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Exploring Spatial Patterns of Overflights at Olympic National Park

Map of Olympic National Park (boundary layer dated 2017).
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Abstract

This study explored spatial patterns of overflights at Olympic National Park (OLYM). Overflights were analyzed from July 27th, 2021 to January 2nd, 2023 using Automatic Dependent Surveillance-Broadcast (ADS-B) data with a total of 525 days of data. Data were collected using data loggers that were deployed at Blyn (located outside of OLYM), Hurricane Ridge, and Hoh Rain Forest. The first phase of analysis focused on all overflights and found a high concentration of overflights above the northeastern portion of OLYM, and definitive flight corridors were identified across the park. The second phase of analysis focused on low-level overflights that fly below 10,500 ft mean sea level (MSL) and fly within 10 miles of the OLYM boundary. Phase 2 figures display four figures based on seasons and show a concentration of flights between 6,001–10,500 ft MSL, except in and around the Port Angeles area where there is a concentration of flights in the 0–6,000 ft MSL altitudinal range. The third phase of analysis selected all low-level overflights below 2,500 ft above ground level (AGL) and within 0.5-mile of the OLYM boundary. Kernel density analysis was conducted using waypoints segmented into 500 ft above ground level (AGL) altitude intervals from 0–2,500 ft AGL. The altitude interval with the highest density of overflights was '0–500 ft AGL'. Kernel density hot spots were observed along the flight corridor and over Port Angeles. Also, overflights flown by known air tour operators and park administration were shown. Overflight patterns of air tour operators mostly follow the recommended air tour route. Lastly, overflights intersecting with Olympic Military Operations Area (MOA) were identified and mapped. This information can be used for planning and management purposes and this study serves as a resource for future research that intends to use more advanced analytics.

Acknowledgements

The authors would like to thank the National Park Service Natural Sounds and Night Skies Division for funding and supporting this project, and specifically Vicki Ward and Warren Deeds. The authors would also like to thank Ruth Scott, Jerald Weaver, Bill Baccus, and Christina Miller from Olympic National Park for their support of maintaining the collection units and downloading and providing us the data.

List of Acronyms

AGL: Above ground level

ADS-B: Automatic Dependent Surveillance-Broadcast

DEM: Digital Elevation Model

FAA: Federal Aviation Administration

GIS: Geographic information systems

MOA: Military Operations Area

MSL: Mean sea level

NPATMA: National Parks Air Tour Management Act

NPS: National Park Service

OLYM: Olympic National Park

Introduction

Olympic National Park (OLYM) is 95 percent designated wilderness covering an area of almost a million acres and is comprised of two detached areas. The largest area is inland and includes, but is not limited to, Hurricane Ridge, Hoh Rain Forest, and Quinault Rain Forest. The other area is along the Pacific Coast and includes 70 miles of wild coastline. OLYM features a variety of ecosystems from glacial mountains to old-growth temperate rainforests (National Park Service, 2023b). The park was created in 1938 to protect Roosevelt elk, the primeval forest, and the wild coastline. The park has some of the largest remnants of ancient forests and has trees reaching a height of up to 300 feet. OLYM visitors are attracted to its wilderness along the rugged coastline and its teeming tidepools as well as its inland lush forests and snowy mountains. An extensive trail network comprised of over 600 miles of trails and plenty of camping opportunities are popular among recreationists. For over six decades, OLYM has annually received more than 2,000,000 visitors (National Park Service, 2023a).

The purpose of this report is to provide an examination of the spatial patterns of overflights at OLYM.

The National Parks Air Tour Management Act of 2000 (NPATMA) (Public law 106-81) requires the National Park Service (NPS) to manage air tours at all units that receive more than 50 air tours per year, with the exception of Grand Canyon National Park and all national parks in the State of Alaska (Beeco & Joyce, 2019). An air tour management plan for OLYM was completed on July 19th, 2022, by the National Park Service (NPS) and Federal Aviation Administration (FAA). The plan was designed to protect natural sounds, wilderness character, wildlife, visitor experiences, and cultural resources (National Park Service, 2022). The plan authorized an annual maximum of 64 air tours that are required to follow a defined route over the park. It is important to understand the travel patterns of low-level overflights, including the air tours, which can be used to understand how low-level overflight noise influences the acoustic environment of the park.

Using Automatic Dependent Surveillance-Broadcast (ADS-B) data, overflights can be tracked. These data include latitude, longitude, altitude, and the unique identification code of the aircraft (Beeco & Joyce, 2019). As of January 1, 2020, the FAA requires all aircraft that enter designated airspace to be equipped with ADS-B technology (see 14 CFR § 91.225 and 14 CFR § 91.227) (Office of the Federal Register (OFR), 2023). OLYM is located under uncontrolled airspace, which means ADS-B is not required on aircraft that fly above OLYM, but below 18,000 ft MSL. Regardless of the airspace designation, prior studies suggest a rather ubiquitous adoption of ADS-B by aircrafts in the United States.

Dataloggers were deployed at OLYM at three different locations including Blyn (located outside OLYM), Hurricane Ridge, and Hoh Rain Forest. Data were collected from July 27th, 2021 to January 2nd, 2023. These data were comprised of 60,662 overflights. After selecting the overflights below 2,500 ft AGL and within the 0.5-mile boundary of the park, the dataset was comprised of 23,925 low-level overflights.

Methods

Data Collection

Data were collected by ADS-B terrestrial data loggers located at Blyn (48.006548 N, −122.97284 W; 1,946 ft MSL), Hurricane Ridge (47.970422 N, −123.498743 W; 5,259 ft MSL), and Hoh Rain Forest (47.857778 N, −123.9325 W; 591 ft MSL) (Figure 1). Blyn is located outside of OLYM at 12.20 miles (aerial distance) from the nearest point of the park perimeter. The data loggers were positioned with an unimpeded and expansive skyward exposure. The loggers recorded ADS-B signals as text files (TSV). The datalogger placed at Blyn captured ADS-B data from July 27th, 2021 to January 13th, 2022 with 171 days of data recording. The datalogger placed at Hoh Rain Forest recorded ADS-B data from January 15th, 2022 to January 3rd, 2023 with 354 days of data recording. The datalogger placed at Hurricane Ridge recorded ADS-B data from August 2nd, 2021 to December 29th, 2022 with 317 days of data recording (with intermittent breaks in the recording). Two of the locations recorded ADS-B data at the same time. So, the total datalogger-days was 842, whereas the net total days was 525 days after removing the overlapping dates from July 27th, 2021 to January 3rd, 2023.

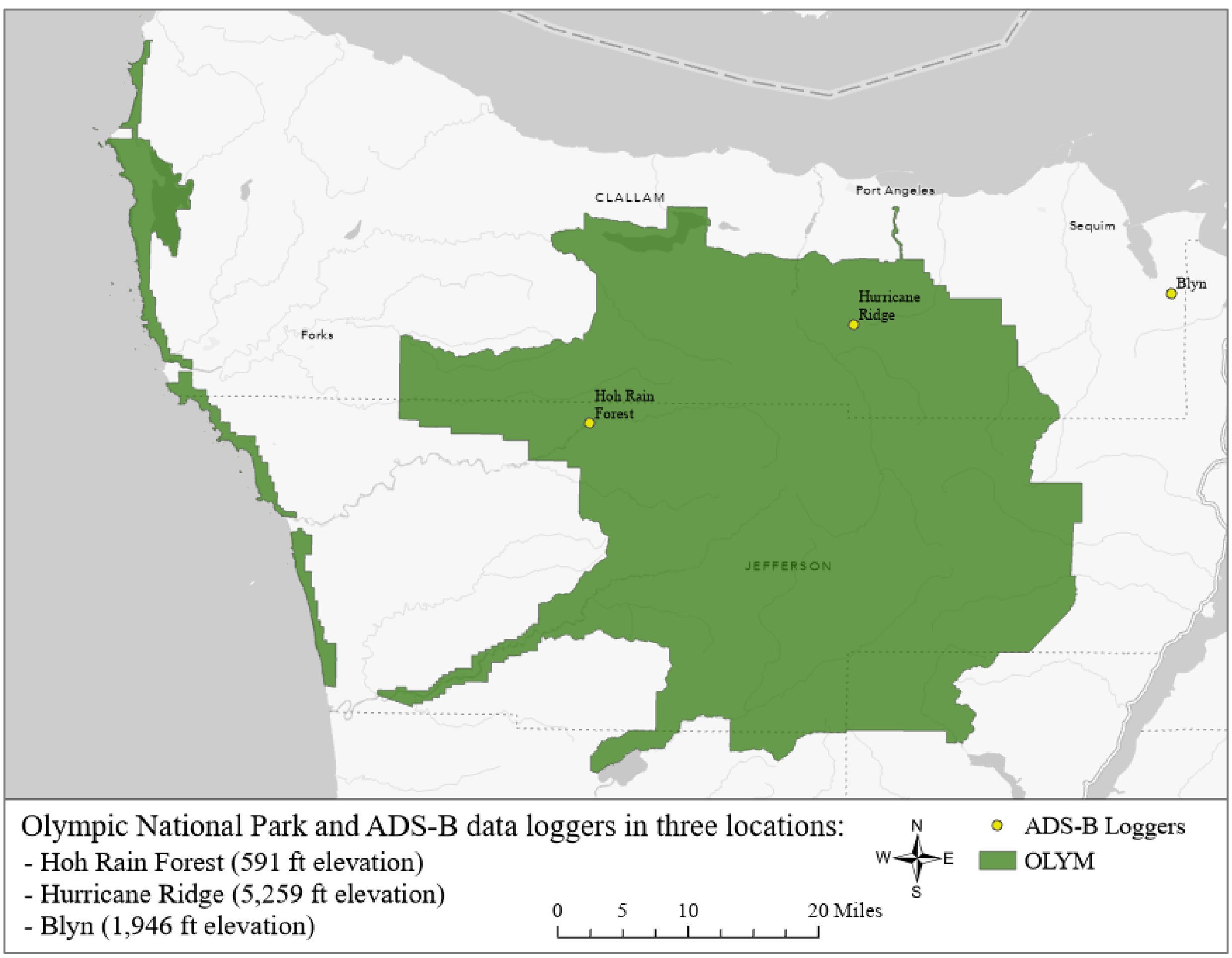

Figure 1. Three locations of ADS-B data loggers.

Data Processing and Cleaning

Data processing, cleaning, and analysis were accomplished using a custom ArcGIS Pro toolbox with multiple Python-based geoprocessing tools that automated and simplified the processing and analysis of ADS-B data. The toolbox conducted the following tasks: processed raw ADS-B data files, removed repeated occurrences of waypoints collected by data loggers, created waypoint and flightline feature classes, merged daily waypoints and flightlines, summarized waypoint altitudes, summarized the number of flights across several temporal scales (monthly, daily, hourly), and summarized the number of flights across aircraft types (rotorcraft, fixed wing single engine, fixed wing multi engine).

This report expresses altitude using mean sea level (MSL) and above ground level (AGL). Altitude expressed in MSL refers to the altitude of an aircraft above sea level, regardless of the terrain below it, whereas altitude expressed in AGL is a measurement of the distance between the ground surface and the aircraft. To calculate AGL altitudes for each waypoint, a 10-meter digital elevation model (DEM) was used (United States Geological Survey, 2023). The AGL altitudes were calculated by subtracting the elevation of the DEM (z-coordinate) from the reported altitudes of the ADS-B logger (z-coordinate) for every point location (x, y) (see Beeco et al., 2020 for the exact method).

ADS-B technology can use barometric altitude or geometric altitude. Barometric altitude is determined by measuring air pressure and must be regularly calibrated. Geometric altitude is calculated using the Global Positioning System (GPS). While error can result from each type of technology, GPS is generally considered a more reliable and accurate measure, but the aviation industry has long used barometric altitudes during flight. Aircraft owners/operators determine which system to use on their aircraft. The analysis in this report does not attempt to correct any error associated with altitude information, as this would be nearly impossible and overly burdensome. Therefore, calculations of AGL can in some cases be less than zero. This can occur for low flying aircraft that have an ADS-B system reporting an altitude lower than actual. Negative AGL calculations can also be due to an aircraft's ADS-B system malfunction. Further, AGL is calculated using 10 x 10 m Digital Elevation Models (DEM). This level of resolution can also introduce some errors. Negative AGL values are reported in the analysis. Finally, in some data sets MSL altitudes in the data are also negative. This is likely a system error. These data generally represent less than 0.1% of the data and are discarded from data analysis.

To explore spatial patterns of overflights at OLYM, analyses were conducted in three phases. Phase 1 and Phase 2 report altitudes using MSL, while Phase 3 uses AGL. MSL is better suited for understanding aircraft patterns across a larger space or scale because the baseline (sea level) does not change. However, AGL analysis was used because Phase 3 includes more detailed examinations of the data, and thus, this analysis better contextualizes the proximity of aircraft above undulating terrain and associated terrestrial resources and visitors' experiences. All maps produced during analysis used Esri basemaps with service layer credits for: Esri, USGS, Washington Game Fish and Parks, HERE, Garmin, SafeGraph, FAO, METI/NASA, EPA, and NPS; and all data were projected to World Geodetic System 1984 Universal Transverse Mercator Zone 10N.

Phase 1 Methods

The purpose of the first phase was to explore all overflight paths above OLYM regardless of flight type or altitude. Thus, the flightline feature class was not cleaned of any flight types nor was an altitude threshold implemented. To understand how flight paths extended beyond the park boundary, a 10-mile buffer around the OLYM boundary was used. One map was produced and shows all overflights during data collection (July 27th, 2021–January 3rd, 2023).

Phase 2 Methods

The purpose of the second phase was to understand low-level overflights above OLYM regardless of flight type. Similar to Phase 1, a 10-mile buffer was used. Low-level overflights were identified as having an altitude of less than 10,500 ft MSL. This altitude was chosen because the highest point at OLYM is on top of Mount Olympus at 7,980 ft MSL (National Park Service, 2023a), and approximately 2,500 ft above the highest point in the park would capture flights that had the greatest impact on the acoustic environment within the park. To understand flight altitudes, a waypoint feature class was used. Four maps were produced (across seasons) that show all overflights that flew beneath 10,500 ft MSL and within 10 miles of OLYM. These maps classified waypoints using MSL altitudes.

Phase 3 Methods

The purpose of the third phase was to focus on all low-level overflights below 2,500 ft AGL and within a 0.5-mile buffer around the boundary of OLYM. Only 64 air tours are authorized to operate per year in OLYM (National Park Service, 2022), so the study aims to assess the utilization of airspace by low-level overflights including, but not limited to, air tours and their potential impact on the acoustic environment of the park. The toolbox joined ADS-B data to the FAA Releasable Database via aircraft unique identifiers (e.g., ICAO address) to determine aircraft tail number, type of registrant (e.g., government), type of aircraft, engine type, model, and owner's name. Instead of screening for suspected flightlines and suspected waypoints, all the waypoints below 2,500 ft AGL and within a 0.5-mile buffer around the boundary of the park were selected.

Point density analysis was conducted for these waypoints. Similarly, using a 500 ft AGL altitude interval, waypoint data were segmented (0–500 ft AGL; 501–1,000 ft AGL; 1,001–1,500 ft AGL; 1,501–2,000 ft AGL; and 2,001–2,500 ft AGL) and kernel density analysis was conducted for each altitude interval. Because each altitude interval had different amounts of waypoints, density classifications were normalized across altitude intervals. To do this, the altitude interval with the highest maximum density of waypoints (0–500 ft AGL) was used to normalize density classification, which required two steps. First, the 0–500 ft AGL altitude density was classified using equal interval percentage breaks with five intervals of 20%. These percentage breaks were determined using the maximum waypoints per square kilometer as the '100%' value. Second, the maximum number of waypoints per each 20% interval was then applied to density classifications for the other altitude intervals. These steps are necessary to ensure density was calculated the same across altitude intervals regardless of the number of waypoints.

The kernel density analysis produced two main figures. The first figure showed density analysis across sequential altitude intervals (beginning with the lowest altitude interval) from 0–2,500 ft AGL. The second figure showed zoomed-in maps of the density hot spots for the 0–500 ft altitude interval. After these steps were accomplished, kernel density outputs were statistically compared for relatedness using the ‘Band Collection Statistics’ tool which conducted a correlation test.

Figures were produced to spatially compare AGL and MSL waypoint trends. The first figure displayed waypoint altitudes between 0–2,500 ft AGL using a 500 ft AGL interval. The second figure displayed waypoint altitudes between 500–10,500 ft MSL using a 1,000 ft MSL interval.

Descriptive analyses were conducted to understand waypoint frequencies across AGL and MSL altitudes; the number of flights across months, days of the week, and hours of the day; and the number of flights across aircraft types. To gain insight into overflight travel patterns across aircraft types, three more figures were produced for fixed wing single engine aircraft, fixed wing multi engine aircraft, and rotorcraft aircraft.

Next, figures were produced to display overflight patterns of known air tour operators by selecting their flights using tail numbers. Figures were produced to display overflights of aircraft that are also used (but not solely used) for park administration. Military aircraft frequently fly between the Olympic Military Operations Area (MOA) on the western part of the park and Naval Air Station Whidbey Island (NASWI) to the northeast of the park. In order to understand these flights, overflights intersecting the MOA were selected. These overflights were cleaned by removing all aircraft types that were not fixed wing multi engine (i.e., fixed wing single engine and rotorcraft were removed) and all engine types that were not turbofan engines (OLYM managers reported that Growler military aircraft are most common, which are equipped with a turbofan engine). A figure was generated to show these overflights. Based on data shared by the park, another figure was generated showing the proposed route of military flights, Air Traffic Expose Area, and a typical flight route for military aircraft. This route is located slightly north of the park boundary, and the Air Traffic Expose Area covers some area around Lake Crescent.

Results

Results — Phase 1

Data loggers were deployed at three locations at varying times of year (see Methods for details): Hoh Rain Forest, Hurricane Ridge, and Blyn (Figure 1) and data were collected for 17 months from July 27th, 2021 to January 3rd, 2023. Figure 2 shows all overflights collected (*n*=60,622). This figure displays travel patterns for all overflights above OLYM. Visual analysis of these data suggests that most flights above OLYM occurred over the northeast area of the park.

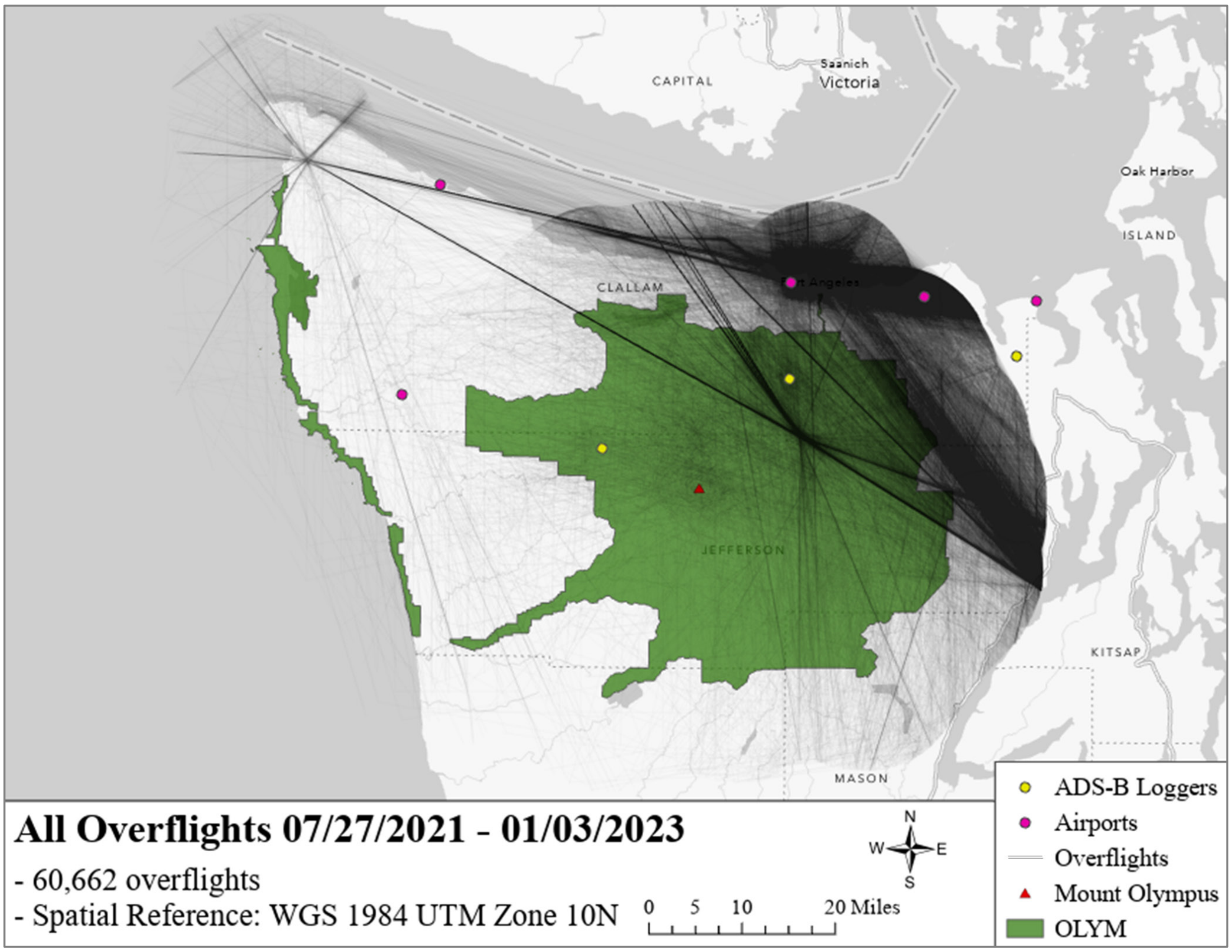

Figure 2. Overflights between July 27th, 2021 and January 3rd, 2023.

Results — Phase 2

Waypoints of low-level overflights that flew below 10,500 ft MSL and within a 10-mile buffer around the park, regardless of flight type, were mapped, which included 5,250,140 waypoints (20,587 overflights). Four figures were produced for summer seasons (April–September) and winter (October–March). Figure 3 shows waypoint MSL altitudes for July 27th, 2021 to September 30th, 2021. Figure 4 shows waypoints MSL altitudes for October 1st, 2021 to March 31st, 2022. Figure 5 shows waypoint MSL altitudes for April 1st, 2022 to September 30th, 2022, which shows parallel flight patterns indicating survey flights. Figure 6 shows waypoint MSL altitudes for October 1st, 2022 to January 2nd, 2023. Circular flight patterns around Mount Olympus are distinct in the figures and are at relatively higher MSL altitudes. Dense waypoints are observed in and around the William R. Fairchild International Airport near Port Angeles and these waypoints are at lower MSL altitudes.

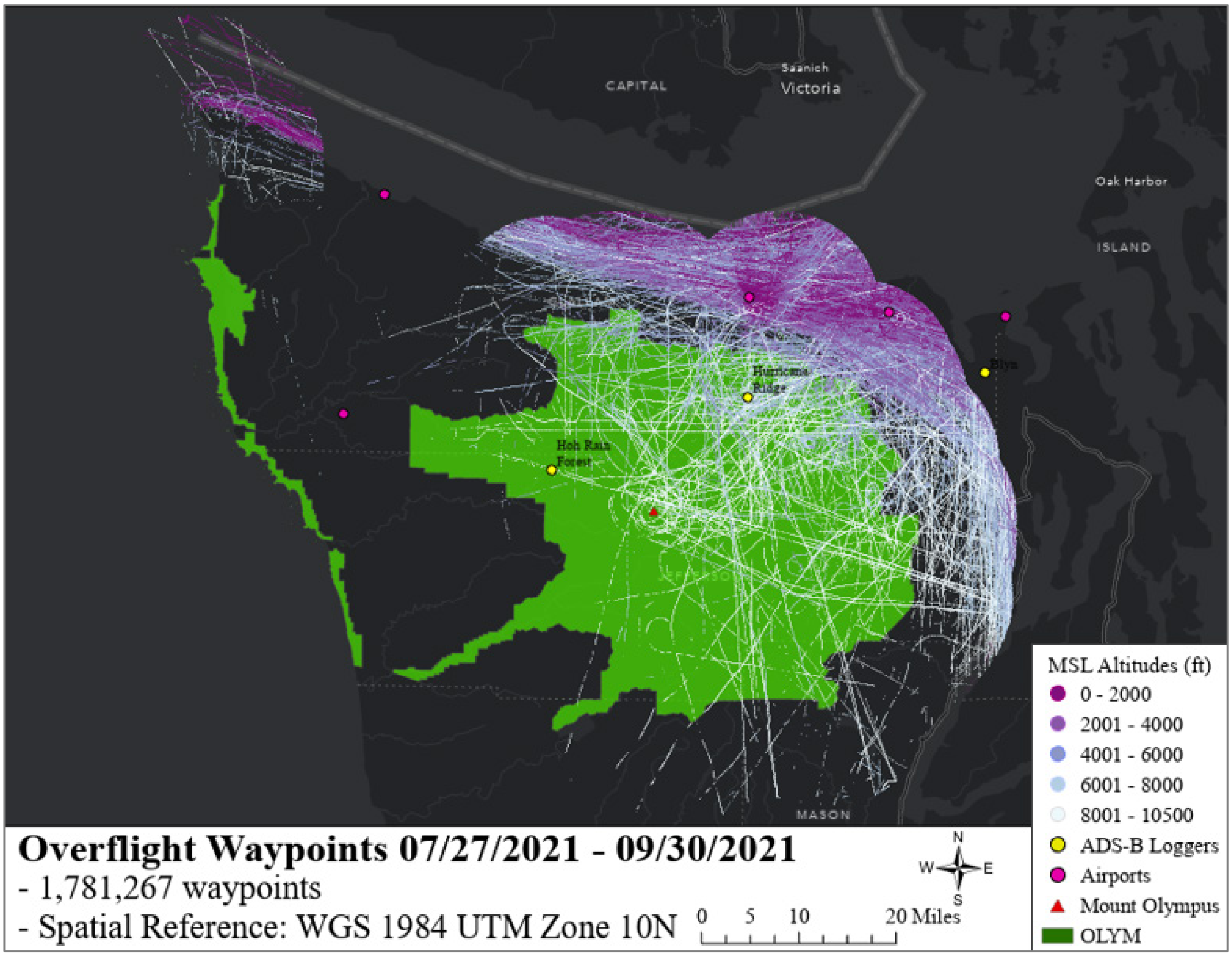

Figure 3. Waypoint MSL altitudes for July 27th, 2021 to September 30th, 2021 (Summer—two months). ADS-B units at Blyn and Hurricane Ridge were active during this time period.

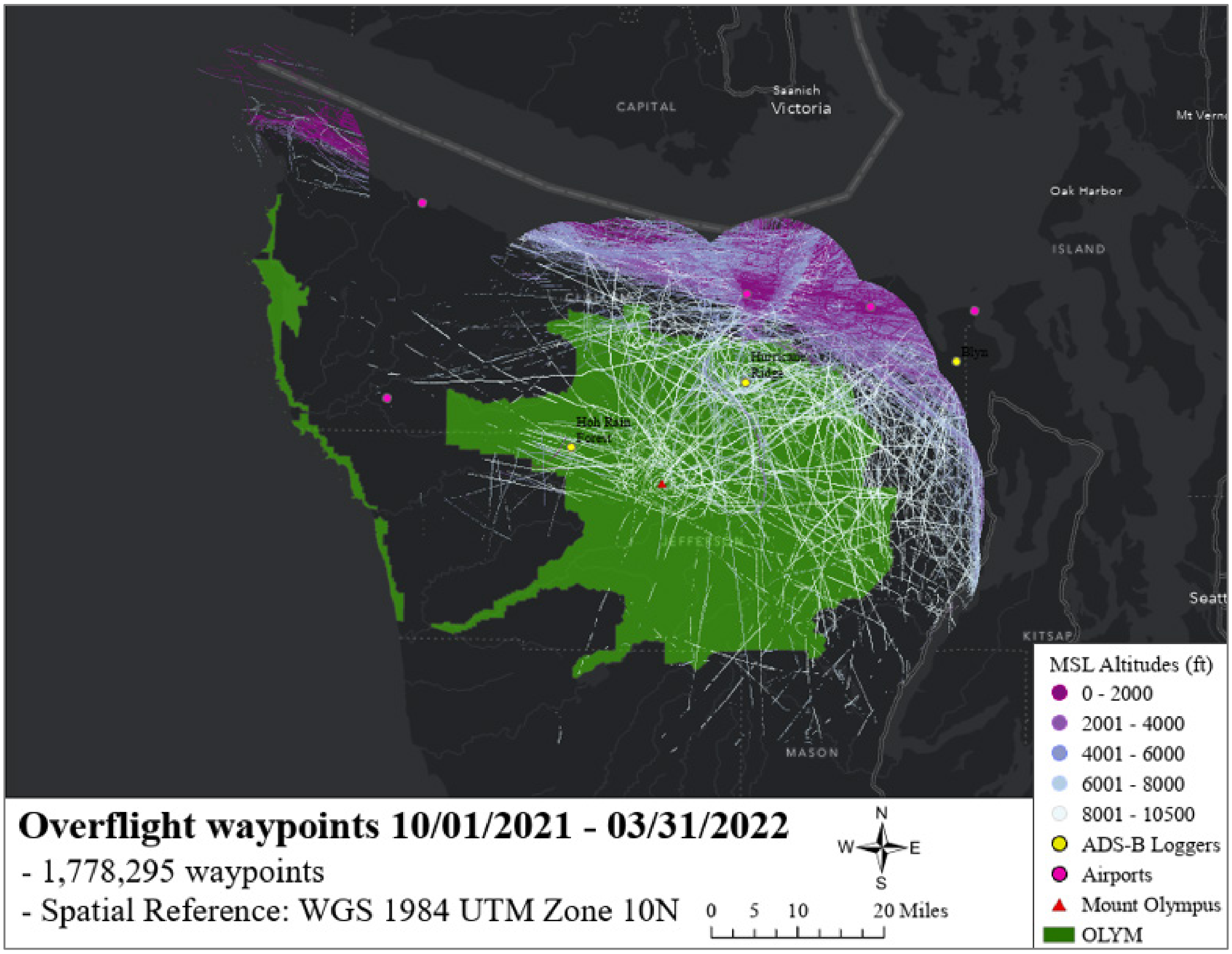

Figure 4. Waypoint MSL altitudes for October 1st, 2021 to March 31st, 2022 (Winter—six months). All three ADS-B unit locations were active during this time period.

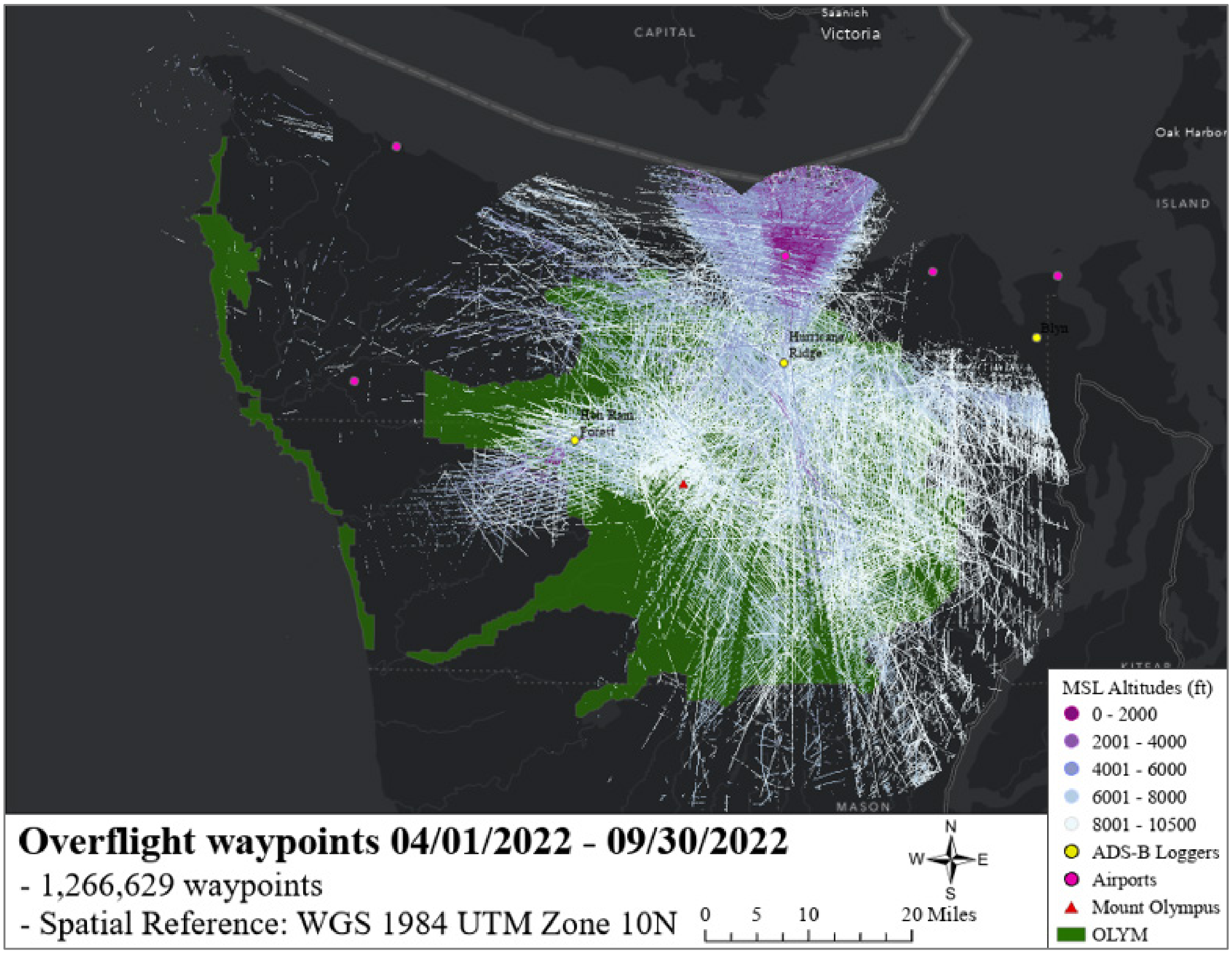

Figure 5. Waypoint MSL altitudes for April 1st, 2022 to September 30th, 2022 (Summer—six months). ADS-B units at Hurricane Ridge and Hoh Rain Forest were active during this time period.

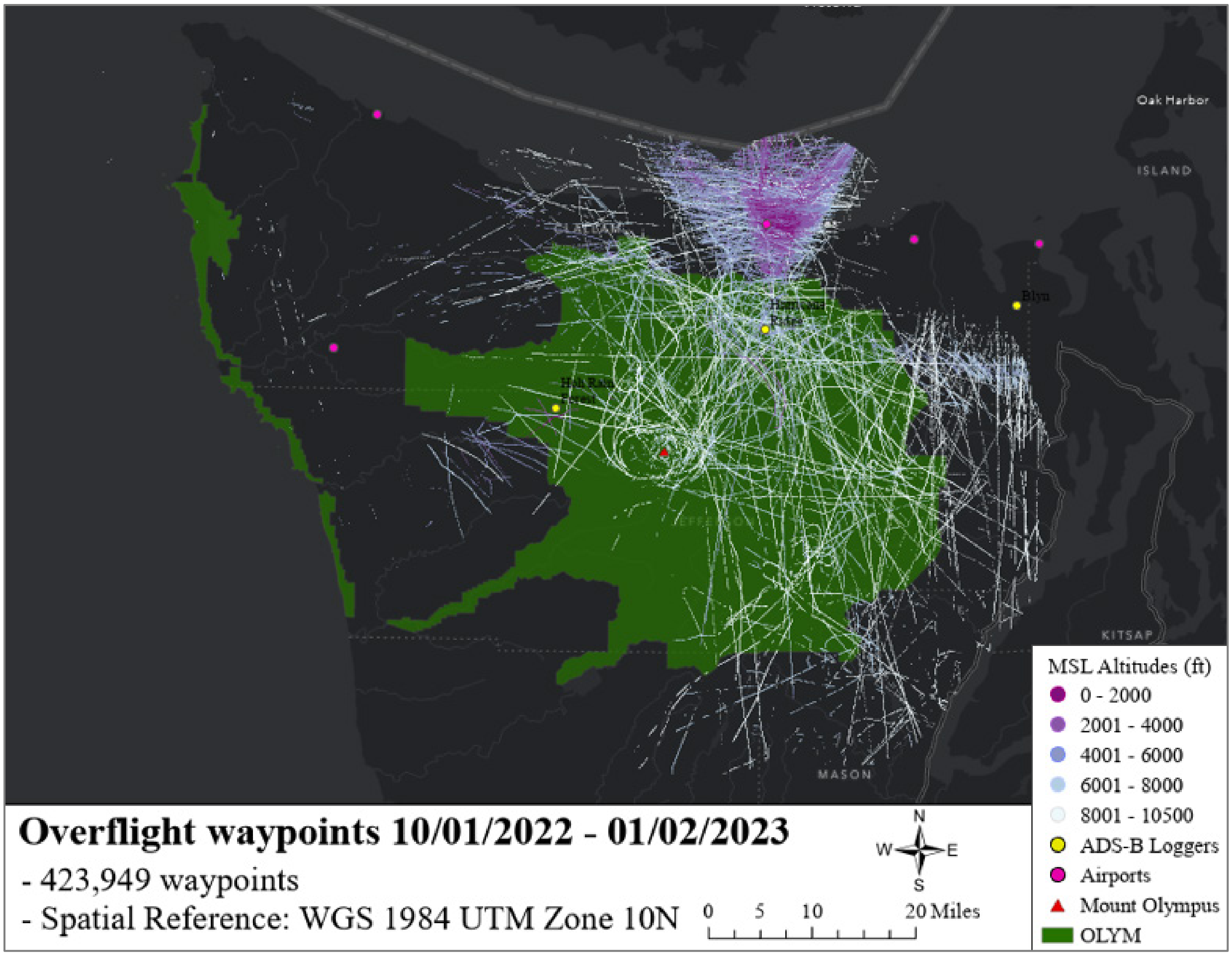

Figure 6. Waypoint MSL altitudes for October 1st, 2022 to January 2nd, 2023 (Winter—three months). ADS-B units at Hurricane Ridge and Hoh Rain Forest were active during this time period.

Results — Phase 3

Phase 3 included two parts—one on further analyzing low-level overflights more generally and another on overflights related to air tours and falling within the Olympic MOA and on the route between NASWI and the Olympic MOA.

Waypoints below 2,500 ft AGL were clipped with a 0.5-mile buffer around the park (Figure 7). There were 1,919,543 waypoints from 23,925 low-level overflights.

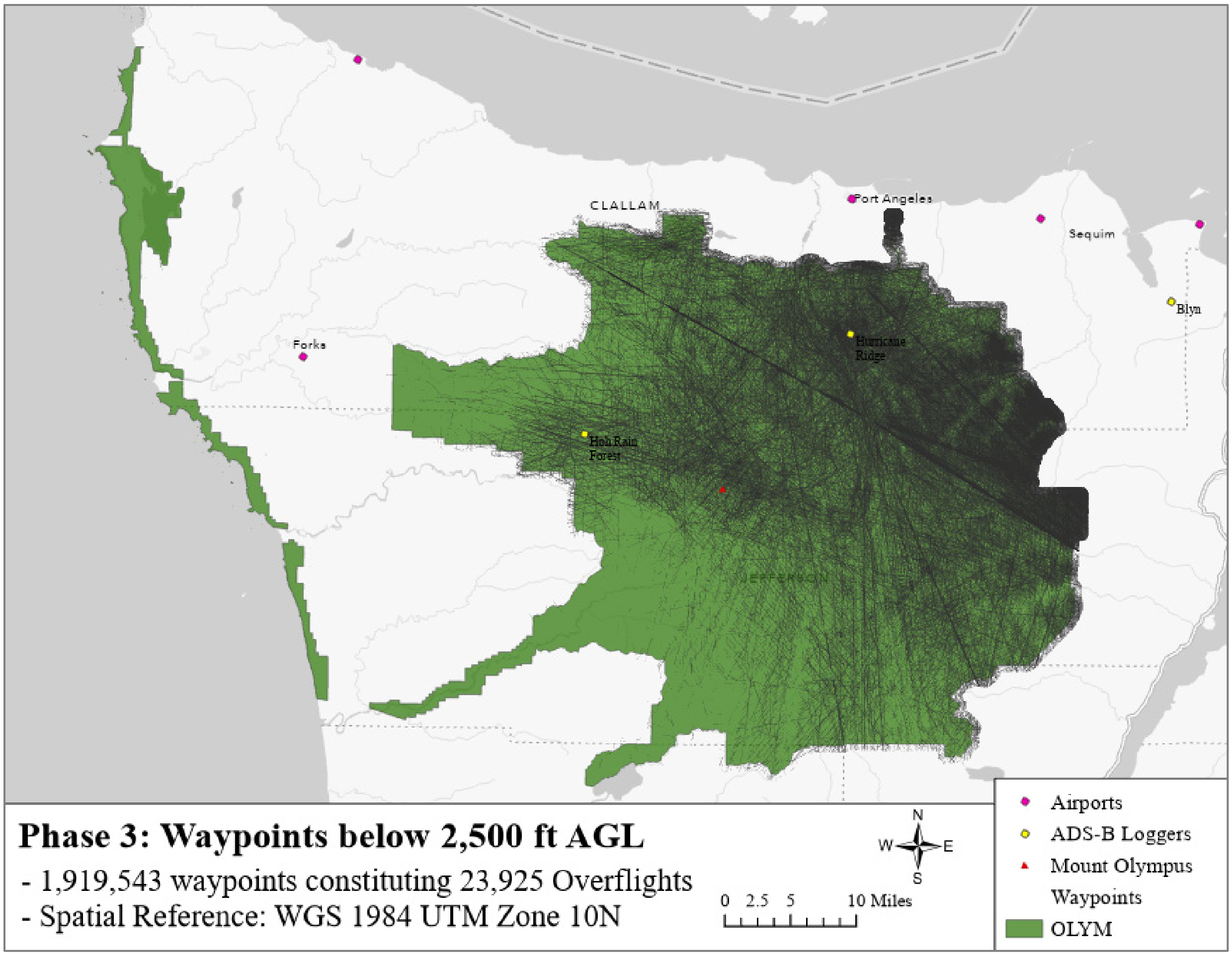

Figure 7. All waypoints below 2,500 ft AGL clipped with a 0.5-mile buffer around the park.

Point density analysis was conducted for the waypoints below 2,500 ft AGL (Figure 8). The density image was laid over the waypoints so that comparison and visualization of the results became easier. A high density of waypoints was observed on the eastern side of the park, just above the flight corridor that likely headed to or from the Seattle-Tacoma International Airport. Another high-density of waypoints was observed over Port Angeles, and a small dense area near Hurricane Ridge, as well.

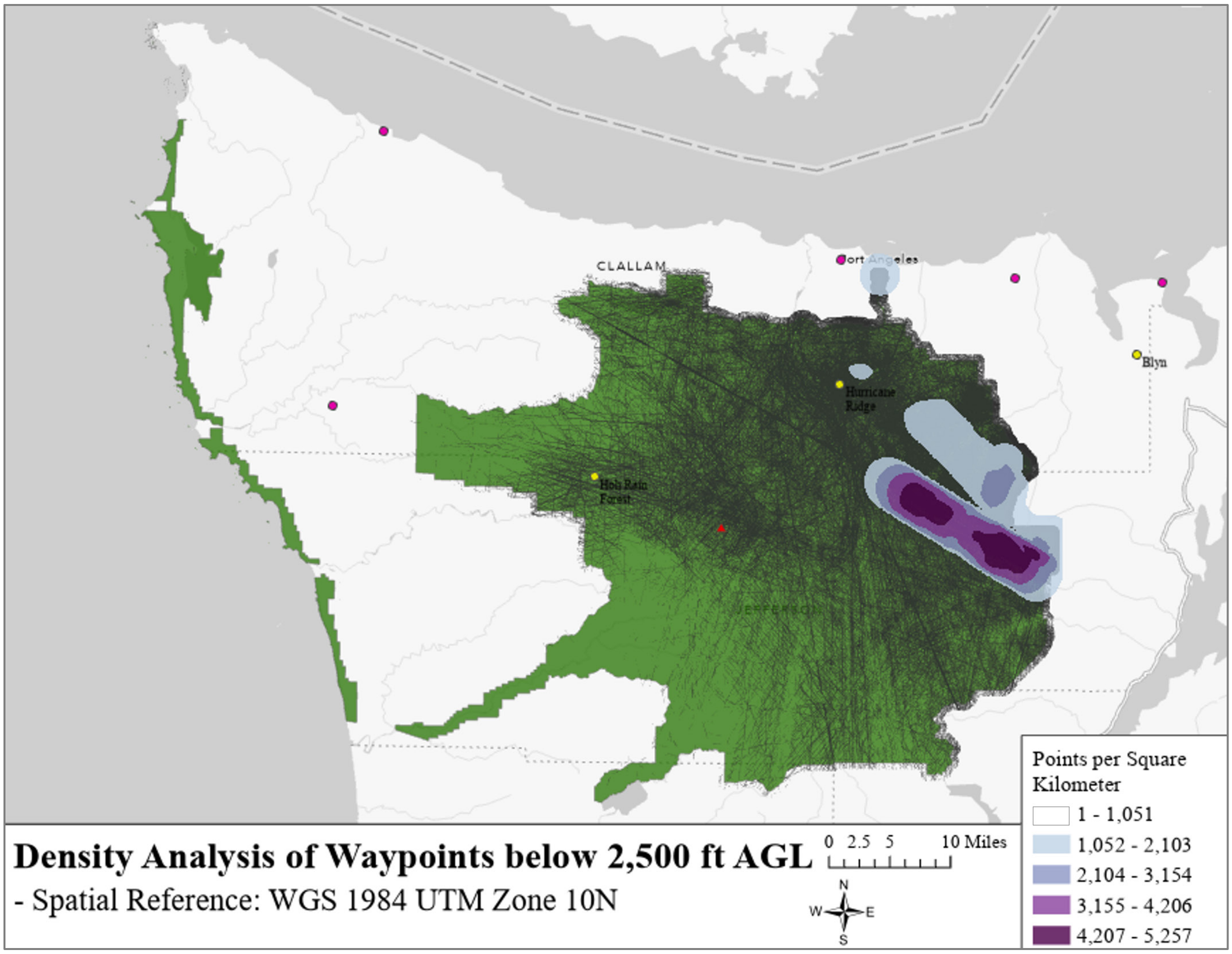

Figure 8. Density analysis of waypoints lying below 2,500 ft AGL.

Similarly, kernel density analysis was conducted for the waypoints in each AGL altitude category from 0–500 ft AGL to 2,000–2,500 ft AGL. Kernel density analysis is based on a kernel function or a probability density function of a random variable (also known as a tapering function), which is zero-valued outside of some chosen interval, normally symmetric around the middle of the interval, usually near a maximum in the middle, and usually tapering away from the middle. The AGL altitude interval that showed the most density was 0–500 ft AGL. Figure 9 shows the kernel density hot spots for 0–2,500 ft AGL. Almost all of the density hot spots are along the flight corridor on the east side of the park whereas one was observed over Port Angeles at the lower AGL category (0–500 ft AGL).

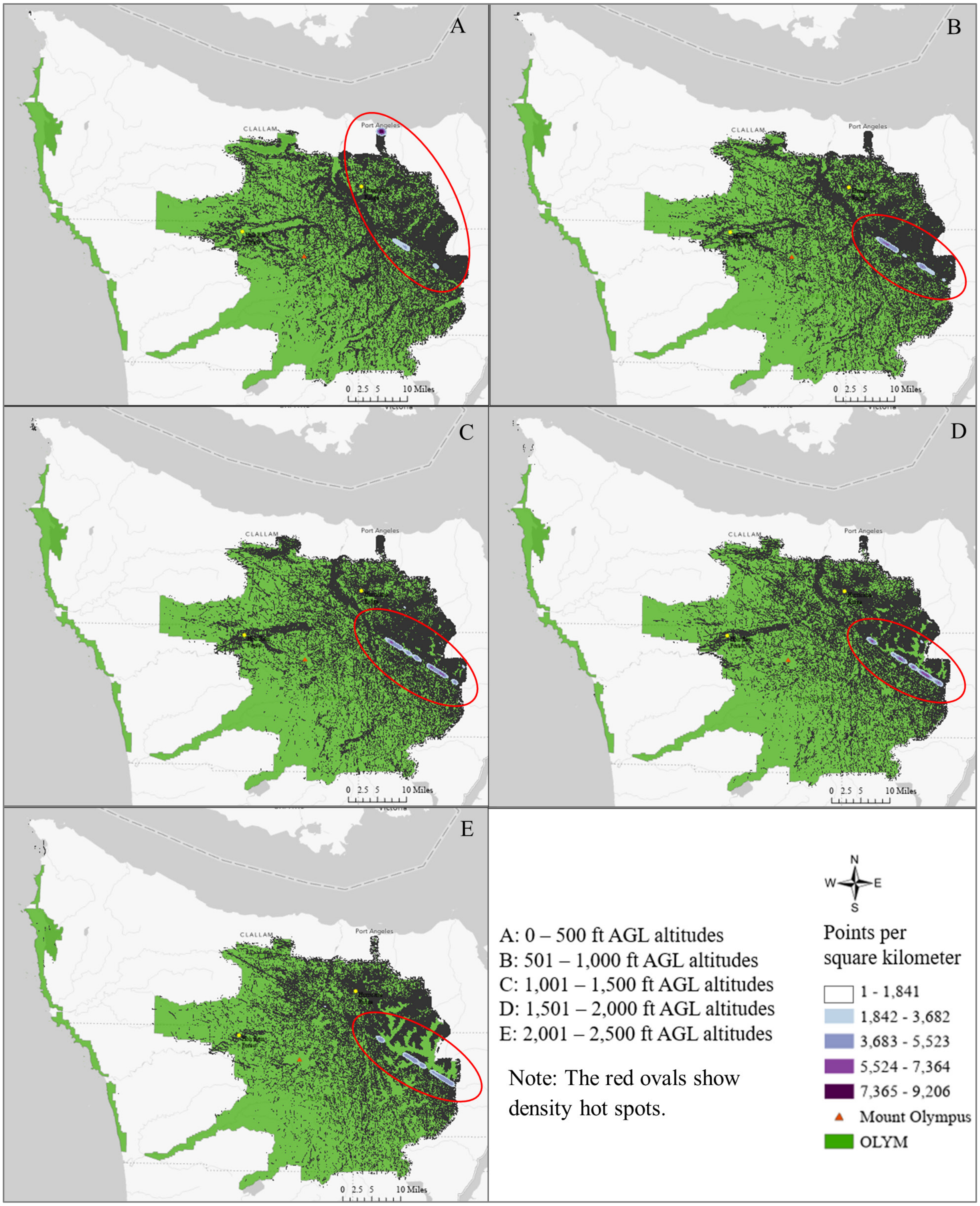

Figure 9. Kernel density across AGL altitudes ranging from 0–2,500 ft AGL.

The AGL altitude interval with the highest density of waypoints is shown in Figure 10. The density hot spots were observed in Port Angeles near William R. Fairchild International Airport and along the flight corridor on the northeastern part of the park, which are mostly likely headed to or from the much larger Seattle-Tacoma International Airport.

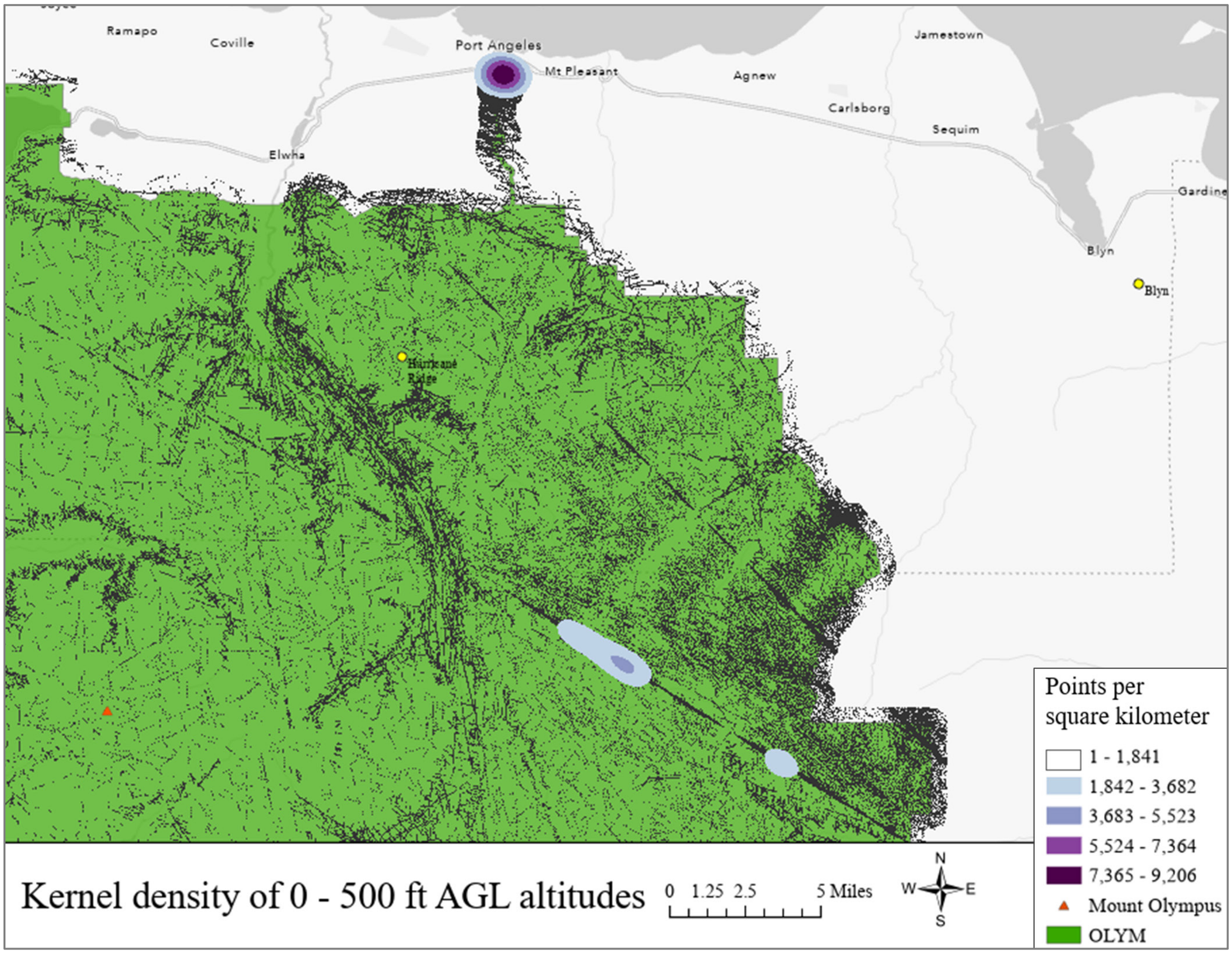

Figure 10. Kernel density image of 0–500 ft AGL altitude.

The correlation coefficients of five density output or raster images were calculated (Table 1). There is a strong correlation between density images of 1,001–1,500 ft AGL and 1,501–2,000 ft AGL (correlation coefficient is 0.92). There is also a strong correlation between 501–1,000 ft AGL and 1,001–1,500 ft AGL (correlation coefficient is 0.84). It is interesting to observe the correlation between 501–1,000 ft AGL and 2,001–2,500 ft AGL (correlation coefficient is 0.86). This means that the concentration of flights in these areas is spread across a range of altitudes, which can lead to more intense noise in these areas.

Table 1. Spatial correlation matrix of Above Ground Level (AGL) altitude point densities.

AGL Altitude Interval	1	2	3	4	5
1. 0–500 ft	–	–	–	–	–
2. 501–1,000 ft	0.53	–	–	–	–
3. 1,001–1,500 ft	0.34	**0.84** [A]	–	–	–
4. 1,501–2,000 ft	0.22	0.66	**0.92** [A]	–	–
5. 2,001–2,500 ft	0.66	**0.86** [A]	0.67	0.47	–

[A] Strong correlation, also shown in bold.

The distribution of the waypoints from 0–2,500 ft AGL altitudes with an interval of 500 ft is shown in Figure 11. The majority of the waypoints are above the northeastern side of the park. The pattern of distribution of the waypoints represented by purple and white dots suggests the undulating topography of the area, especially on the eastern side of the park.

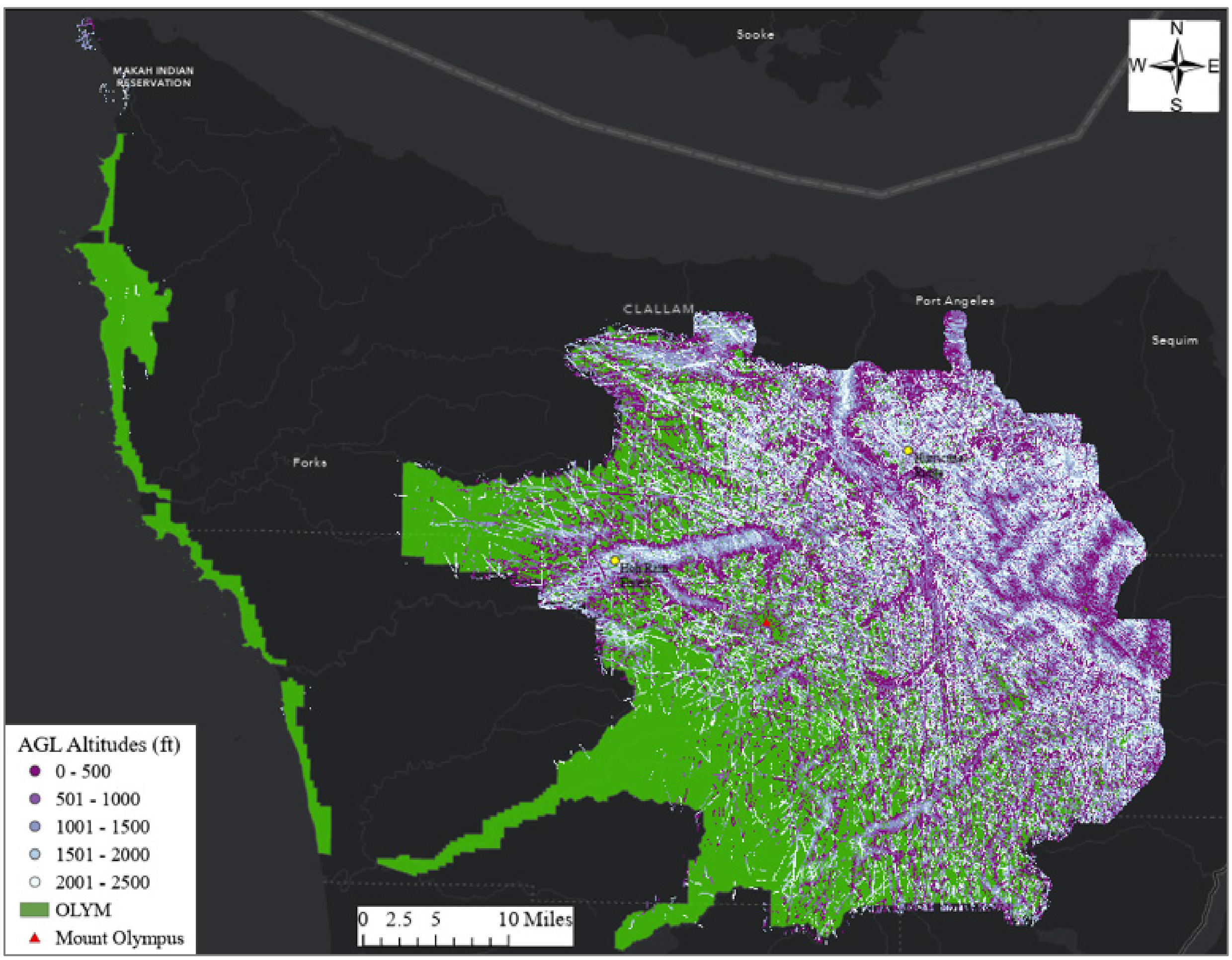

Figure 11. AGL altitude trends of altitudes ranging from 0–2,500 ft AGL for waypoints within 0.5-mile of the OLYM boundary (n=1,231,181 waypoints).

Waypoints with AGL altitude values less than 0 ft within the 0.5-mile boundary of OLYM are shown in Figure 12. Any tracking point with a negative AGL is due to an error, although identifying the exact error can be difficult. Broadly, error sources could be aircraft flying exceptionally low (including for landings or drop-offs) combined with DEM generalization errors and errors between barometric altitude estimates and actual altitude. The distribution of these waypoints is similar to the distribution of the waypoints with AGL altitudes higher than 0 ft. Waypoints are dense in the center and eastern side of the park and along the flight corridor.

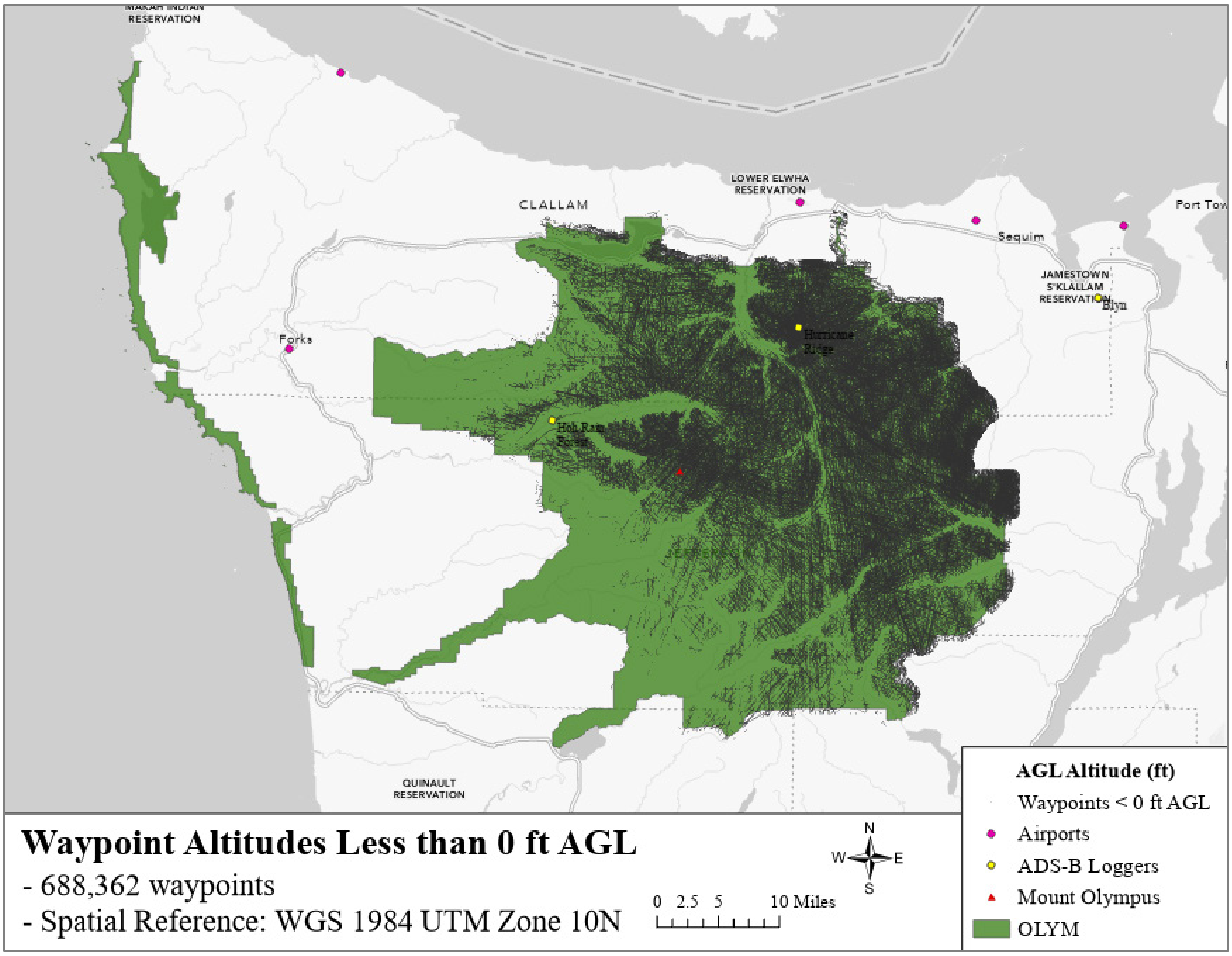

Figure 12. Waypoints with AGL altitude less than 0 ft AGL within 0.5-mile of the OLYM boundary (n=688,362)

Figure 13 shows waypoints at altitudes from 0–10,500 ft MSL with an interval of 1,000 ft. Most of the waypoints are at higher MSL altitudes while over the park and some are at lower MSL altitudes near Port Angeles, Hurricane Ridge, and Hoh Rain Forest. Parallel patterns of some of the waypoints suggested the survey flights. Two patterns really stand out in Figure 13. One, the circular pattern of flights around Mount Olympus, and two, the lower altitude flights just below Hurricane Ridge.

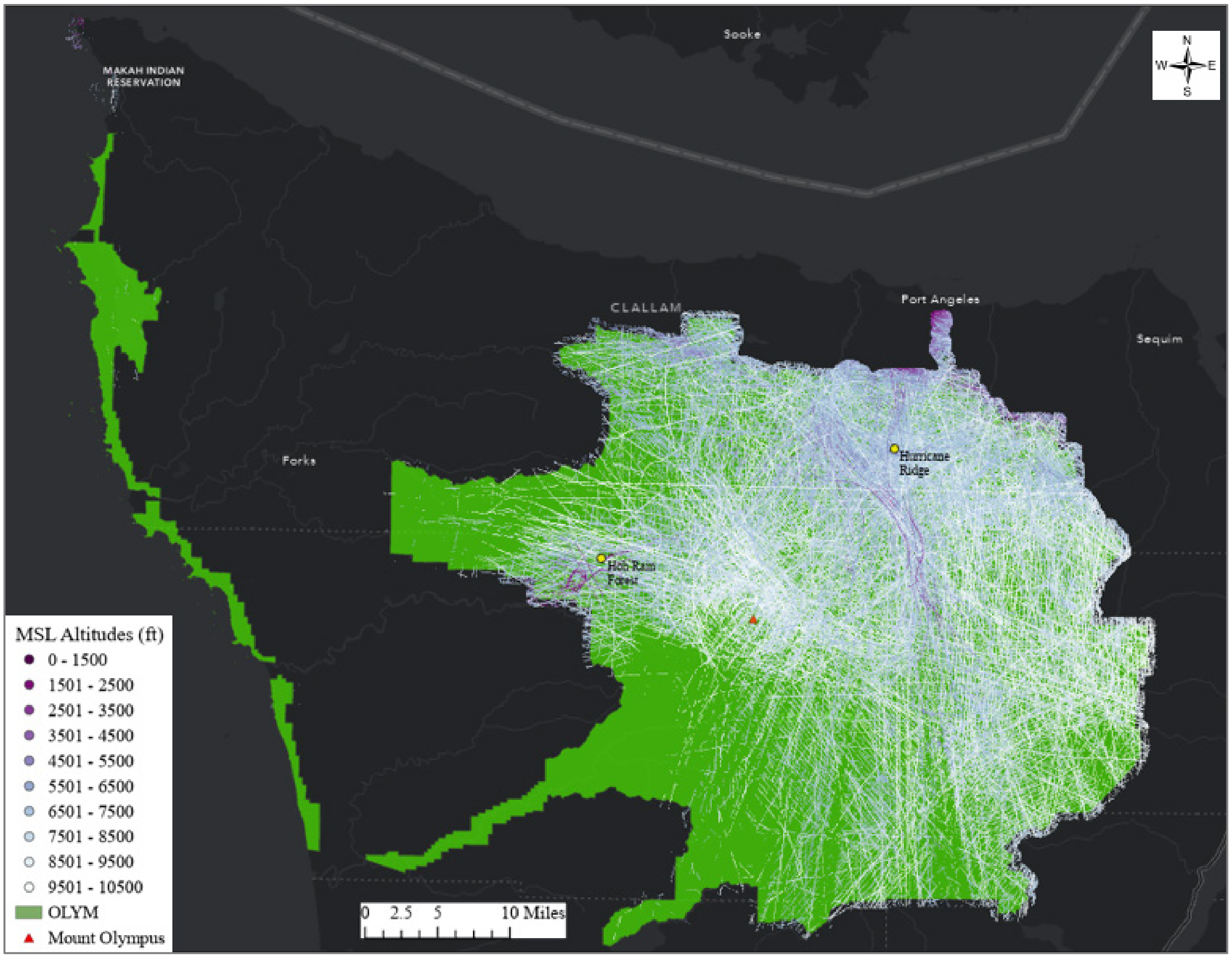

Figure 13. MSL altitude trends of altitudes ranging from 0–10,500 ft MSL for waypoints within 0.5-mile of the OLYM boundary (n=713,649 waypoints).

The distribution of waypoints across the AGL altitudes and MSL altitudes are shown in tables. The waypoints are distributed more or less uniformly in the five AGL altitude categories (Table 2). The waypoints are in higher numbers in the upper MSL altitudes (>5,501 ft MSL) than in the lower MSL altitudes (<5,500 ft MSL) (Table 3), mostly due to the rising topography of the park.

Table 2. Number and percentage of waypoints across AGL altitude intervals (n=1,231,181).

AGL altitude	Number of waypoints	Percentage of waypoints
0–500 ft	222,889	18.10
501–1,000 ft	233,370	18.95
1,001–1,500 ft	262,615	21.33
1,501–2,000 ft	262,167	21.29
2,001–2,500 ft	250,140	20.32

Table 3. Number and percentage of waypoints across MSL altitude intervals (n=713,649).

MSL altitude	Number of waypoints	Percentage of waypoints
0–1,500 ft	23,251	3.26
1,501–2,500 ft	12,840	1.80
2,501–3,500 ft	7,857	1.10
3,501–4,500 ft	16,139	2.26
4,501–5,500 ft	43,432	6.09
5,501–6,500 ft	71,910	10.08
6,501–7,500 ft	102,681	14.39
7,501–8,500 ft	173,950	24.37
8,501–9,500 ft	152,174	21.32
9,501–10,500 ft	109,415	15.33

Low-level overflights were analyzed across months, days of the week, and hours of the day (total flights analyzed = 23,925). Table 4 shows data collected for days in a month, overflights in a month, and the average number of flights per day for the data collection duration, which occurred from July 27th, 2021 to January 3rd, 2023. OLYM received the most low-level overflights in July of 2022 (average number of flights per day = 89). Further, the summer season does seem to be busier than winter.

Table 4. Number of overflights across months (n=23,925).

Month	Number of data collection days *	Number of overflights	Average Number of overflights per day
July 2021	5	404	81
August 2021	31	2,488	80
September 2021	30	1,622	54
October 2021	31	1,822	59
November 2021	30	1,454	48
December 2021	31	1,268	41
January 2022	30	899	30
February 2022	28	209	7
March 2022	31	299	10
April 2022	30	1,045	35
May 2022	31	305	10
June 2022	30	669	22
July 2022	31	2,769	89
August 2022	31	2,226	72

* For some months, data collection did not occur every day because of technological failure.

Table 4 (continued). Number of overflights across months (n=23,925).

Month	Number of data collection days*	Number of overflights	Average Number of overflights per day
September 2022	30	2,273	76
October 2022	31	1,727	56
November 2022	30	1,309	44
December 2022	31	1,114	36
January 2023	3	23	8
Total	**525**	**23,925**	**–**

* For some months, data collection did not occur every day because technological failure.

The analysis also generated the percentage of flights across days of the week (Table 5). The days of the week with the highest percentage of flights were Wednesdays (14.9%) and Thursdays (14.6%). Table 6 shows the percentage of overflights across hours of the day. Most overflights occurred from 11:00 am to 3:00 pm. Table 7 shows the percentage of overflights across aircraft types. Fixed wing multi engine is the aircraft type most common among overflights at OLYM whereas 26.9% of them showed “null” in the aircraft type and 0.1% showed “Glider”.

Table 5. Percentage of overflights across days of the week.

Day of the week	Percentage of overflights
Monday	13.7
Tuesday	14.2
Wednesday	14.9
Thursday	14.6
Friday	14.5
Saturday	14.1
Sunday	14.1

Table 6. Percentage of overflights across hours of the day for weekdays (n=17,181) and weekends (n=6,744).

Hour	Percentage of overflights
6:00am–7:00am	1.6
7:00am–8:00am	2.6
8:00am–9:00am	4.1
9:00am–10:00am	4.9
10:00am–11:00am	5.7
11:00am–12:00pm	7.3
12:00pm–1:00pm	9.0
1:00pm–2:00pm	9.6
2:00pm–3:00pm	7.9
3:00pm–4:00pm	5.4
4:00pm–5:00pm	5.2
5:00pm–6:00pm	4.8
6:00pm–7:00pm	4.6
7:00pm–8:00pm	3.5
8:00pm–9:00pm	4.0
9:00pm–10:00pm	3.9
10:00pm–11:00pm	4.3
11:00pm–12:00am	4.9

Table 7. Percentage of overflights across aircraft type.

Aircraft type	Percentage
Fixed wing single engine	14.2
Fixed wing multi engine	57.1
Rotorcraft	1.8

Three more figures were produced to show the overflight travel patterns of three aircraft types. Figure 14 shows overflight travel patterns for fixed wing single engine aircraft. Figure 15 shows overflight travel patterns for fixed wing multi engine aircraft. Figure 16 shows overflight travel patterns for rotorcraft.

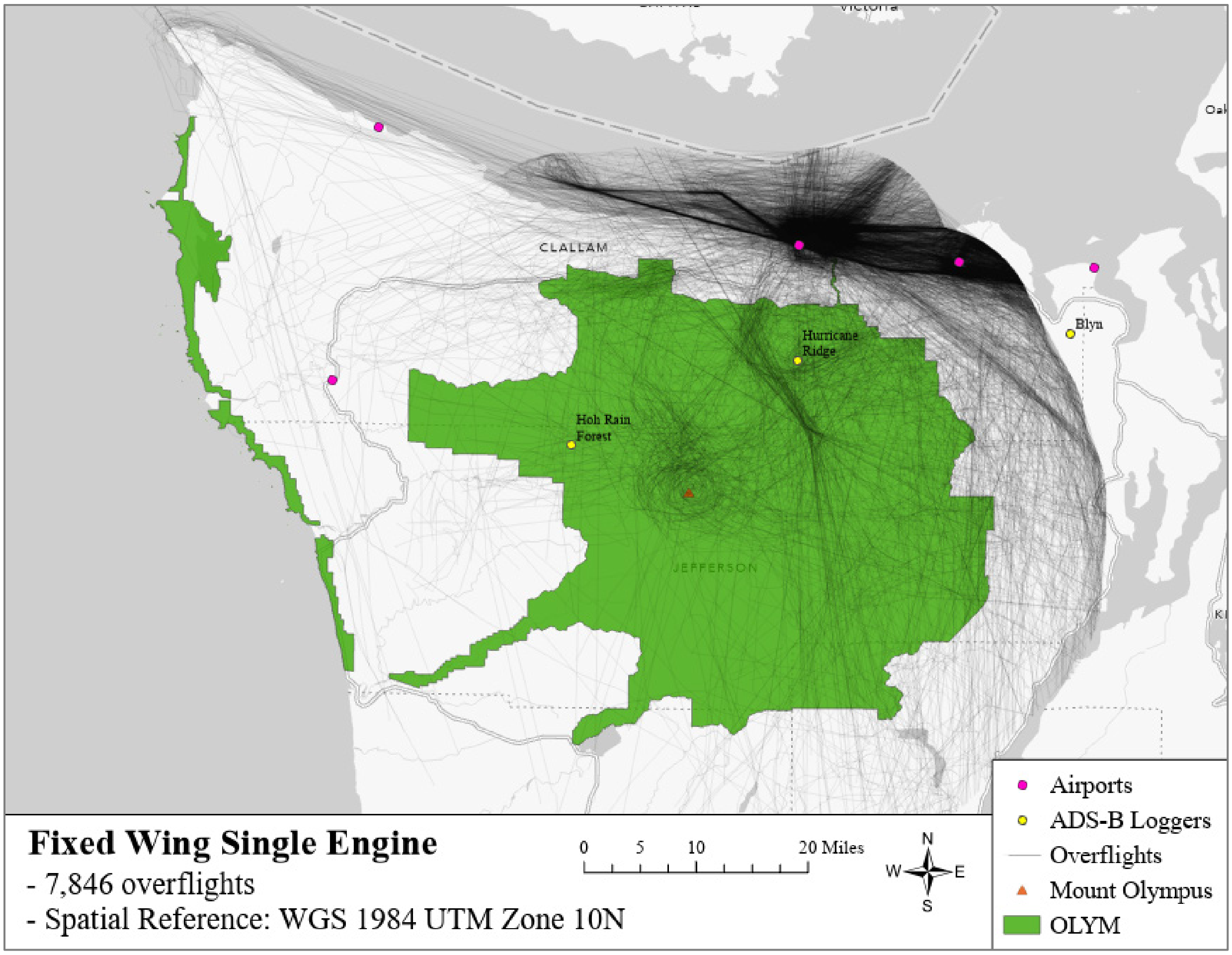

Figure 14. Fixed wing single engine overflight travel patterns.

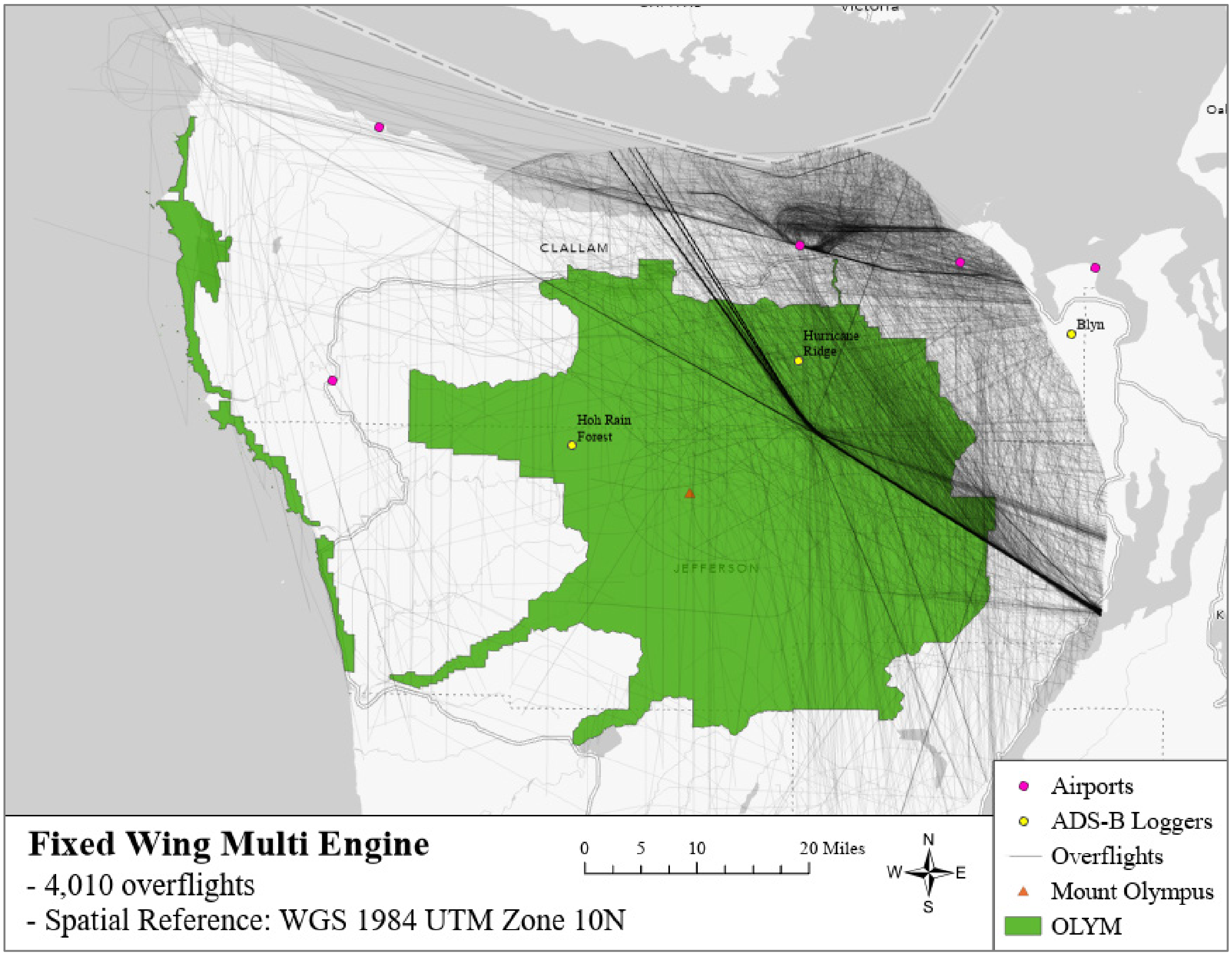

Figure 15. Fixed wing multi engine overflight travel patterns.

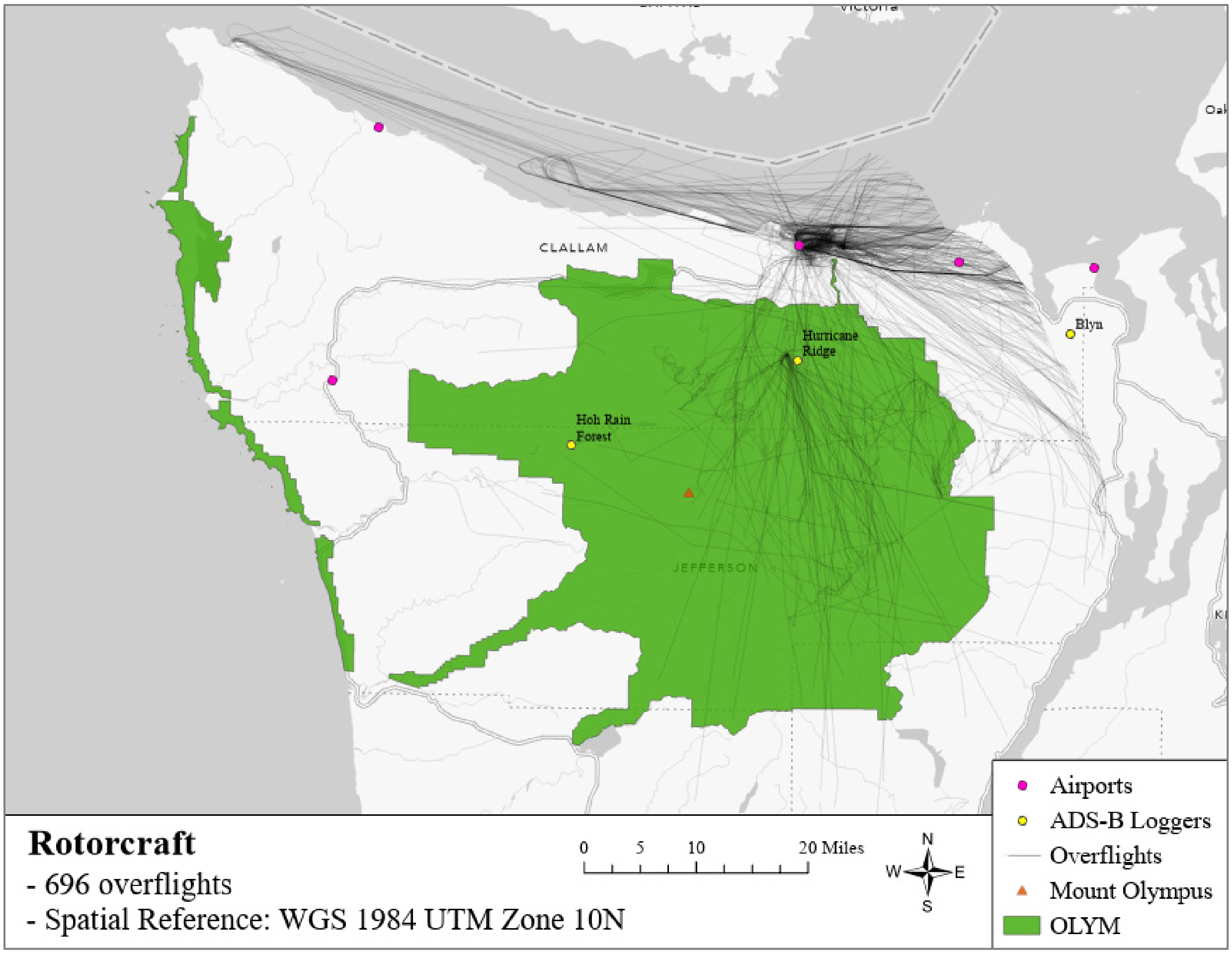

Figure 16. Rotorcraft overflight travel patterns.

Maps were produced displaying the overflights conducted by Rite Bros Aviation, Inc., a registered air tour operator. The air tour route as authorized by the OLYM ATMP is also shown. Figure 17 shows tail number N4793F (Rite Bros Aviation, Inc.), Figure 18 shows tail number N78303 (Rite Bros Aviation, Inc.), Figure 19 shows tail number N4879F (Rite Bros Aviation, Inc.), and Figure 20 shows tail number N673AT (Rite Bros Aviation, Inc.). The data displayed occurred both before and after the establishment of the ATMP.

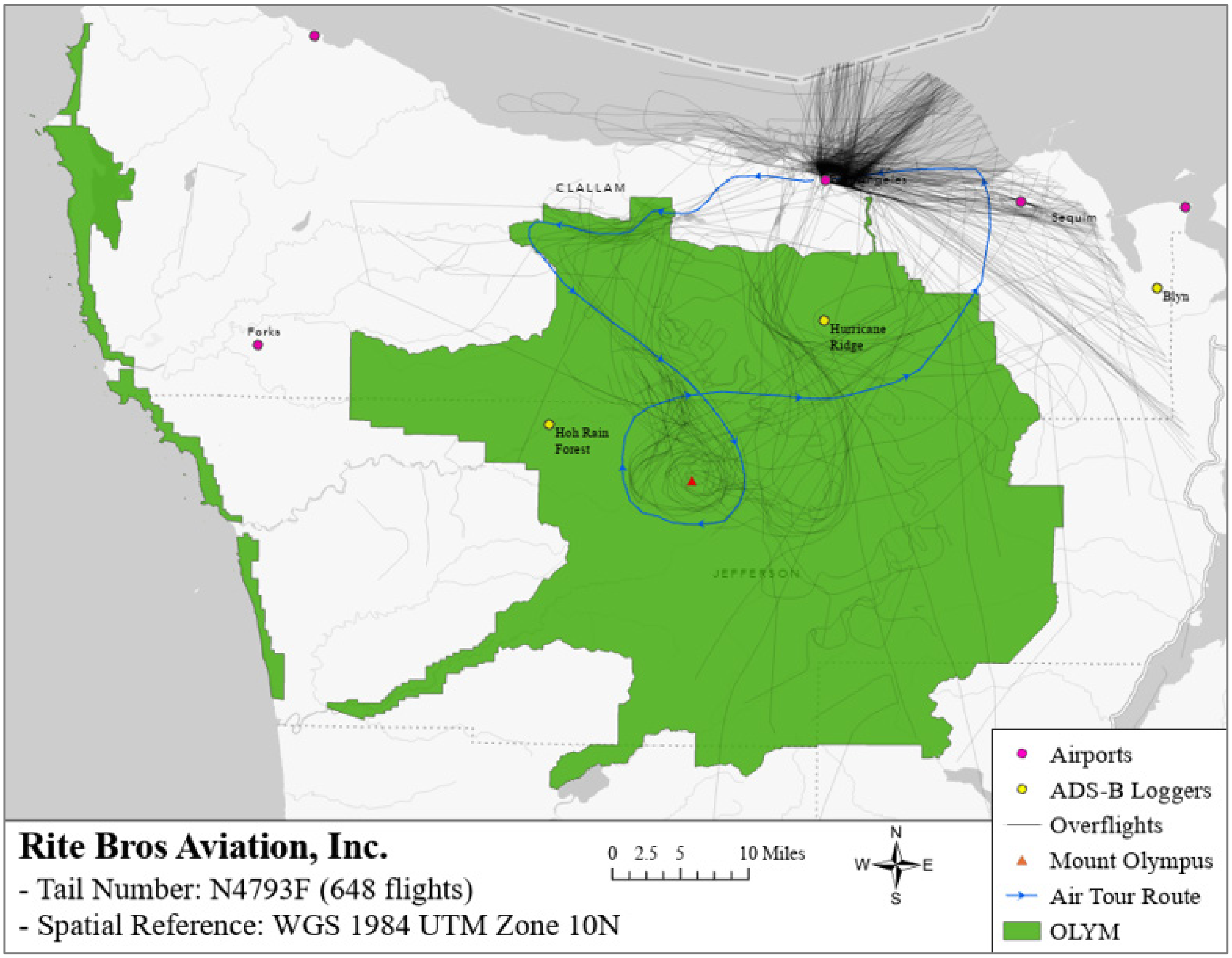

Figure 17. Overflight travel patterns for Rite Bros Aviation, Inc. with tail number N4793F.

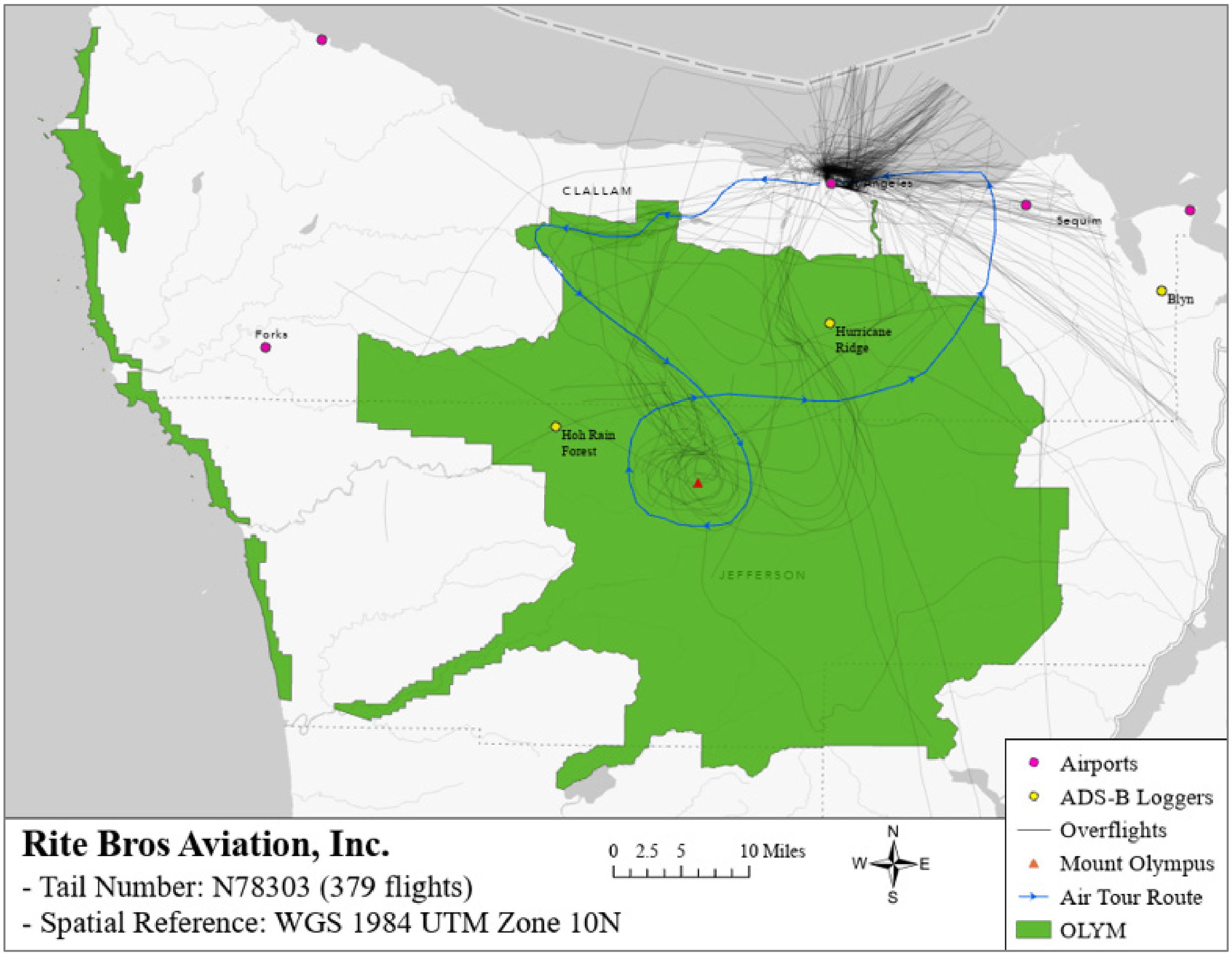

Figure 18. Overflight travel patterns for Rite Bros Aviation, Inc. with tail number N78303.

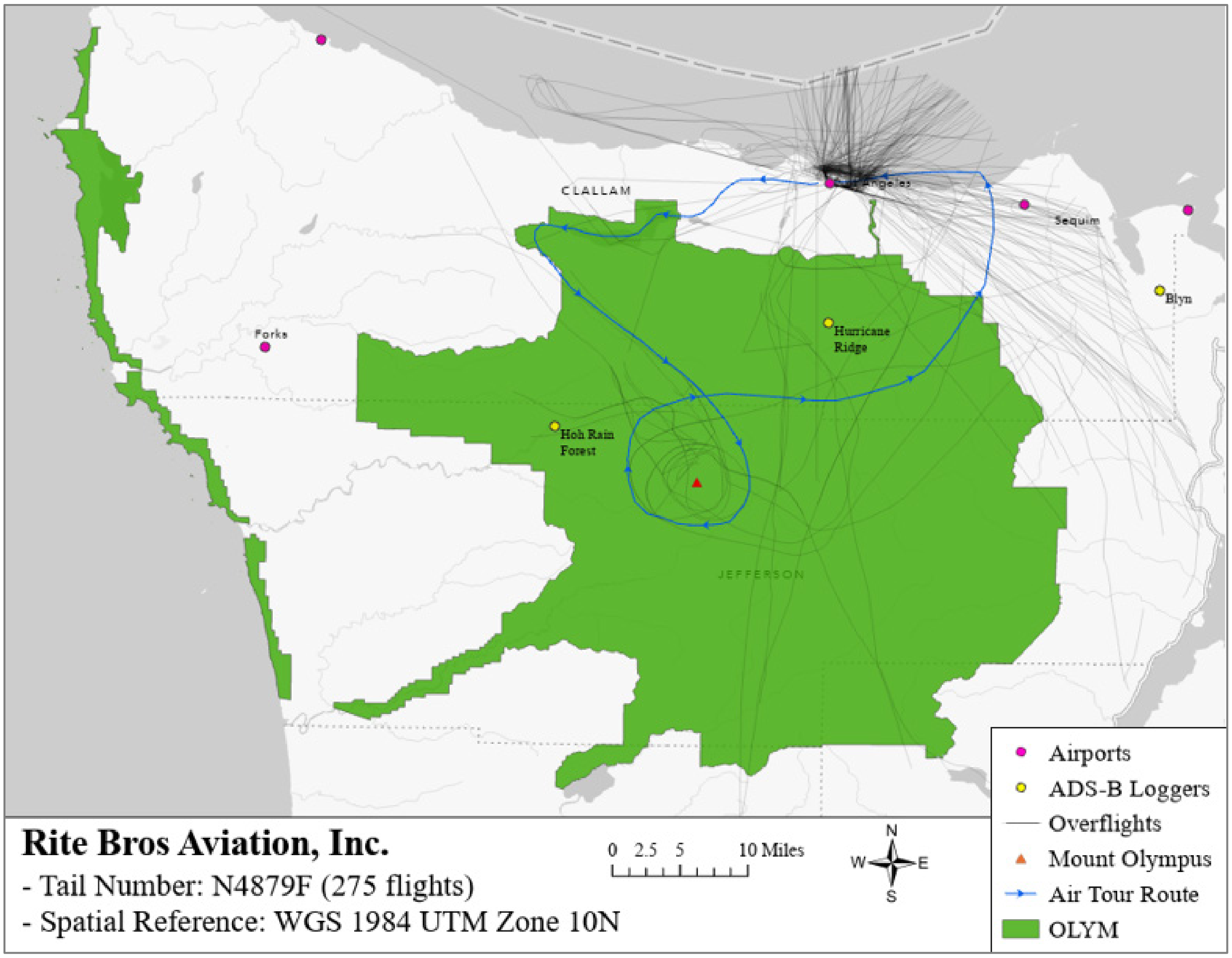

Figure 19. Overflight travel patterns for Rite Bros Aviation, Inc. with tail number N4879F.

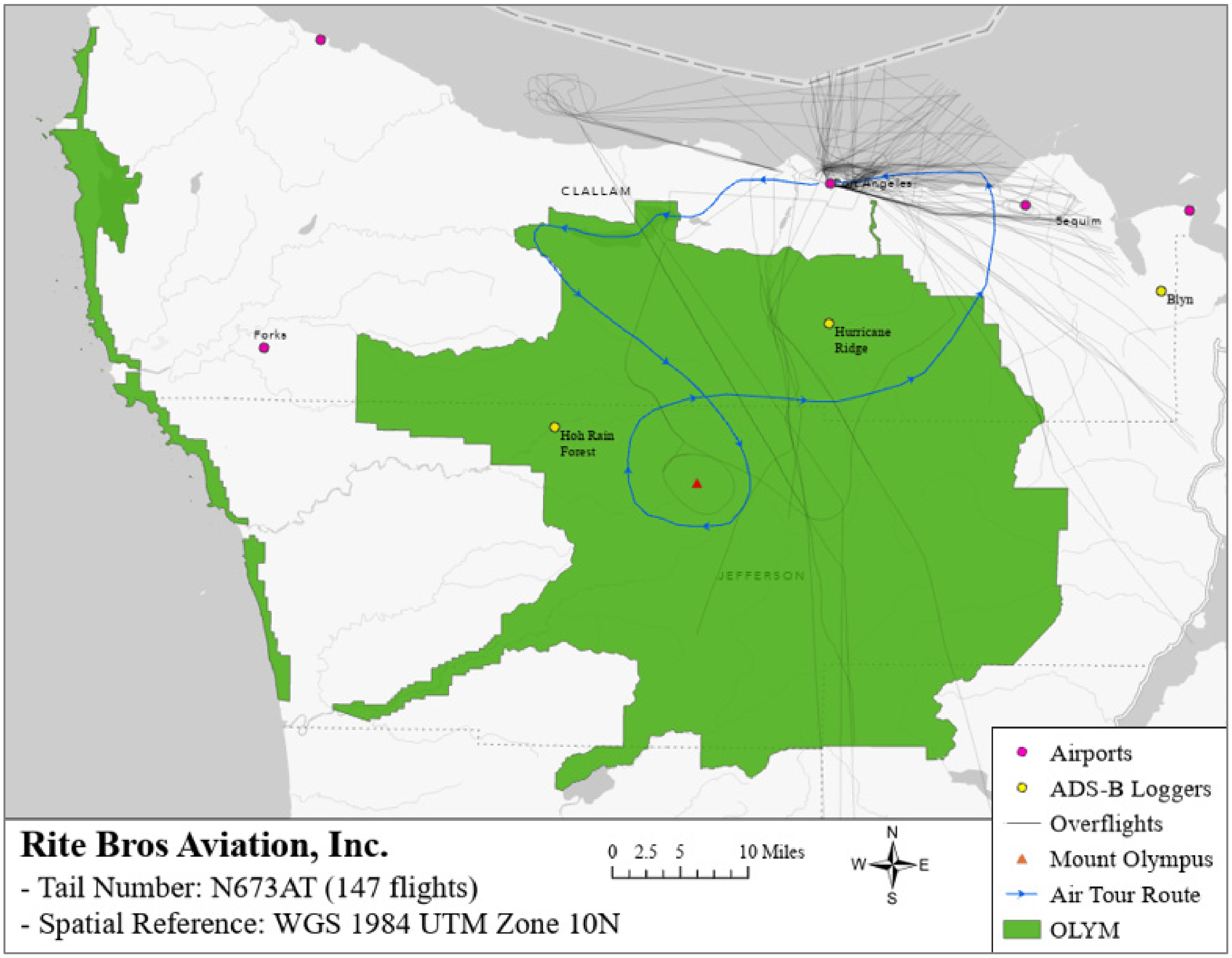

Figure 20. Overflight travel patterns for Rite Bros Aviation, Inc. with tail number N673AT.

Additionally, overflight patterns of two more air tour operators were analyzed. Tail numbers N19752 and N756AW of Seaplane Scenics were mapped but their overflight travel patterns are much further away from the park boundary (Figure 21). Tail number N131VR of Vashon Island Air was mapped and showed three flights, with two of those flights over OLYM. One of the two flights entered the park boundary, curved around Hurricane Ridge and returned (Figure 21). This particular flight was conducted on 07/15/2022 at 10:58am. The overflight pattern of Kenmore air tour operator was analyzed. Tail number N830RR was recorded with 46 flights (Figure 22). None of the flights seem to be air tours over the park.

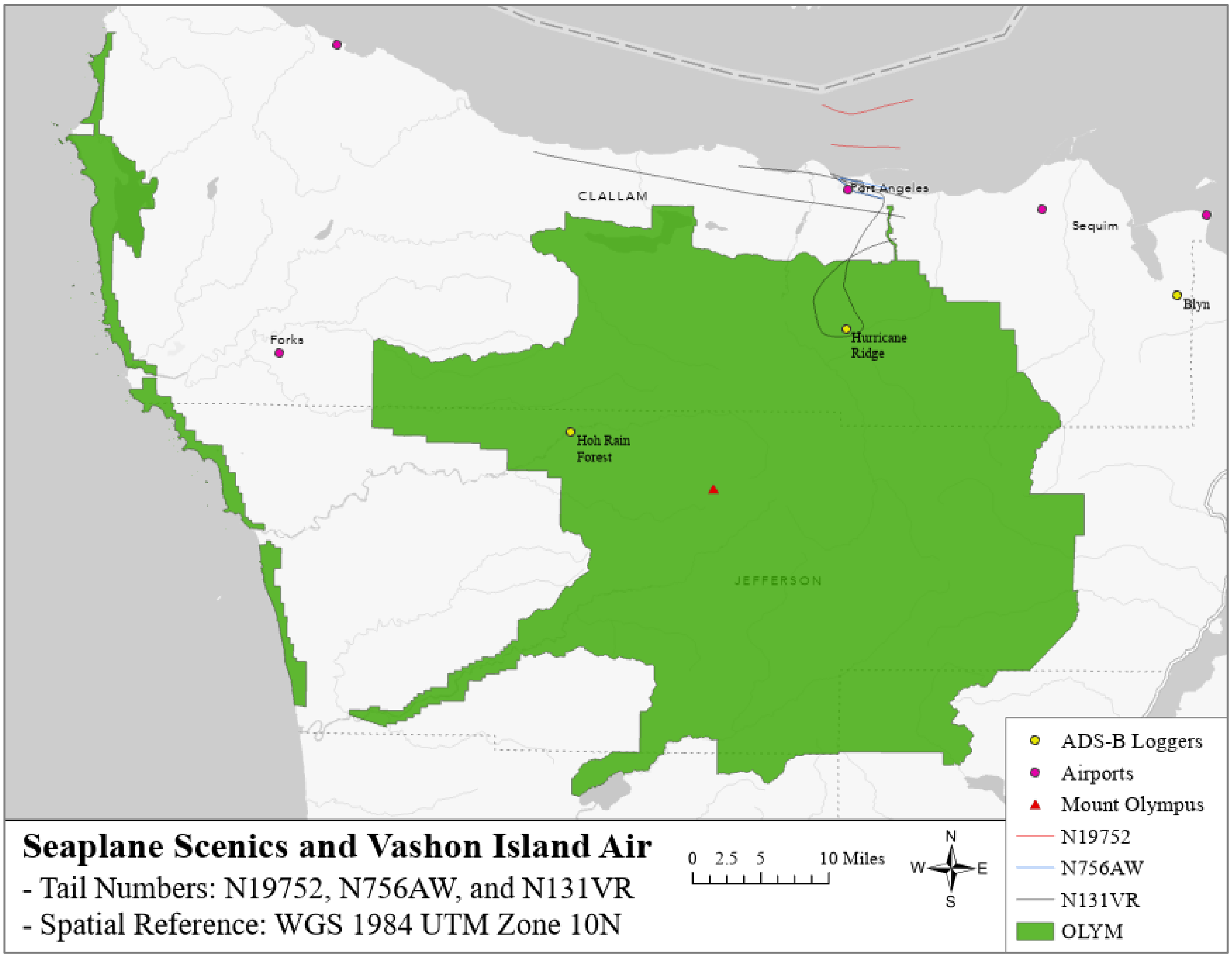

Figure 21. Overflight patterns for N19752, N756AW, and N131VR.

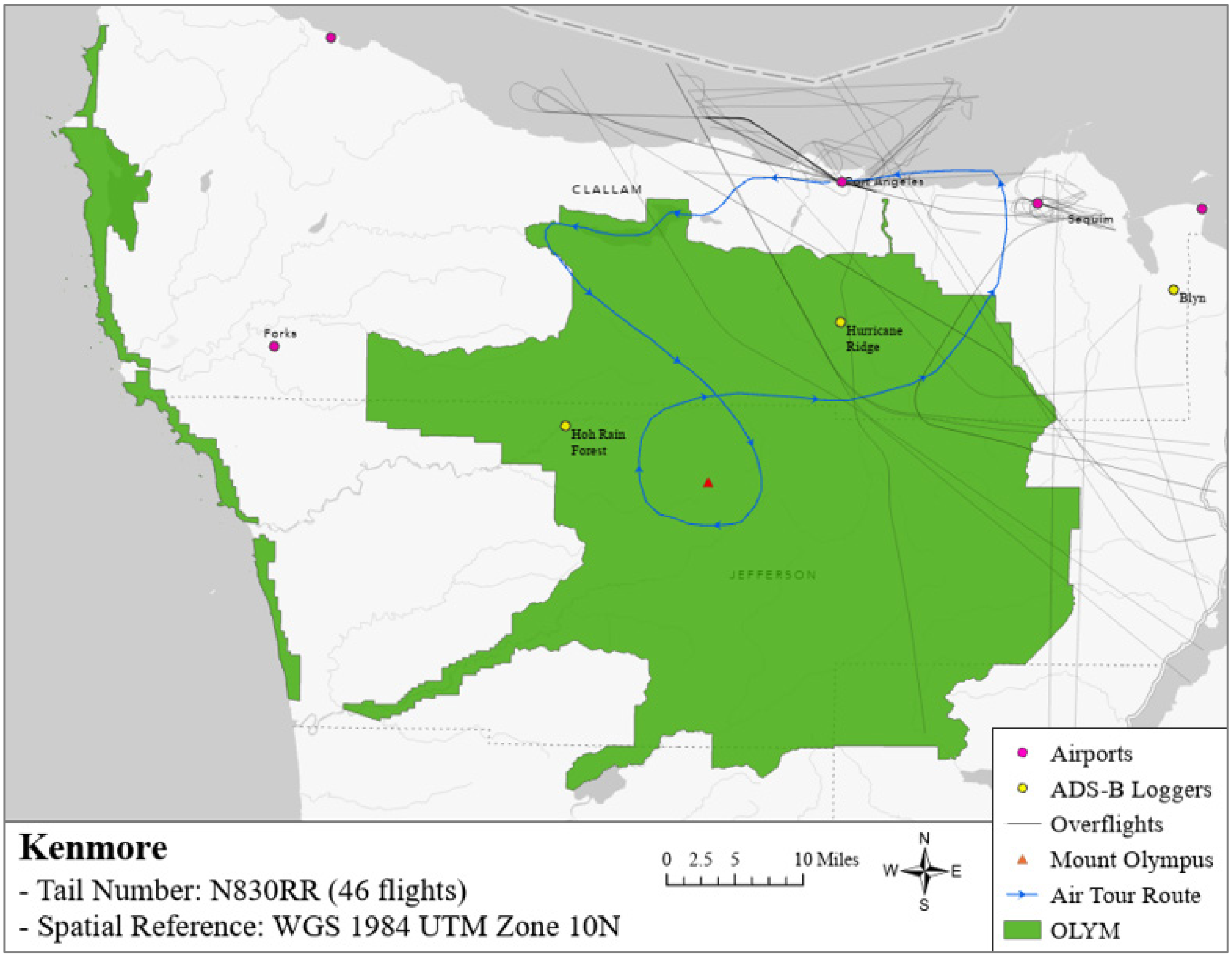

Figure 22. Overflight patterns for Kenmore with tail number N830RR.

Park administration conducted flights on different occasions by leasing helicopters from contractors. This analysis examined the recorded flight paths from the tail numbers commonly used by the park; however, the mapped flight paths may or may not have been part of a contracted administration flight. There were 124 flights conducted using tail number N664MP (Robinson R66) of Leading Edge Aviation (Figure 23). Administration flights conducted using other aircraft were not as frequent (Figure 24). There were 18 flights conducted using N88TA (Bell 206b) of Northwest Helicopters, 14 flights using N117DR (Bell UH-1), 12 flights using N6181A (Bell 206B-III) of Hiline Helicopters, 8 flights using N20WH of Hiline Helicopters, 8 flights using N722LM (Bell 206B-L4) of Northwest Helicopters, and 6 flights using N48MP (Hughes 369 Helo) of Leading Edge Aviation (Figure 24).

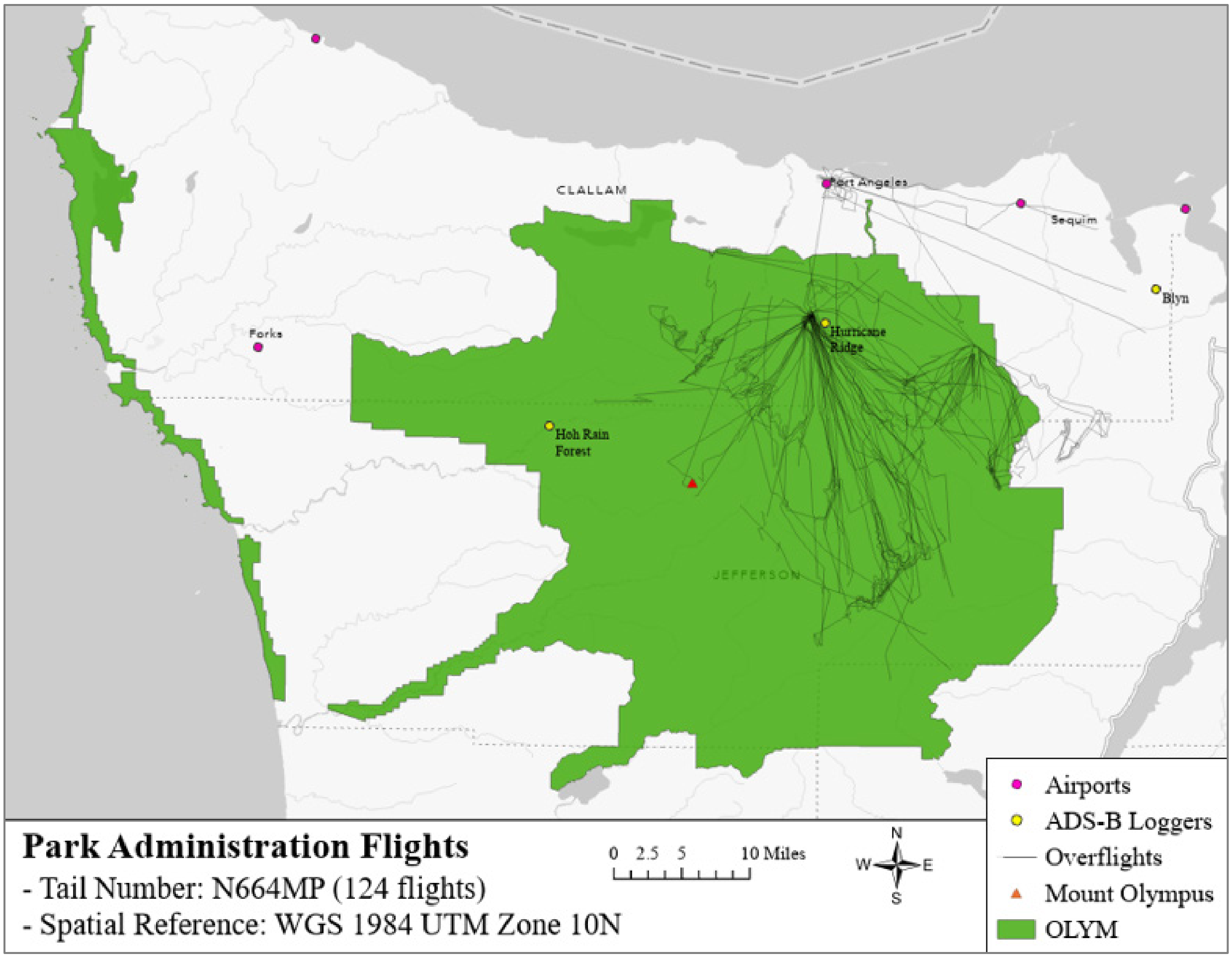

Figure 23. Flights by N664MP, an aircraft sometimes contracted for park administration flights.

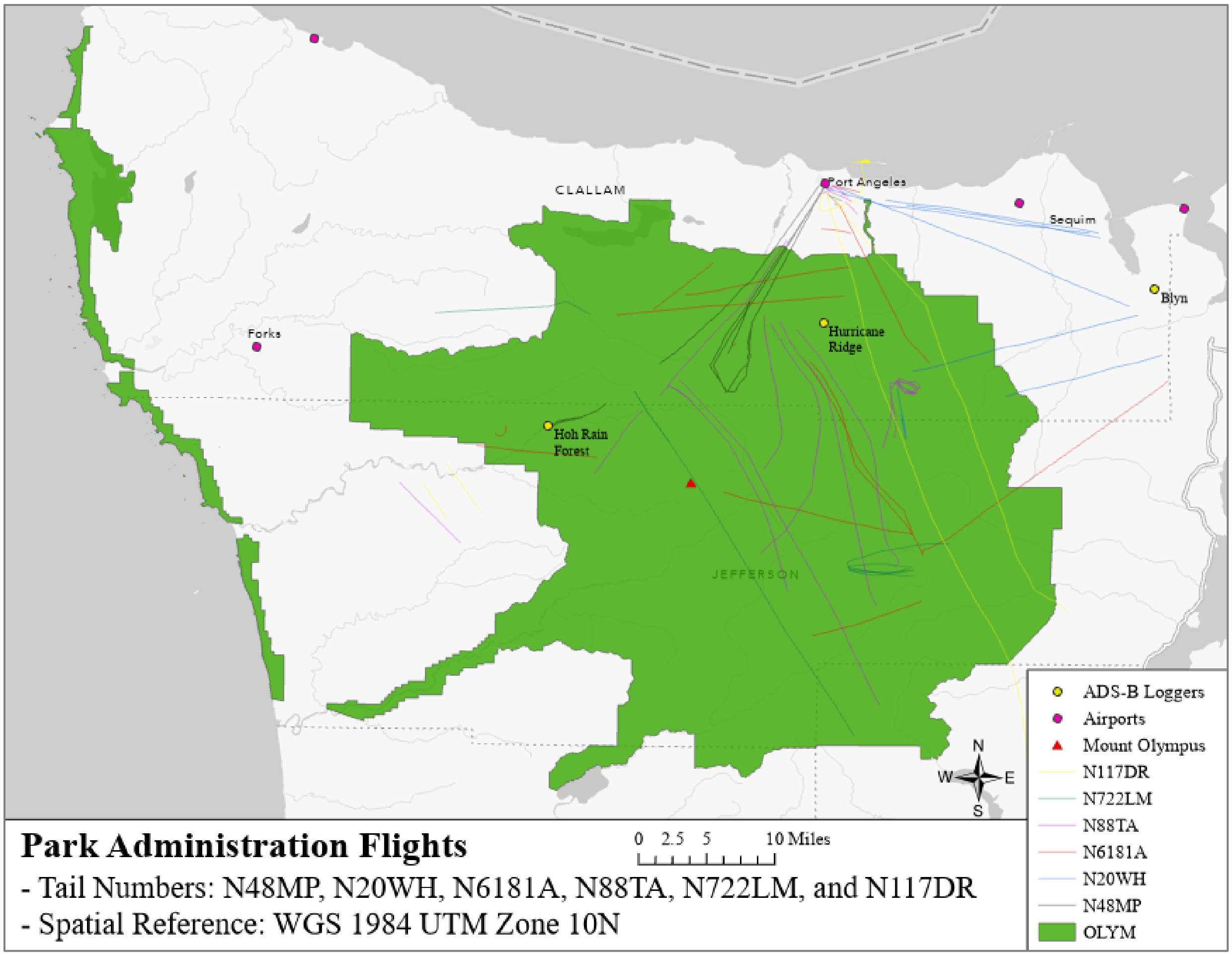

Figure 24. Other aircraft sometimes used for park administration flights.

Olympic MOA covers the western part of OLYM (Figure 25). NASWI lies to the northeast of OLYM. Growlers are fixed wing multi engine aircraft equipped with turbofan engines. The following procedures were used to clean all flights known not to be potential Growlers. First, 1,216 overflights were selected that intersected with the MOA polygon and represented all altitude ranges, including the altitude range for Olympic MOA airspace. The altitude range for Olympic MOA airspace begins at 6,000 ft MSL and goes up to an upper limit of, but not including, 18,000 ft MSL (Northwest Training and Testing, 2020). All aircraft were removed from this dataset that were not multi engine equipped with turbofan engines. As a result, the cleaned dataset contained 587 overflights (Figure 25). However, only 87 overflights contained the details of the aircraft, whereas 500 overflights showed “null” values for N-Number, Type Aircraft, Type Engine, Type Registrant, Name, MFR Model Code, and Model. This information is shared because it is possible military aircraft fly using “anonymous” mode in which their metadata is not shared. No discernable patterns are recognizable.

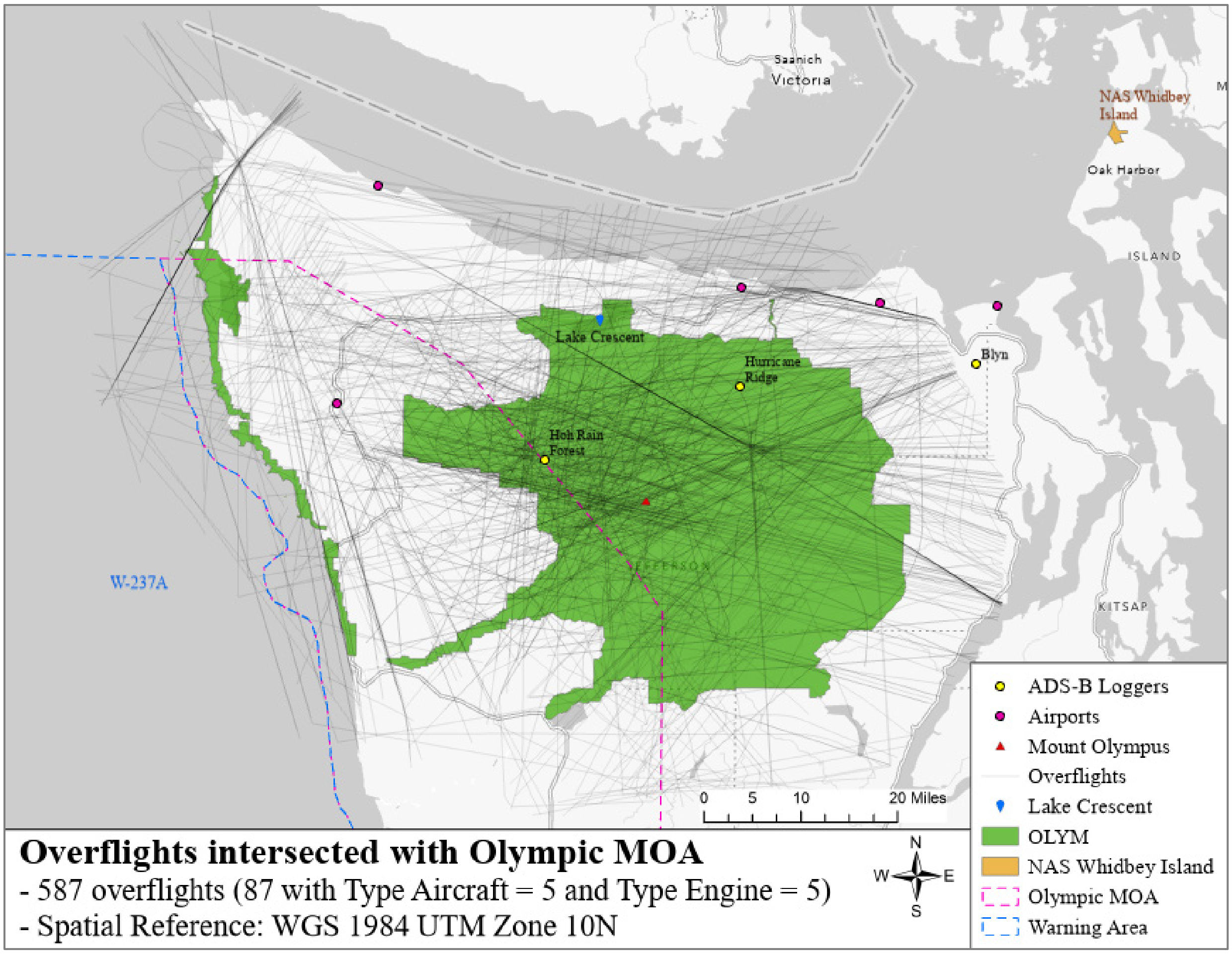

Figure 25. Selected overflights in Olympic MOA.

The FAA and US Navy proposed a new route of entry and exit into Olympic MOA through the northern part of OLYM (Figure 26). The purple line indicates the route from NASWI to the MOA, whereas the blue line indicates the route from the MOA to NASWI. The black dashed polygon shows the Air Traffic Expose Area which includes the Lake Crescent area. A typical military flight route from NASWI to the MOA and back to NASWI is also shown. All overflights were selected that intersected with the Olympic MOA polygon without screening them by engine type and aircraft type. Some of these overflights showed a similar pattern as that of military aircraft routes but a detailed spatial analysis of each overflight was not conducted.

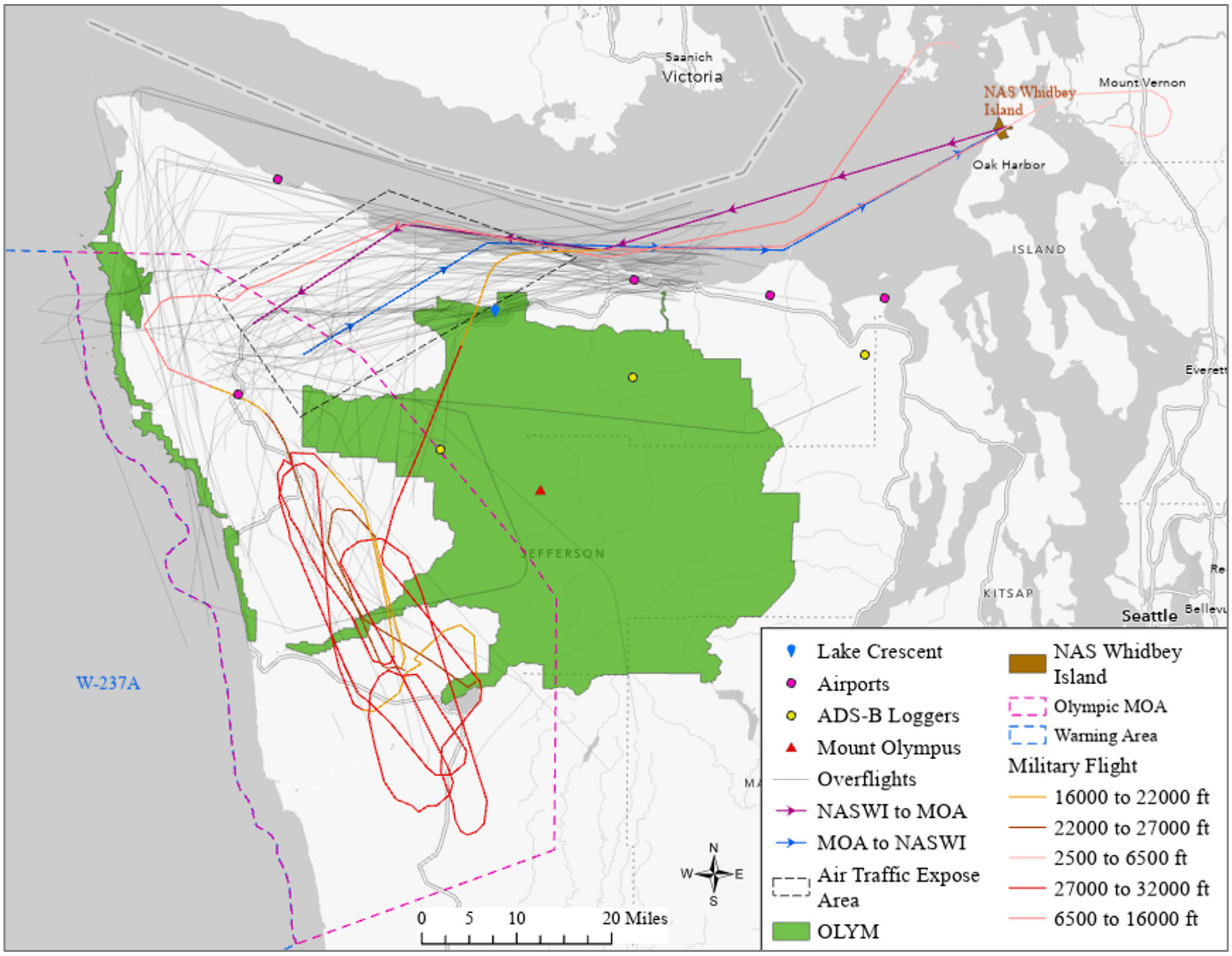

Figure 26. Proposed route and a typical military flight.

Discussion

The purpose of this study was to explore the spatial and temporal patterns of overflights over OLYM by analyzing ADS-B data recorded from July 27th, 2021 to January 3rd, 2023, with a total of 525 days of data collection by the dataloggers. ADS-B dataloggers were deployed at three locations: Blyn (1,946 ft MSL), Hurricane Ridge (5,259 ft MSL), and Hoh Rain Forest (591 ft MSL). The analysis consisted of 60,622 overflights that were analyzed across three phases.

The first phase focused on all overflights that flew within 10 miles of the park boundary. Overflights were concentrated on the north and east sides of the park (Figure 2). William R. Fairchild International Airport is located to the north of OLYM near Port Angeles, which resulted in many aircraft flying over this area. Overflights along the east side of the park were common because of the densely populated Seattle area and the nearby Seattle-Tacoma International Airport. Furthermore, a flight corridor that extends northwest to southeast over OLYM had concentrated flights. This flight corridor is likely used by commercial aircraft traveling from and/or to Seattle-Tacoma International Airport. The western part of OLYM received less concentrated overflights, which showed no consistent patterns.

The second phase focused on low-level overflights. All waypoints below 10,500 ft MSL and within 10 miles of the OLYM boundary were analyzed. Low-level overflights were concentrated near William R. Fairchild International Airport, which suggests these flights were landing and/or taking off from the airport. Also, a loop pattern was detected around Mount Olympus, which is a common flight pattern for air tours (Figures 3, 4, 5 and 6). A comparison of these figures also suggests that summer aircraft traffic is heavier than winter traffic.

The third phase also focused on the low-level overflights, but within the 0.5-mile boundary of the park and below 2,500 ft AGL. Low-level overflights are recommended by the FAA to fly no lower than 2,000 ft AGL when over parks and wilderness areas. These flights likely have greater potential to impact the acoustic environment. This resulted in 23,925 low-level overflights (Figure 7) which was 39.5% of the total overflights (60,622) recorded during that time. The waypoints are highly concentrated on the eastern side of the park and north of the park near Port Angeles. This is evident in the point density maps (Figure 8 and Figure 9). A diagonal flight corridor from northwest to southeast, with concentrated low flights on the southeast end of the route over OLYM, is distinct on the map. A small density patch was observed near Hurricane Ridge suggesting the concentration of low-level overflights near that geographic point (Figure 8). Similarly, kernel density analysis showed density hot spots near Port Angeles and on the diagonal flight corridor (Figure 9). On map E of Figure 9, it is interesting to observe gaps in the pattern of waypoints around the kernel density hot spots. This could be the effect of topography and terrain shielding of the ADS-B signals for that altitude (2,001–2,500 ft AGL).

Phase 3 analysis also showed that July is the month that received the highest number of low-level overflights, followed by August or September (Table 4). This suggests that overflights are more frequent in the summer months. An acoustic study in the park that analyzed audibility at many sites across the park over many seasons confirms that audibility of aircraft is higher in the summer months than winter based on the two seasons of data collected (Pipkin, 2021). The data showed low-level overflights occurred throughout the hours from 6 am to midnight, with the greatest percentage of flights during the hours between 11:00 am and 3:00 pm (Table 6).

Similarly, fixed wing single engine aircrafts showed loop patterns around Mount Olympus, likely suggesting air tours (Figure 14). A point near Hurricane Ridge can be seen from where the flightlines were radially dispersing, so this suggested a take-off or landing point for rotorcraft at that spot (Figure 16).

The OLYM ATMP requires the air tour operator to fly no lower than 2,000 ft–3,000 ft AGL depending on location. However, the effective date of the ATMP was approximately 90 days after signature and was signed on July 19, 2022—making the effective date approximately October 17, 2022. Data analyzed in this report ended January 3, 2023, making very little overlap between the data collection period and the ATMP. Therefore, this report should not be used as a compliance check for the OLYM ATMP. Figures 17 to 20 show the aircraft travel patterns of the only operator approved for air tours in the ATMP, and also display the approved route. The air tours by Rite Bros Aviation, Inc. generally follow this route but with very little precision. Figures 21 and 22 display the routes of air tour operators in the vicinity of OLYM that do not have approval to fly over the park. These figures suggest these operators are not conducting tours over the park.

Additionally, park administration flights were analyzed with N664MP (contracted from Leading Edge Aviation) having the highest number of overflights. These flights used a rotorcraft and flew around the park from the point near Hurricane Ridge (Figure 23). These overflights are also evident in Figure 16 of rotorcraft flight patterns.

A large number of overflights intersect the Olympic MOA. However, many of these overflights had “null” values for their metadata retrieved from the FAA Releasable Database. Only 87 of them included metadata. It is possible that military aircraft are flying in an anonymous mode so that they intentionally can’t be identified. However, no similar flight patterns emerged. Military aircraft frequently fly between NASWI and the MOA, flying along the northern boundary of OLYM. The proposed departure route from NASWI to the MOA, and arrival route from the MOA to NASWI, are shown, and the exposed area to air traffic is also shown which covers a part around Lake Crescent (Figure 26). These flights likely have an impact on the acoustic environment including the areas around the Hoh Rain Forest, the coastal unit, and Lake Crescent. However, noises from vehicles and watercraft were also commonly heard along with aircraft noise depending on the proximity to the road or navigable water (Pipkin, 2021). Aircraft noise was more frequent at Hurricane Ridge than at other sound level monitoring sites (Pipkin, 2021).

This study’s results can be used to further understand overflights at OLYM and the approximate locations that are likely most impacted by aircraft noise. Also, this information can be used in the planning and management of parks to assist with conserving natural soundscapes and conserving the experience of terrestrial visitors. Future research should use more advanced analytics to drive data-driven decision-making to gain a more robust understanding of low-level overflights at OLYM.

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