UNMANNED AERIAL SYSTEMS – OPERATIONAL ASPECTS FOR COLONIAL BREEDING WATERBIRD SPECIES MONITORING

Iulian NICHERSU, Danube Delta National Institute Tulcea, iuli@ddni.ro
Tamiris POGAN, Aerocontrol UAV, tpogan@gmail.com
Mihai BURLACU, Aerocontrol UAV, misuburlacu@gmail.com
Cristian MATICA, Aerocontrol UAV, acitam1@yahoo.com
Cristian TRIFANOV, Danube Delta National Institute Tulcea, kris@ddni.ro
Marian MIERLA, Danube Delta National Institute Tulcea, mmierla@ddni.ro

***Abstract**: The UAS-BIRDD project takes up an interdisciplinary approach to identify, evaluate, design, experimentally test and determine the necessary aspects to define and demonstrate a full cycle functional model and dynamic information support system for wildlife management and environmental research. The primary aims of this study are to determine the location and size (number of breeding pairs) of the main colonies of 15 species of Pelecaniformes, Ciconiiformes and Charadriiformes of communitarian interest from Danube Delta Biosphere using UAV surveys as a non-invasive investigation method and to integrate this data into a GIS-based database in order to analyze the information in relation to habitat features (elevation, vegetation cover, water level).*

***Keywords**: UAV, survey, monitoring model, colonial breeding waterbirds.*

1. Introduction

Conventional ground-based field surveys in the Danube Delta are done from small motorboats that allow entering many of the colony sites in order to localize them (by GPS measurements) and make assessments on bird attendance, species composition, nest numbers and physical characteristics such as vegetation and water depth. During dry years, when the water table is lower, many colonies are out of reach from the ground, in these cases the quantitative and qualitative data being poor. Since most of the terrain of the Danube Delta consists of almost impenetrable dense and extensive reed beds, hardly if at all interspersed by water or other vegetation types, comprehensive ground surveys are practically impossible. Moreover, due to the large size of the Danube Delta, it is logistically impractical to cover the entire area by ground surveys within any single breeding season.

Unmanned aerial vehicles (UAVs) are becoming increasingly employed in applications where conventional large format photogrammetry turns unproductive. Their usage is enabled by transformative high technology that can perform feature rich, cost-effective and time efficient applications for environment, such as wildlife management, wildfire command and control, farming and land use management. By using mini-UAV systems as non-intrusive aerial survey tools adapted to environmental requirements and restrictions that strictly apply in the special natural ecosystem of the Danube Delta Biosphere Reserve, the project provides a valuable visual remote reach to areas forbidden for human access to the environmental researchers of Danube Delta.

In order to attain the goals of the project, existing unmanned aerial systems were redesigned and developed, enabling them for environmental research. Modifications and changes in the platform design and workflow were performed in order to attain: less operational noise and improved visual aspect (very low noise, almost imperceptible, as well as camouflage, dissimulation), specific navigation procedures that allow setting up an efficient task scheduling model, production and use of a local electronic terrain obstacle database in order to improve flight safety and mission planning procedures, additional algorithms for better environmental survey (automatic change detection and classification, birds counting, etc.).

Multiple sensors were used aboard the UAV systems, including lightweight gyro-compensated gimbals (two- or three-axis) for electro-optical and infrared cameras stabilization. Newly-developed communication data links were used for telemetry and live data, assuring interoperability among all aerial platforms used in the project. As most of the field research required operations in the vicinity of virtually un-touched and isolated areas, real time data links turned out to be important factors to the project's efficiency.

2. General UAV Surveying Workflow

2.1 Mission planning

Flight plans are essentially maps depicting the location of each photographic exposure and the flight lines upon which aerial photography is to be obtained. Efficient flight planning amounts to the best balance between safety, accuracy and economy. Flight planning software such as *APM Mission Planner* facilitates designing flight plans using various maps as background, by allowing the setting of various parameters as in the case of conventional manned airborne flights and computing the camera control parameters automatically.

Ahead of each aerial photography mission, camera calibration is mandatory. Different software applications perform different procedures for the purpose of generating a camera calibration file containing the internal orientation parameters: principal distance (calibrated focal length), principal point offset and lens distortion function coefficients. Applying these parameters to the acquired images produces a metric (corrected) image.

In order to increase the accuracy of the data and assure the conversion to the national coordinate systems, a network of ground control points must be designed and materialized prior to the image acquisition flight. The ground control points can be pre-marked using custom-designed targets to allow automatic identification during processing.

2.2 Data acquisition

Accurate georeferencing of the final products requires an accurate determination of the image positions. The most effective way of assuring that is by using survey-level GNSS receivers aboard the UAV system, but this is not always possible. Accurate ground control points may improve the absolute geolocation accuracy, but what's most important is the relative geolocation of the images, that's essential for accurate image reconstruction during the aerial triangulation processing step. This is usually succeeded by using gyro-compensated gimbals to assure the nadiral orientation of the optical axis and by planning and attaining appropriate image overlapping.

Once the ground control points are marked, the topographic survey (generally by using GNSS surveying methods) is carried out. Furthermore, if absolute geolocation turns out to be an important issue, stable features on the ground may be taken into account as ground control points and surveyed subsequently to the flight.

All of the unmanned aerial systems tested and used in this project are capable of flying autonomously. The flight plan is usually uploaded to the autopilot unit onboard the UAV platform prior to the flight, while takeoff and landing procedures may be performed manually or automatically.

For close range observations and short range flights, a VTOL (vertical takeoff and landing) small helicopter and several multicopters were tested, while for large area surveys fixed wing aircrafts turned out to be the appropriate solution.

2.3 Gathering and processing the data

As soon as each flight is over, the data is immediately downloaded and backed up on a portable storage device. The preliminary georeferencing of the images may be performed using the data recorded in the flight log by the autopilot unit or the data output from secondary GPS receivers. A quick flight quality assessment is usually carried out in the field to confirm whether the designated area was fully covered by images and the resulting overlap is adequate for processing the data, or additional flights are in order.

Back in the office, the following data is gathered and converted to the file formats required by the photogrammetric software being used, in this case *Pix4Dmapper*:

- The camera calibration file;
- The georeferenced images, their position being stored as metadata (in the JPEG EXIF);
- The ground control points coordinates table.

After the data is imported, the first step is marking each ground control point on as many images as possible.

The photogrammetric workflow for image-based modelling is carried out further. Processing the data is split into three main phases: *Initial Processing*, *Point Cloud Densification* and *DSM and Orthomosaic Generation*, as labelled in the application window.

Initial processing begins with the automatic keypoint extraction and matching (between images), followed by the bundle block adjustment (the optimization of the external and internal parameters). The point cloud consisting of the automatic tie points resulted from the initial processing is improved in the second phase of the processing, the point cloud densification. The user must select several options: the output datum and coordinate system, the image scale at which the image features are computed, the density of the point cloud, etc.

In the third processing phase the raster and grid digital surface models (DSM) are generated after the user inputs the GSD of the final products, the images are orthorectified and the resulting orthomosaic is automatically generated. However, further editing of the mosaic has always turned out to be required, in order to adjust the seamlines so as to remove moving objects and enhance the overall aspect.

Certain problems arise in the Danube Delta due to the vegetation that causes the image structure (texture) to be highly repetitive. Accurate geolocation is required for processing such image blocks.

3. Results and Discussion. Case study: the Roșca-Buhaiova Protected Area

This paper illustrates the results attained after several flight missions in the Danube Delta, particularly at the Roșca-Buhaiova Protected Area, in the local specific weather conditions.

3.1 Objective

The goal of the missions carried out in the summer of 2014 was basically getting the overall picture, by surveying and estimating the locations of the Pelicans at Roşca-Buhaiova lakes over the course of an entire season, identifying the juveniles and estimating the entire population of pelicans, as well as studying certain patterns in their behavior. Through photogrammetric methods, the area was mapped, using software such as *Pix4Dmapper* for fusing and processing the data from different flight missions.

The work started from limited, reduced practical experience in such an area of expertise, growing into a rush of *going there* and *getting them* all while development was still in progress in respect of the planned steps for building a prototype UAV ready for action, proper for the environmental monitoring job.

3.2 Requirements

Taking into account the local specific (mostly tough) weather conditions, several requirements for aircraft and operations were analyzed:

- *Rain resistance*: the problems identified were not only related to the high temperatures, but also to the high humidity, as rain was a common phenomenon during the flight missions this year;
- *High wind speeds*: the UAV platforms must be able not only to fly in these conditions, but to be fully operational (output useful data) in winds at over 10 m/s, with peaks at 20 m/s (tests were carried out at up to 30 m/s);
- *Hand launch*: this has proven to be an important requirement, as fixed-wing UAV systems above 5 kg MTOW (maximum takeoff weight) require special logistics, such as catapults;

Fig. 1. Hand launched UAV heading for takeoff

- *Belly land*: required in order to avoid special logistics such as recovery nets; water landing capability is to be further investigated, as it might turn out useful in certain situations;
- *Endurance* was determined to be optimal above 30 minutes, since the areas of study are usually at over 10 km from the ground control station (the takeoff-landing site), since appropriate land strips (accessible by boat only) cannot generally be found closer to the protected area;
- *Operational Safety*; in order to attain the safety requirements, construction materials with low kinetic energy at impact are to be used, but resistant enough for flying in bad weather (strong winds, etc.);
- *Stability* in flight and *smooth maneuvering*: these had always turned out to be extremely important for usable outputs from the electro-optical payload, as no camera stabilization/gimbals were used on fixed-wing UAVs at this stage of project, given the extra space the center fuselage section would require for bi- or three-axis camera stabilization mechanisms.

3.3 Flight missions

As stated above, the appropriate locations (meaning some stable ground and accessibility by boat) for takeoff and landing were situated at over 10 km from the area of study. Samples of the flight tracks from two different missions are presented in Figure 2, most of the flight missions being similar or even longer.

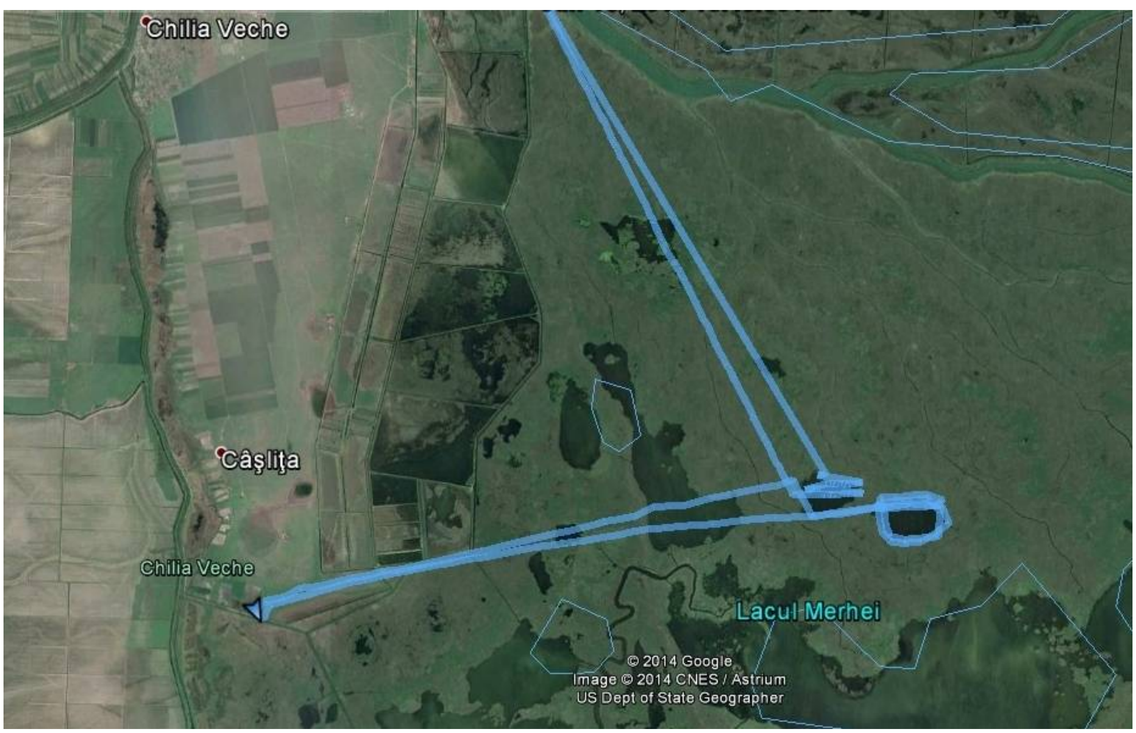

Fig. 2. Sample flight tracks

After several flights, the following conclusions were drawn upon the weather conditions at the Roşca-Buhaiova Protected Area:

- No wind reported only 3 days out of 120; the likelihood of coming across calm days while in the field was minimum;
- Usual wind at 6-8 m/s, at 60 to 100 m above ground (AGL), the wind was always at or above 10 m/s (as reported by the UAV sensors), while above 150 m AGL it usually ranged from 12 m/s to 14 m/s;
- Wind shears up to 18-20 m/s were experienced throughout most of the flight missions;
- Very fast wind direction changes, that affect the mission profile and waypoint navigation accuracy (resulting in missing the waypoints and the planned flight lines);
- Few areas with lot of thermal inversion, convection and mechanical atmospheric turbulences, wind shear being a permanent phenomenon around these areas.

3.4 Sensors used

At this stage, testing was focused on small electro-optical cameras, focusing on several technical specifications.

The optimal camera must have the largest sensor in the smallest body, this being the case of small mirrorless cameras. The lens' focal length must provide a wide field of view, while keeping distortions to a minimum, thus fisheye lens were not considered. An important factor is the weight, but also the size of the camera body, in order to fit on small aircraft. Battery power was not a main issue, as most mirrorless cameras are capable of shooting over 500 pictures per charge (enough for one flight mission). However, for photogrammetric image acquisition, several technical details that are not usually reflected in the producer's specifications are usually important, the minimum shooting interval being one of them. High flying speeds require a short waiting time between consecutive images. While the producers list the burst rate of the camera, in most cases it is not constant throughout the flight. This results in poor frontal overlap if the flying speed of the UAV is not adjusted accordingly. Another important aspect for UAV photogrammetry is the remote control capability of the camera. While some cameras allow the integration with the autopilot unit, others require external intervalometers to do the triggering.

3.5 UAVs tested

During these flight missions several aircrafts and configurations were tested.

The multicopters (in various configurations: quad, X6, X8) turned out to be very good in terms of payload stabilization and maximum weight, but not suitable for these specific missions, as endurance is much lower than that of fixed-wing UAVs. Further development opportunities in this matter include designing and setting up a long endurance waterproof version.

A helicopter was also tested, its maneuverability being the main advantage. However, it turned out to be too large and too noisy in a configuration suitable for the current mission requirements.

Several fixed-wing UAVs were tested, including a classic wing (2 m wingspan) that turned out to be stable in flight, but too slow for rapid cruise to the operations area (over 10 km away from launch site). A delta wing in two different configurations, 1.7 m and 2 m wingspan, 3.5 to 5 kg MTOW, was the most successful for the flight missions, as it answered to a mix of conflicting requirements, such as the low speed needed for loitering in the study area and fast speed for the fast cruise to the study area.

3.6 Products

Taking into consideration the remoteness of the studied lakes, it is obvious that ground control points for georeferencing the data were not used at this stage of the project. Since survey-grade GNSS receivers for small-UAV systems were still under development, the image geolocation was performed with meter-level accuracy.

However, the raw images taken during the flights provided valuable data for analyzing the Pelican colony, as seen in the image sample. Figure 3 (right) depicts a white-tailed eagle (*Haliaeetus albicilla*) overflying the Pelican colony.

Fig. 3. Raw image sample (left); Raw image detail (right)

Furthermore, the raw image stitches that were easily generated (at a ground sampling distance around 2 cm/pixel) also proved to be of great use to the researchers (Figure 4).

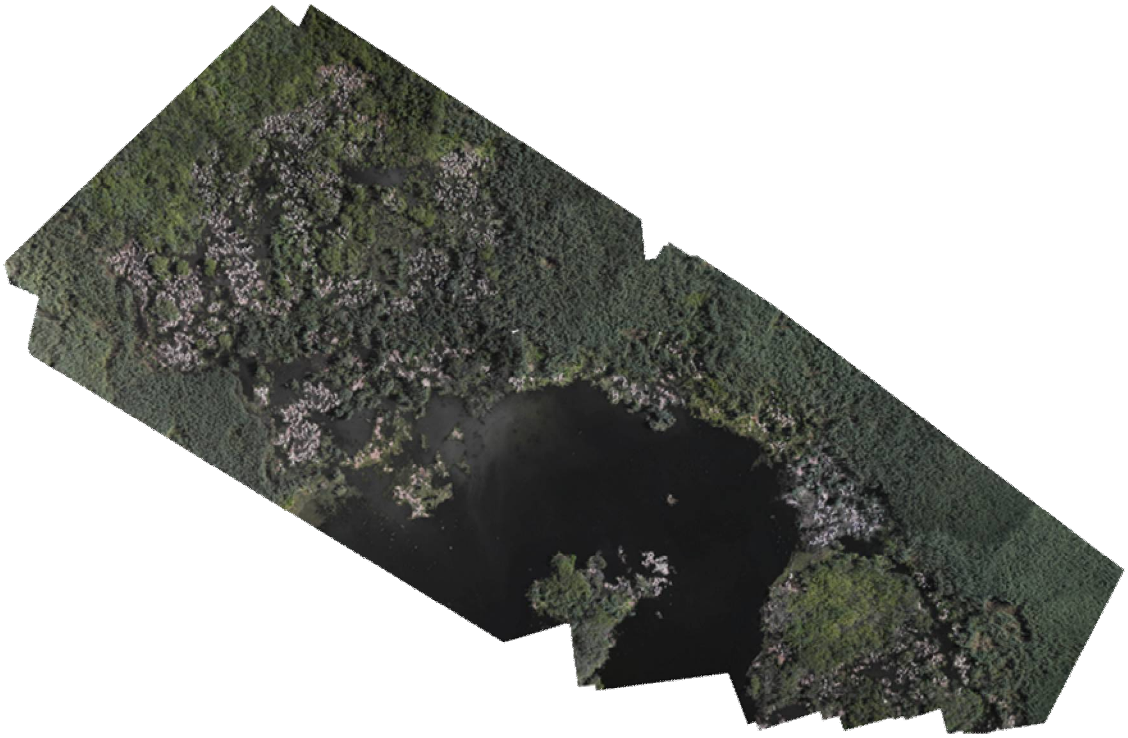

Fig. 4. Raw image stitching sample

High resolution images of the Pelican nursery at Ro□ca-Buhaiova lakes were also captured (depicted in Figure 5).

Fig. 5. Pelican nursery

Photogrammetric processing of the data was performed using the *Pix4Dmapper* software. Its *Alternative Processing Mode* provides special algorithms for processing images with low structure of dense vegetation areas; however, due to the fact that most of the images were from un-stabilized flights (no gimbal was used on the smaller fixed-wing UAVs, as mentioned above), the Digital Terrain Model and orthomosaic were generated only for small, fragmented portions of the study area with low accuracy.

4. Future development

As the experience in the field accumulates, adjustments in the development process are being made in order to fulfill the more and more demanding mission requirements.

Several adjustments have already been made to the UAV platforms in order to increase their stability and endurance, several configurations have yet to be tested in the field, while features such as water landing are have currently undergone into development.

As fixed-wing UAVs proved to be the most useful solution for the specific mission requirements in the Danube Delta, several prototypes are currently under development, such as a center fuselage that integrates a three-axis gyro-compensated gimbal head and a long endurance catapult launch fixed-wing UAV (Figure 7).

Solutions regarding accurate geolocation are also under development. Various GNSS receivers and inertial navigation systems are to be tested along with more efficient gyro-compensated gimbals for better stabilization of the electro-optical payload. One low-cost GNSS receiver currently under development for integration with the *Pixhawk* autopilot system is the *Swift Navigation Piksi*. By using carrier phase RTK measurements, centimeter-level relative positioning becomes available even for small-UAVs.

Fig. 7. Catapult launched fixed-wing UAV

During the following flight missions the latest electro-optical cameras are to be tested in order to determine the most efficient mapping solution in terms of ground sampling distance and productivity. These cameras are to be mounted and tested in various geometrical configurations (oblique, or nadiral and oblique combinations), in order to improve the automatic aerial triangulation process for dense vegetation areas and provide an efficient method for corridor mapping and moving targets extraction. For these purposes, an octocopter is also currently under development (Figure 8).

Fig. 8. Octocopter

As the involvement in community development in the field of unmanned aerial systems is growing and new technical solutions emerge, several of the difficulties encountered so far are expected to be overcome in the following period.

5. Summary

The information obtained facilitates the study of the colonies of Pelecaniformes, Ciconiiformes and Charadriiformes from Danube Delta Biosphere Reserve and offers a first strong base to evaluate and predict the evolution in time and space of the colonies. The data that will be further gathered will enable the researchers to quantify the rate of growth and loss for each colony, furthermore enabling the evaluation of the available surface of favorable habitats around every colony.

The project will produce a precise and comprehensive assessment of the colonial waterbirds from ROSPA0031 Danube Delta and Razim-Sinoie Complex that overlap the Danube Delta Biosphere Reserve, which will be a strong base for the regular progress reports that our country has the obligation of delivering to the European Committee for Natura 2000 Directive.

6. References

1. *UAS inovative survey and monitoring model for colonially breeding waterbird species from Danube Delta Biosphere Reserve, Funding Application for Joint Applied Research Projects PN-II-PT-PCCA-2011-3;*
2. *Eisenbeiss, H. – UAV Photogrammetry, Institut für Geodäsie und Photogrammetrie, Zurich, 2009;*
3. *Pix4Dmapper software manual. Source: http://support.pix4d.com.*

Acknowledgements

This work was supported by a grant of the Romanian National Authority for Scientific Research, CNDI – UEFISCDI, project number 70.