual cues produced by UAS are potential sources of disturbance that can impact wildlife in different ways depending on the characteristics of the species and the attributes of the UAS. Significant factors that influence animal reactions may include physical properties of the UAS such as size, shape, color, and engine-type as a proxy for sound level, and flight operations including altitude, distance, and approach angle (Goebel et al., 2015; Pomeroy et al., 2015; Vas et al., 2015; Christiansen, et al., 2016; Smith et al., 2016). In addition, wildlife responses depend on characteristics of the animal and vary by taxon, species, and individuals within the same species depending on their breeding status and life-history stage (Drever et al., 2015; Brisson-Curadeau et al., 2017; Mulero-Pázmány et al., 2017; Ramos et al., 2018; Weimerskirch et al., 2018; Rebolo-Ifrán et al., 2019; Weston et al, 2020).

There were limited studies that were explicitly designed to measure the behavioral or physiological response of wildlife to UAS, so this review includes forty peer-reviewed studies that either explicitly measured wildlife disturbance to UAS or reported on wildlife disturbance, including sixteen that evaluated birds, fifteen that evaluated marine mammals, five that evaluated both birds and marine mammals, and four that evaluated turtles. In many of the studies that reported on wildlife disturbance, the information was provided as an anecdote to other research and the studies were likely designed in a manner to minimize the impact of animals. Of the studies that rigorously evaluated wildlife disturbance, the majority measured behavioral responses and only a few measured physiological responses of wildlife to UAS, although several studies indicated it should be a focus of future research. Overall, regardless of study design, twenty-three of the forty peer-reviewed studies documented a change in animal behavior in response to UAS that ranged from minor actions such as vigilance, escape, or agonistic behavior, to extreme events such as the flushing of a bird colony or marine mammal haul-out site. A greater portion of studies of birds reported behavioral responses (fourteen out of twenty-one papers) as compared to marine mammals (five out of twenty papers). Turtles also had a large portion of studies report behavioral response when flights were below 10 m (33 ft) (three out of four papers), however, there were far fewer published studies on turtles than on birds or marine mammals.

Effects of UAS on Birds

Birds are known to be especially sensitive to anthropogenic disturbances, however, limited studies have measured the disturbance effects explicitly of UAS. As seen in *Appendix A*, six of the twenty-one studies included in this review evaluated waterfowl, seven studies evaluated penguins, and the remaining eight studies evaluated other seabirds in addition to penguins. The level of disturbance to UAS varied by taxon and depended on life-history traits of species and their breeding status, as well as acoustic and visual characteristics of the UAS including the level of sound produced, flying altitude, and in-flight patterns. Studies that evaluated mixed flocks of waterfowl and UAS documented a minimal amount of disturbance, especially when the UAS was flown at higher altitudes above 60 m (197 ft) (Chabot & Bird, 2012; Drever et al., 2015; Vas et al., 2015; Barnes et al., 2018). Other studies that evaluated Gentoo and Adélie Penguins documented behavioral responses that were most notable during flights at lower altitudes below 30 m (98 ft) (Mustafa, et al., 2017; Rümmler et al., 2018; Krause et al., 2021). The studies evaluating other seabirds documented responses that varied by species and their breeding status (Chabot et al., 2015; Dulava, 2015; McClelland et al., 2016; Brisson et al., 2017; McIntosh et al., 2018; Weimerskirch et al., 2018). For a complete list of species included in these studies, see *Appendix A*.

Acoustics

UAS can acoustically disturb wildlife depending on the level of sound produced by the motors in relation to the background sound level of the surrounding environment. Gas-powered UAS tend to be louder than electric-powered and may increase disturbance of birds when flown at lower altitudes. A recent study by Korczak-Abshire et al. (2016) compared the level of wildlife disturbance elicited by a gas-powered versus electric-powered fixed-wing. Researchers flew both models over a colony of Adélie Penguins at altitudes of 350 m (1,148 ft) above ground level (AGL) and found an increase in display of vigilance behavior by penguins when flying the gas-powered fixed-wing. It should be noted that the level of vigilance behavior observed in response to the UAS was considered similar to when a skua flew over the penguin colony at 5 m AGL without attacking nesting birds (Korczak-Abshire et al., 2016). In another study, researchers noted the level of sound generated by a gas-powered UAS may have increased flushing behavior especially at lower altitudes, however, this study was not designed to rigorously evaluate wildlife disturbance (Dulava et al., 2015). Additionally, a systematic literature review by Mulero-

Pázmány et al. found gas-powered engines produced more behavioral responses, suggesting sound produced by UAS is an important source of disturbance (Mulero-Pázmány et al., 2016). In addition to engine-type, the background sound level of the surrounding environment also influences whether UAS creates an acoustic disturbance. Goebel et al. (2015) found the sound produced by an electric hexacopter was lower than the background sound levels of the nesting colony during the egg-laying period when flown at 30 m (98 ft) and above, suggesting the sound of the UAS would be lost in the background (Goebel et al., 2015). Another consideration for the potential impacts of acoustic disturbance is the distance from animals during take-off and landing. Although few studies primarily focused on acoustic disturbance specifically, many of the studies reported the expected level of sound produced by the UAS (Perryman et al., 2014; Dulava et al., 2015; Vas et al., 2015; McClelland et al., 2016; Rümmler et al., 2016; Rümmler et al., 2018; Krause et al., 2021) with a few studies noting that changes in sound intensity were greatest during take-off (Arona et al., 2018; Harris et al., 2019; Weston et al., 2020). Rümmler et al. (2016) used an octocopter that emitted a sound level measured at 70 dB at 5 m and tested various flight schemes including varying takeoff distances. They found that even the largest takeoff distance tested, 50 m (164 ft), was likely not sufficient to avoid disturbance of penguins (Rümmler et al., 2016). Vas et al. (2015) also recommended launching further than 100 m (328 ft) to avoid disturbance of birds based on pre-trials their team conducted (Vas, et. al., 2015).

<u>*Altitude*</u>

Generally, behavioral responses of birds increased as UAS were flown at lower altitudes and during vertical flight patterns (Dulava et al., 2015; Rümmler et al., 2016; Mustafa et al., 2017; Weimerskirch et al., 2018; Krause et al., 2021). The exact altitude at which birds began showing behavioral responses varied by species. For example, when using the same UAS and flight patterns, Adélie Penguins reacted when UAS were flown at the highest tested altitude, 50 m (164 ft), and Gentoo Penguins reacted at 30 m (98 ft) and below (Rümmler et al., 2018). Weimerskirch et al. (2018) compared the behavioral response of 11 southern seabird species to UAS flown at various altitudes and found at the highest tested altitude of 50 m (164 ft) only one species, Southern Giant Petrel, reacted to the UAS. When it was flown lower between 10-25 m (33-82 ft), additional species reacted to the UAS including Light-mantled Albatross, Giant petrels, and Sub-Antarctic Skua, while Sooty Albatross, Wandering Albatross, and Southern Rock-hopper Penguin were less sensitive to the flight at these altitudes (Weimerskirch et al., 2018). Other studies reported no bird disturbance when the UAS was flown at 60 m (197 ft) (McEvoy et al., 2016), 100 m (328 ft) (Jones et al., 2006), or 183 m (163 ft) (Chabot & Bird, 2012), although this depended on the type and model of UAS and included different species across studies (see *Appendix A*).

<u>*Flight Pattern*</u>

Other studies have found that the approach angle and in-flight maneuvers of the UAS can have a significant impact on bird behavior. Multiple studies found that birds reacted the strongest when the UAS was directly overhead and vertically descended to lower altitudes (Vas et al., 2015; Rümmler et al. 2016; Mustafa et al., 2017; Weimerskirch et al., 2018). Both Rümmler et al. (2016) and Mustafa et al. (2017) found the behavioral response of penguins was strongest during vertical descents to 20 m (66 ft) even when compared with horizontal flight patterns at this same altitude (Rümmler et al., 2016; Mustafa et al., 2017). Weimerskirch et al. (2018) similarly discovered animals showed the strongest reaction when the UAS made a vertical descent from 10 m (33 ft) to 3 m (10 ft), however this study did not test horizontal flight patterns below 10 m (33 ft) for comparison (Weimerskirch et al., 2018). Lastly, Vas et al. (2015) studied the potential impact of color, speed, frequency of flight, and approach angle of UAS on 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 with the strongest response recorded during vertical descents (Vas et al., 2015).

Size & Shape

The size and shape of the UAS may also influence the level of disturbance, especially when combined with specific flight patterns that are similar to a predators' flight patterns. A study by McEvoy et al. (2016) examined different UAS and their disturbance effects on large mixed flocks of species in Australia (McEvoy et al., 2016). The authors evaluated the impact of different shape and wing profiles of UAS and found multirotor and fixed-wing configurations had minimal disturbance effects especially when flown above 40 m (131 ft) altitude (McEvoy et al., 2016). The UAS shape that elicited the strongest response was the delta-wing design (Topodrone-100) when combined with flight patterns that resembled that of a known predator at the study sites (direct approach at altitudes less than 80 m (263 ft) or banking maneuver while changing altitude). 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 authors also recommended that take-off and landing sites be located out of sight of the target species and any necessary descent and banking maneuvers occur when the UAS is not directly overhead of the flock to minimize disturbance (McEvoy et al., 2016).

Characteristics of Animals

The sensitivity to UAS flown at various altitudes and approach angles varied by species and depended on their life-history characteristics and the individual's breeding status. Weimerskirch et al. (2018) compared the responses of various seabird species to flights ranging from 10-50 m (33-164 ft) and found species of adult penguins breeding in large colonies showed few reactions even when the UAS was flown at lower altitudes below 25 m (82 ft), whereas species in small open colonies appeared to be highly sensitive, exhibiting increased vigilance or agonistic behavior. These sensitive species included northern giant petrel, southern giant petrel, imperial cormorant, Subantarctic skua, and light-mantled sooty albatross. The disturbance also varied by breeding status and life-cycle stage. In King Penguins, chicks and molting adults showed extreme behavior modifications and signs of panic when the UAS was flown at 25 m and below. Breeding adults showed little to no behavior modification, however, their heart rate increased when the UAS was flown at lower altitudes, suggesting that observed behavior modifications of some species may not fully reflect their stress levels (Weimerskirch et al., 2018).

Effects of UAS on Marine Mammals

While the use of UAS in marine ecology has increased dramatically, there has been a limited number of studies that have been targeted to explicitly document the effects of UAS operations on marine mammals. This review includes a summary of twenty published studies of marine mammal disturbance and UAS, including eight on cetaceans, nine on pinnipeds, and three on sirenians. Some of the studies included were not explicitly designed to evaluate the behavioral or physiological responses of marine mammals to UAS, but instead reported on whether or not a wildlife disturbance to UAS occurred as part of other research. As seen in *Appendix B*, the majority of studies that involved marine mammals reported no behavioral response during UAS flights. Of the five studies that reported changes in animal behavior, many included pinnipeds, suggesting that marine mammals that spend considerable amounts of time on land or above water may be more sensitive to both visual and acoustic effects of UAS (Pomeroy et al., 2015; Smith et al., 2016; Adame et al., 2017; McIntosh et al., 2018; Ramos et al., 2018; Krause et al., 2021). Overall, the level of disturbance observed in these studies depended on the flight altitude and the positioning of the UAS.

<u>*Acoustics*</u>

Whether UAS were acoustically disruptive to marine mammals depended on the taxon, model of UAS, and the background sound level. Arona et al. (2018) assessed the acoustic properties of a small electric fixed-wing UAS and found it was acoustically unobtrusive and unlikely to disturb gray seals at breeding colonies (Arona et al., 2018). Other studies have suggested that UAS are acoustically disruptive to pinnipeds that are hauled out or above the surface of the water. Krause et al. (2021) found Antarctic fur seals were more likely to react from UAS when it approached from upwind versus downwind, suggesting the sound of the UAS was causing an acoustic disturbance (Krause et al., 2021). McIntosh et al. (2018) found that disturbance among Antarctic fur seals was low until the large, multirotor quadcopter descended to an elevation where the sound became noticeable (McIntosh et al., 2018). Pomeroy et al. (2015) compared the reaction of gray seals to various UAS models and found breeding and molting seals reacted to the larger, noisier multirotor octocopter at greater ranges of distance (Pomeroy et al., 2015). Christiansen et al. (2016) recorded sound levels produced by two models of electric multirotor quadcopters and found the sound levels they produced above the surface were within ranges known to cause disturbance to some marine mammals like sea otters and pinnipeds. However, when flown at altitudes of 5 m (16 ft) and 10 m (33 ft), the underwater sound levels of the UAS were barely detectable above ambient levels and the acoustic disturbance to cetaceans was predicted to be very small (Christiansen et al., 2016). In addition to this acoustic modeling, Christiansen et.al (2020) found minimal acoustic disturbance by UAS for southern right whales during field experiments using an electric, multirotor quadcopter (Christiansen, et.al, 2020).

<u>*Altitude*</u>

In the five published studies that documented disturbance of marine mammals, the altitude of the flight and the position of the UAS relative to the animal impacted the level of disturbance. Multiple studies documented pinniped species looking up at the UAS and or flushing into the water, especially when UAS were flying at lower altitudes. Pomeroy et al. (2015) found that gray seals reacted to flights flown at 30 m (98 ft) and below, with molting and breeding individuals showing more signs of disturbance. Harbor seals also reacted to lower flights, however it varied depending on the location of the haul-out site. At a more frequently disturbed haul-out, harbor seals showed no reaction to UAS when flown at 30 m (98 ft), however, at a more isolated haul-out, seals exhibited behavior when UAS were flown at 50 m (164 ft) and higher (Pomeroy et al., 2015). In another study, California sea lions started showing vigilance and some flushing behavior when UAS were flown at 10 m (33 ft) (Adame et al., 2017). Krause et al. (2021) found that Antarctic fur seals did not react when the UAS was flown at 46 m (151 m), however, responses increased when the UAS was flown at 30 m (98 ft) and below (Krause et al., 2021).

The majority of studies that examined cetaceans did not document a visual disturbance of whales from UAS flown at a variety of altitudes ranging from 5-210 m (5-689 ft), especially for baleen whales. Domínguez-Sánchez et al. (2018) found no significant changes in blue whale behavior (surface and dive times, blows per surfacing, blow interval, blow rates, etc.) during UAS flights flown at 5 m (16 ft) above each whale (Domínguez-Sánchez et al., 2018). In other studies, no behavioral response was observed for blue whales (Durban et al., 2016), bowhead whales (Koski et al., 2015), gray whales (Acevedo-Whitehouse et al., 2013; Torres et al., 2018), fin whales (Acevedo-Whitehouse et al., 2013), humpback whales (Acevedo-Whitehouse et al., 2013), or killer whales (Durban et al., 2015). However, behavior responses to UAS have been recorded for a toothed whale species in two separate studies. Bottlenose dolphins were observed actively moving away from the aircraft when it was flown at 13 m AGL (Acevedo-Whitehouse et al., 2013), as well as briefly orienting toward the aircraft when it was flown overhead at altitudes between 11-30 m (36-98 ft) (Ramos et al., 2018).

There were only two published studies that included sirenians. In one study, no disturbance of Amazonian manatee was recorded during the study higher altitudes greater than 100 m (328 ft) (Jones, et. al., 2006). In a separate study, Ramos et al. (2018) documented Antillean manatees changing swim directions in reaction to UAS flights less than 104 m (341 ft) primarily when the UAS was directly or nearly overhead (Ramos et al., 2018). While altitude and flight position seem to influence the level of disturbance for some marine mammals, it is difficult to distinguish whether acoustics of the UAS, altitude, or visual cues from the shadow overhead are the source of disturbance or rather a mix of these factors.

Effects of UAS on Turtles

There have been several studies and reviews assessing the application of UAS for sea turtle ecology to monitor turtle abundance and behavior, however, as seen in *Appendix C,* there are very few published studies that specifically assess disturbance of sea turtles from UAS. Given the small number of available published studies, this reviews also included any available studies of freshwater turtles as an additional reference. As such, this review includes four studies that reported on behavioral response of turtles to UAS, two that included species of sea turtles and two that included species of freshwater turtles. Generally, flights below 10 m (33 ft) disturbed turtles, although it is not clear if these behavioral responses were caused from visual or auditory cues. Overall, more research is needed to evaluate the impacts of UAS on turtles.

Acoustics

There were no studies that primarily focused on the acoustic disruption of UAS to sea turtles although a few papers provided a brief comparison of the range of auditory sensitivity detected by sea turtles to the sound levels produced by specific models of UAS. Bevan et al. (2018) noted green sea turtles and loggerhead sea turtles may be able to detect the sound of UAS flown between 5-10 m (16-33 ft); This is based on previous studies that showed these two species can detect frequencies of 100 to 1,000 Hz in water and commercial UAS can produce frequencies of 50 to 200 Hz, 57.8-80 dB when flown at altitudes between 5-10 m (16-33 ft) (Bevan et al., 2018). Similarly, in a literature review by Rees et al. (2018), the authors compared two separate studies, on that the reported frequency range of sea turtles (100 to 1000 Hz with peak sensitivity between 100 and 500 Hz; 80 dB re 20 µPa) and another that reported sound levels of an electric multirotor UAS (Mikrokopter hexacopter). Comparing these two studies, the authors noted sea turtles are unlikely to hear the sound produced by UAS at the tested altitudes of 16 m and 60 m as the sound level produced did not exceed 80 dB re 20 μPa (Rees et al., 2018).

<u>*Altitude*</u>

Bevan et al. (2018) evaluated the behavioral response of three species of sea turtles (green turtles, flatback turtles, and hawksbill turtles) to UAS flights ranging between 5-40 m (16-131 ft). The surveys were conducted over a variety of habitat including nesting beaches, nearshore waters, and reefs in tropical Australia. Sea turtles did not appear to react to the shadow cast by UAS nor did they exhibit any avoidance behaviors when UAS were flown at 10 m (33 ft) above nesting beaches, 15 m (49 ft) above reef habitat, and 20 m (66 ft) above near-shore habitat–the lowest tested altitude in the near-shore environment. During several encounters in the near-shore habitat, sea turtles spent relatively little time at the surface, which the authors noted was not considered a behavioral response in this study, but could be interpreted as such (Bevan et al., 2018). In another study, Sykora-Bodie et al. (2017) conducted flights over nesting beaches with fixed-wing UAS at 90 m (295 ft) and did not observe any disturbance to olive ridley turtles at this altitude (Sykora-Bodie et al., 2017).

In addition, there have been two studies that reported on the optimal flight altitude to minimize disturbance of freshwater turtles to UAS. Biserkov & Lukanov (2017) conducted on-site tests to determine the best height for UAS flights and found flights below 10 m (33 ft) disturbed basking freshwater turtles, especially when speeds were over 7 km/h (Biserkov & Lukanov, 2017). Escobar et al. (2020) observed minimal disturbance of yellow-bellied sliders and painted turtles during UAS flights at 10 m (33 ft) and 20 m (66 ft). Across forty flights, there were six instances (0.7 % of turtles) of minimal escape or disturbance behavior from turtles basking on artificial basking structures (Escobar et al., 2020).

V. REVIEW OF UAS PERMITTED ACTIVITIES IN NATIONAL MARINE SANCTUARIES

Since 2015, there have been fifty-three permits issued within NOAA Regulated Overflight Zones (NROZ) that permitted flights by an FAA licensed UAS operator and were either directed at observations or monitoring of wildlife or had potential for interactions with wildlife.[1] As seen in *Appendix D*, twenty-nine of these permits included an annual report of all activities conducted under the permit including information on whether UAS affected any wildlife in the vicinity; twenty permits did not have an annual report submitted at the time of this review; and the remaining four permits will not have any reports as they were unable to conduct any flights due to weather or other circumstances. Of these twenty-nine permits with annual reports, seven recorded behavioral responses of marine mammals or birds to UAS activities–three that involved marine mammals, three that involved birds, and one that involved both (see *Appendix E*) and none that involved sea turtles. Some permits issued for low UAS flights within NROZ were not directing their operations specifically on wildlife research and therefore in many cases the permit conditions generally set parameters that limited the possibility of having a wildlife interaction.

[1] Note: amendments to existing permits were counted as the same permit, but all amendments were reviewed in this assessment.

For example, one permit prohibited launching or operating UAS if winds were above 20 knots to reduce the risk of the operator losing control of the UAS and crashing it on or near wildlife. It also required the use of flight management software that set a wind warning for the system, whereas flights would be terminated as soon as practical and suspended until conditions improve. Other permits that were directed at observing or monitoring wildlife included more specific permit conditions to prevent wildlife interaction. Outlined below is a summary of permit conditions and spatial limitations for all fifty-three UAS permits, as well as details of the seven reported wildlife interactions.

Overview of Permit Conditions

Overall, all but one permit, GFNMS-2014-006-A1, included specific conditions and spatial limitations to reduce disturbance to wildlife. For birds, these conditions often included keeping a 1,000 ft horizontal buffer from seabird colonies during nesting season, not flying below 300 ft over rafting seabirds nor launching UAS within 300 ft of seabirds and 500 ft of rafting seabirds, avoiding large offshore rocks and islands, keeping a 300-400 ft buffer from sensitive species like Snowy Plovers and Black Oystercatchers, and avoiding known nests like the Peregrine Falcon nest along Highway 1 in Big Sur. For marine mammals, these conditions often included keeping a 1,000 ft horizontal buffer from marine mammal haul-out sites and at-sea marine mammal aggregations, keeping a 300 ft buffer from marine mammal or sea turtles listed as Threatened or Endangered according to the Endangered Species Act, carefully planning shoreline crossings, and flying above 66 ft over sea otters (any flights between 66 - 197 ft require a biological monitor and report). Other permits specified that flights must be 50 ft or higher when flying above any white sharks.

In addition to these wildlife conditions, all permits identified additional spatial limitations within NROZ including minimum flying altitudes and specific off-limit areas. The minimum altitude specified in permits ranged from 50 ft to 400 ft above sea level (ASL) depending on the permit and unless otherwise noted (i.e., whether there were other conditions relevant to wildlife as mentioned previously). A few specific permits allowed UAS flights at lower levels between 16-35 ft (see *Appendix D*). Areas that were off limit to UAS flights or required special planning included Carroll Island, Sea Lion Rock, Año Nuevo Island, Elkhorn Slough, Piedras Blancas rocks, Hurricane Point, Santa Barbara Island, Anacapa Island, and Castle Rock at San Miguel Island.

Multiple permits also specified additional conditions including the type/model of UAS and flight operation protocols including weather, flight patterns, and environmental monitoring requirements. As seen in *Appendix D*, most permits allowed for multirotor UAS including quadcopters (38 permits) and hexacopters (9 permits), while only a few permitted fixed-wings (4 permits) or did not specify a type. Many of the permits also specified conditions related to flight operations including recommended weather conditions for deployment – low winds, high visibility, and calm seas. Several permits specifically required the use of a handheld anemometer to ensure wind speeds are below 13-20 knots depending on the permit (GFNMS-2019-006-A4; MBNMS-2021-006-A; GFNMS-2021-004) or stated a maximum permissible wind of 13-25 knots for flight operations but did not require an anemometer. In addition, a few permits specified types of flight patterns that should be avoided including rapid changes in speed and direction. Many permits also required a qualified biologist to be present as an environmental monitor for at least a portion of flights to record observations of any environmental impacts of the activity including disturbance to wildlife.

Reported Wildlife Disturbance

There were seven annual reports that recorded a behavioral response of marine mammals or birds to UAS flights, although not all of them classified the responses as a wildlife disturbance. Behavioral responses recorded in the reports ranged from minor vigilance behavior (raised head) to more extreme aggressive (attacking) or escape responses (flushing). Three of these permits included activity that were specifically directed at observation or monitoring of wildlife and the other four permits had the potential for wildlife interaction but were not directed at wildlife observation or monitoring. Two of the permits also required MMPA permits from National Marine Fisheries Service (NMFS) that authorized Level B harassment (i.e., takes) of marine mammals which allowed for observations or incidental disturbance during aerial and ground surveys. These seven instances are described in detail below and a summary table can be found in *Appendix E*.

<u>Birds</u>

The annual report for permit GFNMS-2017-004-A1 describes five flights at Gualala Point Island and one flight outside of the NROZ at Shell Island that were conducted to collect aerial imagery of birds. Over the course of two of these flights, there were several instances of disturbance during the launch of the UAS that involved nesting western gulls and black oystercatchers. During the first flight, a nesting pair of Western Gulls and two pairs of Black Oystercatchers stood up and flew off as the UAS lifted off. The gulls returned fifteen minutes later, and the black oystercatchers returned to their nest sites after the UAS began the approach back to the bluff for landing. During the second flight, two nesting western gulls stood and flew off as the UAS was launched and returned approximately seven minutes later. Based on their experience, the authors recommended best practice protocols for future flights including careful consideration of UAS approach height, angle, and speed. The authors found slow, shallow-angled descent/ascents were the least disturbing to birds. Specifically, Brandt's Cormorants and Common Murres tolerated a slow descent from 300 to 200 ft AGL to the seaward side of Gualala Point Island, followed by a slow horizontal overflight of the nesting area.

The annual report for permit MBNMS-2017-030 also reported wildlife disturbance of Western Gulls and a pair of Black Oystercatchers at Shark Fin Cove in Davenport. The flights were conducted to collect aerial imagery of iconic landscape features of the Big sur and Monterey Bay coastlines. The UAS was launched from the bluff area just north of Shark Fin Cove and when it flew close to the cliff face gulls began circling it and occasionally vocalizing. A Black Oystercatcher also flew close by, vocalized in response to the UAS, flew around it for roughly two minutes, and then flew away. When the operator moved the UAS further offshore, positioning it at least 30 m (98 ft) offshore from the cliff, the birds lost interest in the UAS.

Lastly, the annual report for permit MBNMS-2020-022, described one instance of disturbance where a mixed flock of seabirds fledged from their roosts, circled back to the same roosts while the UAS was still flying overhead, and then appeared undisturbed for the remainder of the flight at Moss Landing Harbor jetties. The flight was conducted to collect photos of the Moss Landing Harbor jetties for accurate elevation data and the altitude at the time of the incident was not reported, but the permit specified the altitudes must be between 285-400 ft ASL. In this report, the observer noted some on-site challenges of being an observer including making quick estimates of distance, wildlife, and gauging degree of disturbance that warrants flight processes to be stopped. No other disturbances were observed, although Brown Pelicans and a sea otter were observed in the vicinity during this flight.

Marine Mammals

The annual report for permit MBNMS-2019-029-A2 recorded two instances of sea otters reacting to UAS disturbance out of six flights that were flown within NROZ between October 23 and November 2, 2020, and twenty-four total flights within Monterey Bay to collect aerial images of wildlife and landscapes. These activities also required MMPA permits, a permit from USFWS for sea otter take and a permit from NMFS that authorized Level B harassment (i.e., take) during filming that allowed observations and incidental disturbance. The environmental observer took note of these instances; however, he did not classify these as wildlife disturbance. In the first instance, a DJI Mavic 2 UAS was 70 ft above a group of six to ten sea otters that were seen resting, rolling, and grooming throughout the flight at Moss Landing. One juvenile sea otter reacted to the UAS by raising its head, at which point the operator ascended and moved the UAS so it was not directly overhead. The sea otter then settled and resumed normal behavior. The second instance occurred during a 20-minute flight at Moss Landing when the UAS was 60 ft AGL and hovering off to the side of a single adult sea otter. The sea otter briefly raised its head to look at the UAS before continuing normal foraging behavior.

In another report, for permit MBNMS-2021-002 that was issued to collect aerial image of wildlife and landscapes, the spotter recorded five instances in which female elephant seals turned their head towards the UAS. These flights were conducted at the North and South point beaches of Año Nuevo State Park on January 28, 2021, and February 10, 2021, and required an additional MMPA permit issued by NMFS. The survey utilized two quadcopters, a DJI Inspire 2 and a DJI Mavic Pro 2, and were never below 50 ft AGL nor did they deviate from the mainland or waters immediately surrounding the mainland. The flights were launched from locations that were 50 m (164 ft) from any visible wildlife. No further details of the flights or wildlife were disclosed.

Lastly, the annual report for GFNMS-2019-006-A2 noted that no wildlife disturbance occurred during a total of sixteen flights in 2019 and 2020 to collect aerial imagery of bull kelp. The report did include a description of one instance at an unpermitted site, Del Mar South, where a harbor seal estimated to be at least 300 m (984 ft) from the launch site raised its head when the UAS was launched but was not flushed from its position. No further details of the incident were disclosed. The report also noted weather, including fog and wind speeds, as well as limited capabilities to recharge batteries in the field were the primary issues encountered during UAS flights.

Mixed

The annual report for permit MBNMS-2018-017 observed two instances of wildlife disturbance during flights to film actors at Grimes Ranch in Big Sur. The first disturbance involved gulls that exhibited attacking behavior, approaching the UAS from above while it was already in flight. The operator used evasive maneuvers to move the UAS down and away from the gull and adjusted the flight pattern to avoid repeated disturbance. The authors of the report noted that the higher altitude approaches which had the UAS coming in above the gulls seemed to trigger the more aggressive response behavior. The second instance of disturbance involved a solitary sea lion that was hauled out at a sandy beach north of the filming area. When the UAS flew near the beach at 100 ft AGL, the sea lion began quickly moving toward the water. The operator increased the flying altitude moved it away from the beach and the sea lion stopped its retreat to the ocean, went back up the beach slope, and resumed resting behavior. In both instances, the disturbances reported seemed to subside quickly once the flight pattern and altitude changed.

VI. DISCUSSION

UAS are proving to be an effective and efficient tool for wildlife monitoring and management, as well as for commercial and educational purposes. They can help shorten field work duration, allow for repeated studies in areas that might have otherwise been inaccessible, provide high resolution images for more accurate counts, and provide a low-cost alternative to fixed-wing aircraft for capturing imagery of the marine environment for commercial or education purposes. When used responsibly, they can also reduce the impact on animals as compared to other monitoring methods (Chabot et al., 2015; Mustafa et al., 2017; Rümmler el at., 2017). UAS produce less noise than a manned-aircraft and many studies have concluded that UAS elicited substantially less disturbance behavior when flown at the equivalent heights of manned aircraft (Acevedo-Whitehouse et al., 2010; Moreland et al., 2015; Marine Mammal Commission, 2016; McEvoy et al., 2016). However, UAS can still be disruptive to wildlife and their use near marine mammals, birds, and sea turtles should be carefully considered.

While there has been an increase in the number of articles studies assessing the potential for harassment from UAS, more detailed, specific information overall is still relatively limited. Published literature that systematically documented the behavioral response of wildlife to UAS and various factors that influenced the response is only available for a handful of taxa, and for some, like turtles, where there is information available, it is very sparse. In many studies, wildlife disturbance or the lack thereof is mentioned, but the information seems to stem from largely descriptive observations mentioned solely in the context of other research and/or does not rigorously evaluate disturbance response (Jones et al., 2006; Hodgson et al., 2013; Perryman et al., 2014; Koski et al., 2013; Durban et al., 2015; Dulava et al., 2015; Durban et al., 2016; Biserkov & Lukanov, 2017; Sykora-Bodie et al., 2017).

Another limitation in available literature is the lack of research on physiological responses of wildlife to UAS. Only two of the published studies in this review included an evaluation of physiological reactions. The remaining thirty-four studies only evaluated behavioral responses; these studies may not have captured the full scope of effects as some disturbances can cause physiological changes that are not outwardly apparent. Ditmer et al. (2014) found that black bears increased heart rates by as much as 400% when UAS were hovering above them, even though they appeared outwardly calm which would indicate initially that no harassment had occurred (Ditmer et al., 2015). Similarly, Weimerskirch et al. (2018) found adult King Penguins displayed no outward behavioral response to UAS, yet their heart rates increased as UAS were flown at lower altitudes–demonstrating that an animal may still experience stress without displaying an observable behavioral response (Weimerskirch et al., 2018). To help fill these gaps in available literature, future studies should be explicitly designed to measure physiological and behavioral responses of wildlife to UAS. In addition, there are several studies on wildlife disturbance to UAS that were not included in this review as they were not peer-reviewed. Formal publications of these existing studies could help make the available literature more robust.

Lastly, the literature reviewed did not specifically address uncontrolled landings of UAS as a source of wildlife disturbance. However, incidents of in-flight UAS failures resulting in crashes into sensitive wildlife areas have been documented. As mentioned in the introduction, there was an incident that involved an uncontrolled landing of a UAS at the state managed Bolsa Chica Ecological Reserve in Southern California in June 2021. The uncontrolled landing of the UAS resulted in roughly 3,000 Elegant Terns flushing and abandoning their nests with approximately 2,000 eggs (Levenson, 2021). The incident highlights the potential risk of significant wildlife disturbance from uncontrolled landings of UAS. Personal communication with experienced UAS operators at Oceans Unmanned Inc., as well as recommendations from Duffy et al. (2017), suggest flight planning considerations should include weather, in particular wind speed and direction, as well as battery performance, and overall system capabilities and limitations to mitigate the risk of an uncontrolled landing and ensure safe UAS operations (Duffy et al., 2017).

Even though the available information is limited, certain conclusions regarding the harassment of wildlife from UAS can still be reached based on these reviewed published papers and permit reports. However, these conclusions are subject to change with more research becoming available on a wider range of taxa and species. From the forty published papers and fifty-three permits reviewed, it is evident that wildlife reactions to UAS vary by species and are influenced by physical characteristics of the UAS (engine-type, size, and shape) and mode of operation (flight altitude and in-flight maneuvers), although it is difficult to distinguish whether acoustics or visual cues are the primary source of disturbance for some of these factors.

The literature reviewed also suggests an overall absence of a wildlife response when UAS are flown above certain altitudes, which, to emphasize again, is dependent on the type of species and the type of interaction and may also be related to the level of sound produced. Flights at 50 m (164 ft) and below caused disturbance for multiple species of marine mammals and birds (Ramos et al., 2018), with flights below 30 m (98 ft) causing significant disturbance for some animals (Dulava et al., 2015; Rümmler et al., 2016; Mustafa et al., 2017; Rümmler et al., 2018; Weimerskirch et al., 2018; Krause et al., 2021). Flights at higher altitudes of 100 m (328 ft) and above caused minimal disturbance for many species of birds and marine mammals, although again this depended on species, breeding status, flight patterns, and sound level produced by the UAS (Chabot & Bird, 2012; Jones et al., 2006; Drever et al., 2015; Koski et. al., 2015; Korczak-Abshire, et al., 2016; McEvoy et al., 2016; McIntosh et al., 2018). In addition, the size of the UAS seems to also affect animal reactions, with larger UAS producing responses at higher altitudes than small ones (Mulero-Pázmány 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). A vertical approach and the hovering behavior of 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). As seen in some of the documented wildlife interactions in permit reports, when a disturbance occurred it was often abated by moving the UAS away from the animal and ascending to higher altitudes.

VII. CONCLUSION & RECOMMENDATIONS

Based on this review and other similar literature reviews (Duffy et al., 2017; Mustafa et al., 2018; Harris et al., 2019), it is difficult to extrapolate precise conditions to reduce wildlife disturbance, like flight altitude and distance, given the response of wildlife to UAS varies depending on the size, shape, engine-type of the UAS; flight speeds, in-flight maneuvers, and flight patterns established by the operator; as well as characteristics of the species, their breeding-status, species composition, and local site conditions. Thus, we recommend policy makers and resource managers use the precautionary principle when creating guidelines and regulations related to UAS in areas with sensitive wildlife. For example, when considering flight altitude, we recommend agencies exercise caution given the different levels of disturbance at various altitudes and between different species and thus set the minimum flight altitude for permittees at the highest altitude practical given the objective of the permit, relevant FAA regulations, and the potential wildlife in the area. To help streamline these considerations, we recommend agencies create site-specific guidelines for areas, like current NROZ, that protect areas with sensitive wildlife. These guidelines should consider the type of wildlife in the area, their breeding colony characteristics and breeding period, as well as environmental conditions including typical ambient sound levels and topography.

In addition to creating site-specific guidelines, we suggest the following specific recommendations for agencies to consider as possible requirements for permit applications or when issuing permits that allow the use of UAS in areas with sensitive wildlife:

- Permittees/operators should **consult any additional appropriate natural resource protection agencies, spatial databases, and local field biologists** to understand wildlife presence, applicable breeding seasons, and any known nesting sites in the area.

- Permittees/operators should **undertake detailed pre-flight planning** to understand jurisdictional regulations, topography, weather, and other potential hazards and considerations relevant to local wildlife.

- Permittees/operators should consider topography, prevailing wind speed and direction, and sound levels emitted by the UAS to **establish safe and suitable locations for take-off and landing** that are an optimal distance and downwind from wildlife, and ideally out of visual sight from present wildlife.

- Permittees/operators should carefully **select UAS type most appropriate for specific objectives**–ideally low-noise or small UAS compared to noisier or larger units and profiles that do not resemble predator species.

- Permittees/operators should **avoid planning any flights during the breeding period** when possible. If flights must occur, permittees/operators should consider higher minimum flight altitudes and increasing the distance of take-off and landing sites from wildlife congregations.

- Permittees/operators should **have a contingency plan for unanticipated or uncontrolled landings** including alternative landing sites and protocol for retrieving the aircraft if practical. Temporary abandonment of the UAS may be required to avoid further disturbance.

- Permittees/operators should **establish operating protocols to minimize wildlife disturbance** if it occurs in the field, including increasing flight altitude and changing the flight pattern to move UAS away from the animal(s) or ceasing operations if there is excessive disturbance.

- Permittees/operators should **avoid sudden changes in movement or flight maneuvers directly overhead animals** including vertical descents.

- Permittees/operators should **fly at the highest feasible altitude for achieving objectives** and avoid low altitude flights over wildlife whenever possible, although specific altitude recommendations will depend on species, breeding status, ambient sound levels, and characteristics of the UAS.

- Permittees/operators should **have a designated person or observer on site to monitor and record any animal reactions** before, during, and after flights.

- Permittees/operators should **submit a report of flight details and any animal interactions**. Since current permit reports vary in detail and quality, it could be beneficial to create a standardized template for this report to ensure detailed information is included.

- In the event of an unplanned forced or uncontrolled landing, permittees/operators should **carefully consider if the aircraft can be safely removed** without disturbing wildlife or sensitive habitat. Temporary abandonment of the UAS may be required to avoid further disturbance.

In addition to these recommendations, we also suggest the following considerations based on field experience and UAS operational expertise:

- Permittees/operators should **use a handheld anemometer to ensure onsite wind speed is under the UAS manufacture's maximum operating limits**. Launching or operating a UAS beyond those limits should be prohibited. In addition, any wind warnings received during the flight from the ground control station should result in the cancellation of the flight and return for landing.

- To ensure safe performance, **battery powered UAS should be recovered by permittees/operators with a minimum of 30% capacity** regardless of remaining flight time.

Permitted activities can play a key role in helping gather more information about UAS and wildlife interaction specific to these areas and create more robust guidelines in the future. The information reported in annual ONMS permit reports should be reviewed regularly and utilized to craft more specific subsequent permit requirements. UAS technology and research is rapidly evolving, and future studies may help fill some of the information gaps and improve guidelines. As such, we also recommend reviewing new literature regularly and updating guidelines as needed.

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APPENDIX

Appendix A. Summary of Literature Review of UAS Disturbance to Birds

Source	Species	Wildlife Disturbance?	Response Details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Noise Level
SEABIRDS								
Brisson et al., 2017	Common Murre, Glaucous Gull, Iceland Gull, Thick-Billed Murre	Yes	Behavioral response depended on species and breeding status. Of all four species, Iceland Gulls were the most reactive to the UAV with most individual flying off their nest. For murres, non-breeding birds were more likely to flush than breeding birds.	Rotary	not specified	25 m (82 ft)	25-80 m (82-262 ft)	not specified
Chabot et al., 2015	Common Tern	No	There were 8 up flights/panics observed following takeoff of the first flight on the first few days and 4 up flights/panics during control periods. The study found no statically significant evidence that UAS caused more overall disturbance to the colony.	Fixed-wing, electric	AI-Multi (2.1 m)	91-122 m (299-400 ft)	Overhead	not specified
Dulava et al., 2015	Bufflehead, Double Crested Cormorant, Green-winged Teal, Mallard, Northern Shoveler, Ring-necked Duck, Ruddy Duck, Surf Scoter, Tundra Swan, Western Grebe, Western Gull	Yes	There was an increase in flushing behavior of waterbirds when the gas-powered VTOL were flown at altitudes below 30m. Level of disturbance depended on species.	VTOL, Gas-powered; Fixed-wing, electric	Honeywell RQ-16 T-Hawk; AeroVironment RQ-11A	15-120 m (49-394 ft)	Overhead	81-90 dBa at 15 m

Source	Species	Wildlife Disturbance?	Response Details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Noise Level
Goebel et. al., 2015	Chinstrap Penguin, Gentoo Penguin; Antarctic fur seal, leopard seal	No	No disturbance recorded of penguins during flights at 30-60 m. The noises of the UAS hovering at 30 m were lower than the ambient noises recorded near a nesting colony during the egg-laying period.	Multirotor (hexacopter), electric	APH-22 (<60 cm)	30-60 m (98-197 ft)	Overhead	not specified
Korczak-Abshire, et al., 2016	Adélie Penguin	Yes	Birds were not disturbed by the electric UAS flying at 350 m AGL. However, birds did notice the gas-powered UAS, especially when flown directly overhead, which elicited a similar disturbance level as natural disturbances like predators flying overhead.	Fixed-wings, gas-powered & electric	CryoWing Mk1 (3.8 m); Skywalker X-8 (2.1 m)	350 m (1,148 ft)	Overhead	not specified
Krause et al., 2021	Chinstrap Penguin; Antarctic fur seal, leopard seal	Yes	Generally, behavioral responses increased as UAS were flown at lower altitudes (<30 m) and for penguins, responses increased as the breeding season progressed.	Multirotor (hexacopter), electric	APH-22 (<0.6 m)	8-46 m (26-151 ft)	Overhead	31.3–57.8 db at 0–90 m
McClelland et al., 2016	Atlantic Yellow Nosed Albatross, Brown Skua; Sooty Albatross, Tristan Albatross	No	This study found no indication of disturbance to seabirds.	Multirotor, electric	DJI Phantom 2 (0.35 m)	20-150 m (66-492 ft)	Overhead	60 dB at 2 m
McIntosh et al., 2018	Peregrine Falcon, Silver Gull; Australian fur seal	Yes	Silver gulls appeared aware of the larger UAS, but did not leave their nests or flush when flown at altitudes from 60-80 m. There was no observable disturbance when the smaller UAS was flown at 40 m and above.	Multirotor (hexacopter, quadcopters)	Gryphon Dynamics X8-1400 (1.4 m); DJI Phantom 4/4 Pro (0.35 m)	40-80 m (131-262 ft)	not specified	not specified

Source	Species	Wildlife Disturbance?	Response Details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Noise Level
Mustafa et al., 2017	Adélie penguin, Chinstrap penguin	Yes	Behavioral response of both species was more pronounced at lower altitudes of 20 m and below. Vertical ascents to 20 m elicited the strongest response in both species, suggesting that this type of flight pattern may be perceived as a greater threat than horizontal flights passing over the birds.	Multirotor (octocopter), electric	HiSystems, MK ARF Okto XL	10-50 m (33-164 ft)	Overhead	not specified
Perryman et. al., 2014	Adélie penguin, Chinstrap penguins; Antarctic fur seal, leopard seal, Weddell seal	No	No sign of disturbance to the penguins from the UAS during flights ranging in altitude from 50-140 m.	Multirotor (hexacopter, quadcopters)	Microdrone GmbH md4-1000; APQ-16tr	50-140m (164-459 ft)	Overhead	70 dB at 5 m
Rümmler et al., 2016	Adélie Penguin	Yes	Disturbance increased immediately after takeoff (takeoff distances ranged from 30-50 m away) and remained while the UAS was flown between 20-50 m, which significant increases at 20m and below (nearly all individuals were vigilant) and were stronger during vertical flight patterns.	Multirotor (octocopter), electric	MK ARF Okto XL (0.73 m)	10-80 m (33-264 ft)	Overhead	70 dB at 5 m

Source	Species	Wildlife Disturbance?	Response Details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Noise Level
Rümmler et al., 2018	Adélie Penguin, Gentoo Penguin	Yes	Behavioral response was more pronounced during flights at lower altitudes (behavior increased markedly at altitudes of 10-20 m). Adélie Penguins showed behavioral response when UAV were flown at highest tested altitude, 50 m, and Gentoo Penguins showed behavioral response from 30 m and below.	Multirotor (octocopter), electric	MK ARF Okto XL (0.73 m)	10-50 m (33-164 ft)	Overhead	70 dB at 5 m
Sarda-Palomera et al., 2012	Black-headed Gull	No	Minimal colony disturbance was recorded. Note disturbance was calculated based on the number of gulls in flight in each still image captured by the UAS.	Fixed-wing, electric	Multiplex Twin Star II (1.42 m)	30-40 m (98-131 ft)	Overhead	not specified
Weimerskirch et al., 2018	Gentoo Penguin, Imperial cormorant, King Penguin, Light-mantled Sooty Albatross, Macaroni Penguin, Northern Giant Petrel, Sooty Albatross, Southern Giant Petrel, Southern Rockhopper Penguin, Subantarctic Skua, Wandering Albatross	Yes	Behavioral response of birds increased as the altitude of the UAS decreased, with the most extreme behavior modifications occurring during a vertical descent to 3 m. The level of disturbance varied by species, breeding status, and life-cycle stage.	Multirotor (quadcopter), electric	DJI Phantom 3 (0.35 m)	10-50 m (33-164 ft)	Overhead	60 dB at 2 m

Source	Species	Wildlife Disturbance?	Response Details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Noise Level
OTHER WATERFOWL								
Barnes et al., 2018	Lesser Snow Goose	Yes	Behaviors like nest maintenance, high scanning, head-cocking, and off-nest behaviors increased when there were UAS flight operations (even control flights >500 m), suggesting bird are visually aware or disturbed by the noise of the UAS at >500 m altitude. There was considerable variation in responses between individuals.	Fixed-wing, electric	Timble UX5 (1 m)	75-500 m (246-1640 ft)	Overhead	not specified
Chabot & Bird, 2012	Canada Goose, Snow Goose	No	No behavioral response (flushing, leaving, or joining flocks) were recorded during UAS surveys.	Fixed-wing, electric	CropCam (2.5 m)	183 m (600 ft)	Overhead	not specified
Drever et al., 2015	American Green-winged Teal, American Wigeon, Dunlin, Mallard, Northern Pintail	Yes	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. Level of disturbance depended on species.	VTOL/Responder UAS	ING Robotic Aviation Responder	20-122 m (66-400 ft)		not specified
Jones et. al., 2006	Egret, White Ibis, Wood Storks; manatee	No	Birds were not disturbed by the noise of the UAS at flight altitudes of 100 to 150 m and when launched in a direction away from the birds.	Fixed-wing, gas-powered	FoldBat (1.5 m)	100-150 m (328-492 ft)	Overhead	not specified

Source	Species	Wildlife Disturbance?	Response Details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Noise Level
McEvoy et al., 2016	Australasian Shoveler, Black Swan, Blue Billed Duck, Eurasian Coot, Grey Teal, Hardhead, Musk Duck, Pacific Black Duck, Pink-eared Duck	Yes	Little or no obvious disturbance effects when UAVs were flown at least 60 m above the water level (fixed wing models) or 40m above individuals (multirotor models). At lower altitudes and when the fixed-wing UAV directly approached or rapidly changed altitude, disturbance ranged from swimming away from the UAV to leaving the water surface and flying away from the UAV.	Fixed-Wing (delta & glider); Multirotor (quadcopter & octocopter), electric	UAVER Avian-P (1.6 m); Skylark II (3 m); Drone Metrex Topodrone-100 (2 m); DJI Phantom (0.4 m); FoxTech Kraken-130 (1.8 m)	40-120 m (131-394 ft)	Overhead	not specified
Vas et al., 2015	Common Greenshank, Semi-wild Mallard, Wild Flamingo	Yes	The approach angle (20, 30, 60, 90) had a significant impact on the level of disturbance, with the strongest reaction when he UAS approached from 90 degrees (overhead). The color of the UAS, approach speed, and repeated approaches did not have a significant impact.	Multirotor (quadcopter)	DJI Phantom (0.35 m)	30 m (98 ft)	5 - 30 m	60 dB at 2 m
Weston et al., 2019	mix of waterfowl and seabirds, species not specified	Yes	At all altitudes tested, escape responses were recorded even when the UAS was not directly overhead. Birds were more likely to initiate an escape response when the UAS was launched from a shorter distance, although this varied by species. No escape responses were recorded when the UAS was launched from 120 m away.	Multirotor, electric	DJI Phantom 3 (0.29 m)	4-10 m (13-33 ft)	Overhead	not specified

Appendix B. Summary of Literature Review of UAS Disturbance to Marine Mammals

Source	Species	Wildlife Disturbance?	Response details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Sound Level
CETECEAN								
Acevedo-Whitehouse et al, 2013	bottlenose dolphin, fin whale, sperm whale, humpback whale, gray whale	No	Large whales showed no additional avoidance behaviors when approached by UAS than observed during vessel-based activities, however dolphins were observed actively moving away.	Aquacopter (model helicopter)	Raptor 30 V2 Thunder Tiger	13 m (43 ft)	Overhead	not specified
Christiansen et al, 2016	humpback whale	NA	Sound levels produced by the UAS are within ranges known to cause disturbance to some marine mammals like sea otters and pinnipeds above the surface. Sounds of the UAS may be heard underwater by toothed whales when the UAS is flown at 10 m or lower, but the effect is likely to be small, even for animals close to the surface.	Multirotor (quadcopter), electric	SwellPro Splashdrone (0.5 m), DJI Inspire 1 Pro (0.56m)	5-40 m (16-131 ft)	Overhead	80 dB re 20 µPa with frequencies centered at 60 Hz and 150 Hz.
Christiansen et al, 2020	southern right whale	No	No behavioral response (change in swim speed, absolute turn angle, inter-breath interval, or respiration rate) of southern right whale mother-calf pairs were detected. The recorded sound levels of the UAV were low and close to ambient sound levels.	Multirotor (quadcopter), electric	DJI Inspire 1 Pro (0.56 m)	5 m (16 ft)	Overhead	86.0 ± 3.9 dB re 1 µPa with frequencies between 100-1,500 Hz
Domínguez-Sánchez et al., 2018	blue whale	No	No significant changes in surface and dive times, blows per surfacing, blow interval, full cycle length, and blow rates during UAS flights.	Multirotor (quadcopter), electric	DJI Phantom 2	5 m (16 ft)	Overhead	not specified
Durban et al., 2015	killer whale	No	No behavioral responses observed during any flights.	Multirotor (hexacopter), electric	APH-22 (<0.6 m)	35-40 m (115-131 ft)	Overhead	not specified

Source	Species	Wildlife Disturbance?	Response details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Sound Level
Durban et al., 2016	blue whale	No	No behavioral responses observed during any flights. The UAS flights at 50-60 m above the surface level allowed important information about size, health, and behavior to be gathered at lower altitudes and with a limited sound footprint as compared to manned aircraft.	Multirotor (hexacopter), electric	APH-22 (<0.6 m)	50-60 m (164-197 ft)	Overhead	not specified
Koski et al., 2015	bowhead whale	No	No behavioral responses recorded	Fixed-wing, electric	TD100E	120-210 m (394-687 ft)	Overhead	not specified
Torres et al., 2018	gray whale	No	No behavioral response of gray whales was recorded.	Multirotor (quadcopter)	DJI Phantom 3 Pro or 4	25-40 m (82-131 ft)	Overhead	not specified
PINNIPED								
Adame et al., 2017	California sea lion	Yes	At 15 m and above, there was no pinniped species disturbance observed and did not elicit visible reaction. At 10 m, sea lions were observed looking up and some flushing behavior. UAS sometimes disrupted yellow-footed gulls, which in turn scattered more sea lions into the water.	Multirotor (quadcopter), electric	DJI Phantom 3	10-40 m (33-131 ft)	Overhead	not specified
Arona et al., 2018	gray seal	No	No behavioral responses were observed for gray seal adults and pups. The study included acoustic measurements and found that the UAS was loudest during take-off with sounds above 160 Hz. However, there was also variation in ambient sound and overall, the UAS was acoustically unobtrusive and did not contribute consistently to variation in soundscape.	Fixed-wing (delta-wing),	eBee (0.96 m)	75-80 m (246-263 ft)	Overhead	50 dB re 1 µPa across 1/3 octave bands

Source	Species	Wildlife Disturbance?	Response details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Sound Level
Goebel et al., 2015	Antarctic fur seal, leopard seal; Chinstrap Penguin, Gentoo Penguin;	No	No behavioral responses of seals were observed when flying at 23 m and above.	Multirotor (hexacopter), electric	APH-22 (<0.6 m)	30-60 m (98-197 ft)	Overhead	not specified
Krause et al., 2021	Antarctic fur seal, leopard seal; Chinstrap Penguin	Yes	Generally, behavioral responses increased as UAS were flown at lower altitudes (<30 m). Fur seals were more likely to react from UAS when approached from upwind, likely due to the sound of the UAS. The respiration rates of Leopard fur seals were highest for the control group, suggesting elevated respiration rates may have been impacted by researchers arriving to the area rather than the UAS flights.	Multirotor (hexacopter), electric	APH-22 (<0.6 m)	8-46 m (26-151 ft)	Overhead	31.3–57.8 dB at 0–90 m
McIntosh et al., 2018	Australian fur seal; peregrine falcon, silver gull	Yes	Flights using the larger UAS caused disturbance at 60 m (the point at which sound of the UAS first became noticeable), with the most disturbance recorded when UAS was hovering directly overhead. There was no observable disturbance when the smaller UAS was flown at 40 m and above.	Multirotor (hexacopter, quadcopters)	Gryphon Dynamics X8-1400 (1.4 m); DJI Phantom 4/4 Pro (0.35 m)	40-80 m (131-263 ft)		not specified
Moreland et. al., 2015	ribbon seal, spotted seal	No	Comparison with manned aircraft surveys showed marked reduction in disturbance during UAS operations.	Fixed-wing, gas-powered	ScanEagle (3.11 m)	122 m (400 ft)	Overhead	not specified
Perryman, et al., 2014	Antarctic fur seals, leopard seals, Weddell seals; Adélie Penguins, Chinstrap Penguins	No	Focusing on the acoustic impact, no reaction of pinnipeds was observed while flying at 23 m AGL.	Multirotor (hexacopter, quadcopter);	Microdrone GmbH md4-1000; APQ-16tr	23-140 m (75-459 ft)	Overhead	70 dB at 5 m

Source	Species	Wildlife Disturbance?	Response details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Sound Level
Pomeroy et al., 2015	gray seal, harbor seal	Yes	Behavior response of seals varied by species and individuals. There was little to no behavioral reactions of harbor seal at 30 m altitude on frequently disturbed haul-out sites, however, at more remote haul-out site flushing was observed during flights of 50 m. For both breeding and molting gray seals, animals showed vigilant behavior during flights at 30 m, however, molting seals showed a stronger response.	Multirotor (quadcopter, hexacopter, octocopter)	DJI 450, Cinestar 6, Vulcan 8, Skyjib 8	30-50 m (98-164 ft)	10 - 220 m	not specified
Sweeney et al., 2015	Steller sea lion	Yes	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 unmanned aircraft)	Multirotor (hexacopter), electric	APH-22 (<0.6 m)	45-60 m (148-197 ft)	Overhead	not specified
SIRENIAN								
Hodgson et al., 2013	dugongs	NA	When flown at 304 m, it seemed unlikely that noise from the ScanEagle would be audible to marine fauna underwater.	Fixed-wing, gas-powered	ScanEagle (3.11 m)	152-304 m (499-997 ft)	Overhead	85-90 dB at 6 m
Jones et al., 2006	manatee; egret, white ibis, wood stork	No	No disturbance observed while flying at 100m AGL	Fixed-wing, gas-powered	FoldBat (1.5 m)	100-150 m (328-492 ft)	Overhead	not specified

Source	Species	Wildlife Disturbance?	Response details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Sound Level
Ramos et al., 2018	Antillean manatee, bottlenose dolphin	Yes	Dolphins responded to flights at 11-30 m and often only changed their behavior briefly, orienting towards the aircraft. Manatees elicited a stronger response than dolphins, sometimes fleeing the area, and reacting to flights ranging from 6-104 m in altitude. Both species reacted strongest when the UAS was directly overhead when the UAS is the loudest, suggesting noise may be one of the factors contributing to the animal's detection of the aircraft.	Multirotor (quadcopter)	DJI Phantom II Vision +, DJI 3 Professional, DJI 4	5-120 m (16-394 ft)	Overhead	not specified

Appendix C. Summary of Literature Review of UAS Disturbance to Turtles

Source	Species	Wildlife Disturbance?	Response details	UAS Type	UAS Model & Wingspan	Vertical Heights	Horizontal Distance	Sound Level
SEA TURTLES								
Bevan et al., 2018	flatback turtle, green turtle, hawksbill turtle	Yes	Sea turtles did not react to the shadow cast by the UAS, nor did they exhibit any avoidance behaviors when the drone was flown at 10 m (33 ft) above nesting beaches, 15 m (49 ft) above reef habitat, and 20 m (66 ft) above near-shore habitat–the lowest tested altitude in the near-shore environment.	Multirotor (quadcopter), electric	DJI Phantom 4 Pro	5-40 m (16-131 ft)	Overhead	57.8±81 dB, and frequencies of 60 and 150 Hz)
Sykora-Bodie et al., 2017	olive ridley turtle	No	No behavioral responses observed during any flights over nesting beaches.	Fixed-wing, electric	eBee (0.96 m)	90 m (295 ft)	Overhead	not specified
FRESHWATER TURTLES								
Biserkov & Lukanov, 2017	European pond turtles, red-ear sliders	Yes	Flights below 10 m (33 ft) disturbed basking freshwater turtles, especially when speeds were over 7 km/h during on-site tests.	Multirotor (quadcopter), electric	DJI Phantom 3 Pro	Below 10 m (33 ft) – not specified	Overhead	not specified
Escobar et al., 2020	yellow-bellied sliders, painted turtles	Yes	Minimal disturbance during flights at 10 m (33 ft) and 20 m (66 ft). Across forty flights, there were six instances of minimal escape or disturbance behavior from turtles basking on artificial basking structures (0.7% of turtles).	Multirotor (quadcopter), electric	MJX Bugs 3	10-20 m (33-66 ft)	Overhead	2.1 dB above ambient at 20 m

Appendix D. Overview of UAS permits issued by ONMS

Permit Number	Sanctuary where flights in NROZ are permitted	Permit includes spatial limitations specific to wildlife?	Minimum allowed altitude in NROZ	Annual Report Received?	Wildlife disturbance?	UAS Type	UAS Model
DIRECTED AT WILDLIFE							
GFNMS-2017-004-A1	GFNMS	Yes	100 ft	Yes	Yes, seabirds	Quadcopter	DJI Inspire 2
MBNMS-2019-029-A2	MBNMS	Yes	50 ft	Yes	Yes, marine mammals	Quadcopter	DJI Mavic 2 Pro, DJI Phantom Pro 4, DJI Inspire 2
MBNMS-2021-002	MBNMS	Yes	50 ft	Yes	Yes, marine mammals	Quadcopter	DJI Inspire 2 and DJI Mavic Pro
OCNMS-2017-005	OCNMS	Yes	150 ft	Yes	No	Hexacopter	APH-22
MULTI-2017-003-A1	GFNMS, MBNMS	Yes	150 ft	Yes	No	Fixed-wing	Sensfly eBee Plus or Freefly Alta6
OCNMS-2019-009	OCNMS	Yes	150 ft	Yes	No	Hexacopter	APH-22
MBNMS-2020-002-A2	MBNMS	Yes	50 ft	Yes	No	Quadcopter	DJI Mavic 2 Pro, DJI Phantom Pro 4, DJI Inspire 2
MBNMS-2020-030	MBNMS	Yes	50 ft	Yes	No	Quadcopter	DJI Mavic 2 Pro 4 or DJI Inspire 2
MBNMS-2019-033	MBNMS	Yes	100 ft	Yes	No	Hexacopter, Octocopter & Fixed-wing	APH-22, APH-28, APO-42, FireFly 6
MULTI-2019-005	CINMS, MBNMS, GFNMS, CBNMS, OCNMS	Yes	50 ft	Yes	No	Hexacopter	APH-22
MULTI-2019-009-A1	CINMS, MBNMS, GFNMS, CBNMS	Yes	33 ft	Yes	No	Quadcopter	DJI Phantom 3, DJI Phantom 4; LEM-Hex 44 or Free Fly Alta 5
OCNMS-2018-004	OCNMS	Yes	150 ft	Yes	No	Hexacopter	APH-22

Permit Number	Sanctuary where flights in NROZ are permitted	Permit includes spatial limitations specific to wildlife?	Minimum allowed altitude in NROZ	Annual Report Received?	Wildlife disturbance?	UAS Type	UAS Model
OCNMS-2020-005	OCNMS	Yes	150 ft	Yes	No	Quadcopter, Hexacopter	DJI Mavic Pro & APH-22
MBNMS-2015-036-A1	MBNMS	Yes	50 ft	Yes	Not reported	Quadcopter	DJI Phantom
MULTI-2014-013-A2	GFNMS, MBNMS	Yes	50 ft	Yes	Not reported	Quadcopter	DJI Phantom
MULTI-2019-020-A3	GFNMS, MBNMS	Yes	50 ft	Yes	Not reported	Quadcopter	DJI Phantom 4 Pro
MBNMS-2017-018	MBNMS	Yes	75 ft	No	No Report Received	Quadcopter	DJI Phantom 3
MBNMS-2020-019	MBNMS	Yes	50 ft (intertidal areas); 200 ft (ocean)	No	No Report Received	Quadcopter	DJI Maveric 2 Pro & DJI Inspire 2
MBNMS-2021-017	MBNMS	Yes	50 ft	No	No Report Received	Quadcopter	DJI M210 or DJI Phantom 4
MBNMS-2020-035	MBNMS	Yes	20 ft	No	No Report Received	Quadcopter	DJI Inspire 2
OCNMS-2020-002	OCNMS	Yes	Not specified (proposed methods suggest 6 ft)	No	No Report Received	Quadcopter	DJI Mavic Pro
MBNMS-2021-001	MBNMS	Yes	16 ft	No	No Report Received	Quadcopter	DJI Mavic 2 Pro;
MBNMS-2021-006	MBNMS	Yes	131 ft	No	No Report Received	Quadcopter	DJI Phantom 4 Pro
MULTI-2019-009-A1	CINMS, MBNMS, GFNMS, CBNMS	Yes	33 ft	No	No Report Received	Quadcopter, Hexacopter	DJI Phantom 3, DJI Phantom 4 Pro, LEM-Hex44. FreeFly ALTA 6
GFNMS-2014-006-A1	GFNMS	No	Not specified	NA	Unable to conduct any flights	NA	NA
MBNMS-2019-023	MBNMS	Yes	50 ft	NA	Unable to conduct any flights	NA	NA
POTENTIAL INTERACTIONS WITH WILDLIFE							
MBNMS-2017-030	MBNMS	Yes	50 ft	Yes	Yes, seabirds		

Permit Number	**Sanctuary where flights in NROZ are permitted**	**Permit includes spatial limitations specific to wildlife?**	**Minimum allowed altitude in NROZ**	**Annual Report Received?**	**Wildlife disturbance?**	**UAS Type**	**UAS Model**
MBNMS-2020-022	MBNMS	Yes	285 ft	Yes	Yes, seabirds	Fixed-wing	SenseFly ebee X
GFNMS-2019-006-A2	GFNMS	Yes	300 ft	Yes	Yes, marine mammals	Quadcopter	DJI Mavic Pro Platinum, DJI Mavic 2 Pro, DJI Matrice 100/200, DJI Phantom 4 Pro
MBNMS-2018-017	MBNMS	Yes	100 ft	Yes	Yes, marine mammals & seabirds		X8 Heavy Lift
MBNMS-2016-008	MBNMS	Yes	50 ft	Yes	No	Multirotor VTOL	Aerial MOB
GFNMS-2017-008	GFNMS	Yes	100 ft	Yes	No	Quadcopter	3DR Solo; Skywalker X8
MBNMS-2017-029	MBNMS	Yes	197 ft	Yes	No	Quadcopter	3DR Solo
MBNMS-2018-031	MBNMS	Yes	50 ft	Yes	No	Quadcopter	DJI Inspire 2
MBNMS-2019-034	MBNMS	Yes	197 ft	Yes	No	Quadcopter	DJI Inspire 2
MBNMS-2018-009	MBNMS	Yes	100 ft	Yes	No	Quadcopter	DJI Phantom, Inspire, and Matrice models
MBNMS-2017-042-A1	MBNMS	Yes	20 ft	Yes	No	Quadcopter	DJI Phantom 3, DJI Mavic 2
MBNMS-2020-003	MBNMS	Yes	98 ft	Yes	No	Quadcopter	DJI Phantom Pro 4
MBNMS-2021-004	MBNMS	Yes	70 ft	Yes	No	Quadcopter	Freefly Alta X
GFNMS-2018-008	GFNMS	Yes	100 ft	No	No Report Received	Quadcopter	DJI Phantom 4 Pro
GFNMS-2021-004	GFNMS	Yes	100 ft	No	No Report Received	Quadcopter	Autel Evo Pro UAS
MULTI-2018-006-A1	GFNMS	Yes	197 ft	No	No Report Received	Quadcopter	DJI Mavic 2 Pro, DJI Matrice 210

Permit Number	Sanctuary where flights in NROZ are permitted	Permit includes spatial limitations specific to wildlife?	Minimum allowed altitude in NROZ	Annual Report Received?	Wildlife disturbance?	UAS Type	UAS Model
GFNMS-2019-006-A4	GFNMS	Yes	300 ft (quadcopters) 400 ft (fixed-wing)	No	No Report Received	Quadcopter, Fixed-Wing	DJI Mavic Pro Platinum, DJI Matrice 100/200/210, DJI Phantom 4 Pro/Pro V2; SenseFly eBeeRTK, aBirdsEyeView FireFLY 6 Pro
MULTI-2019-010-A1	GFNMS	Yes	Not specified	No	No Report Received	Quadcopter	DJI Phantom 4 Pro, DJI Mavic Pro Platinum, Mavic Air
CINMS-2018-011	CINMS	Yes	50 ft	No	No Report Received		
CINMS-2020-001	CINMS	Yes	400 ft	No	No Report Received	Quadcopter	DJI model WM331A
MBNMS-2017-031	MBNMS	Yes	150 ft	No	No Report Received	Quadcopter	DJI Phantom 4
MBNMS-2018-001	MBNMS	Yes	300 ft	No	No Report Received	Hexacopter	xFold Cinema
MBNMS-2020-025	MBNMS	Yes	33 ft	No	No Report Received	Quadcopter	Aegis E900
OCNMS-2017-003	OCNMS	Yes	Not specified	No	No Report Received	Quadcopter	DJI Inspire I
OCNMS-2019-006	OCNMS	Yes	150 ft	No	No Report Received	Quadcopter, Hexacopter	APH-22
GFNMS-2018-004	GFNMS	Yes	100 ft	NA	Unable to conduct any flights	NA	NA
MBNMS-2019-019-A1	MBNMS	Yes	60 ft	NA	Unable to conduct any flights	NA	NA

Appendix E. Summary of Reported Wildlife Disturbance from ONMS Permit Reports

Permit Number	Sanctuary where UAS flights occurred?	Is "take" permitted and by who?	Type of Wildlife Disturbed	Description of Disturbance	UAS Type & Model	Flight Altitude	Total # of Flights	Other Flight Conditions
DIRECTED AT WILDLIFE								
MBNMS-2019-029-A2	MBNMS	Yes, NMFS	Marine Mammal: sea otter	There were two instances of sea otters raising their head in repones to the UAS, one adult and one juvenile on separate occasions.	Quadcopter: DJI Mavic 2 Pro/Phantom Pro 4/Inspire 2	60 ft	24	There were 24 different UAS flights total in Monterey Bay and 6 within NROZ. Winds on average were 5-7 knots, and occasionally up 15 knots.
MBNMS-2021-002	MBNMS	Yes, NMFS	Marine Mammal: elephant seal	There were five instances in which female elephant seals turned their heads toward the UAS.	Quadcopter: DJI Inspire 2 and DJI Mavic Pro	50-1,000 ft	Not reported	Launched from locations that were 164 ft from any visible wildlife.
GFNMS-2017-004-A1	GFNMS	No	Seabirds: Western Gull, Black Oystercatcher	Over the course of two flights, three nesting pair of western gulls stood and flew off when the UAS lifted off and returned within 15 minutes. As one flight began, two pair of black oystercatchers nesting on the island, flew off as the drone was lifting off from the bluff. They returned to their nest sites after the UAS began its flight back to the bluff.	Quadcopter: DJI Inspire 2	100-400 ft	6	High winds, fog, and a low cloud ceiling were all reasons for not being able to fly as scheduled. Wind speed ranged from 2.6-7.8 knots with gusts up to 9.6 knots.

Permit Number	Sanctuary where UAS flights occurred?	Is "take" permitted and by who?	Type of Wildlife Disturbed	Description of Disturbance	UAS Type & Model	Flight Altitude	Total # of Flights	Other Flight Conditions
POTENTIAL INTERACTION WITH WILDLIFE								
MBNMS-2017-030	MBNMS	No	Birds: Western Gull, Black Oystercatcher	When the UAS operated close into the cliff face, the gulls and a black oystercatcher responded to UAS presence by circling it and occasionally vocalizing	Quadcopter: DJI Phantom 4 Pro	Not reported (allowed to be 50 ft)	2	Mix of fog and sun, wind 10-15 knots.
MBNMS-2020-022	MBNMS	No	Birds: mixed (species not specified)	A mixed flock of seabirds fledged from their roosts on a jetty, circled back to the same roost will the UAS was still flying overhead, and appeared undisturbed for the reminder of the flight.	Fixed-wing: SenseFly ebee X	Not reported (allowed to be 285ft)	1	Clear skies, light wind of 5.2 knots S. Pilot was advised to avoid otter resting area nearby, avoided area where Snowy Plovers had been seen, and avoided marine mammal haul-outs.
GFNMS-2019-006-A2*	GFNMS	No	Marine Mammal: harbor seal	Observed one harbor seal (estimated to be at least 984 ft from the launch site) raised its head when the UAS was launched	Quadcopter: DJI Phantom 3/4 Pro	394 ft	16	Launching and landing involved a straight ascent/descent to flight altitude.
MBNMS-2018-017	MBNMS	No	Marine Mammals & Birds: sea lion & gulls	Gulls approached the UAS from above while it was inflight. A hauled-out sea lion began moving toward the ocean until the UAS increased in elevation and moved away from the beach.	X8 Heavy Lift	110-600 ft	17	UAS pilot stayed clear of an area where 40 sea lions could be seen hauled-out and a cliff where a pair of gulls were possibly nesting.

*Note: Disturbance was recorded at a site outside of NROZ