ISSN 1062-3590, Biology Bulletin, 2021, Vol. 48, No. 7, pp. 243–249. © Pleiades Publishing, Inc., 2021.
Russian Text © The Author(s), 2020, published in Zoologicheskii Zhurnal, 2020, Vol. 99, No. 2, pp. 215–222.

A Method for Counting and Identifying the Linear Sizes of Caspian Seals (*Pusa Caspica*) on Rookeries Using Multicopters

M. T. Baimukanov[a], *, L. A. Zhdanko[a], T. T. Baimukanov[a], E. S. Dauynev[a], S. E. Ryskulov[a], and A. M. Baimukanova[a]

[a] *Institute of Hydrobiology and Ecology, Irgely, 040916 Kazakhstan*

**e-mail: institute_he@ihe.kz*

Received December 19, 2018; revised May 26, 2019; accepted May 26, 2019

Abstract—A method is developed for processing pictures taken from multicopters in order to identify the number of Caspian seals and their linear sizes on rookeries. A special protocol records the location (coordinates), date, time, survey altitude, the cloudiness across a scale ranging from one to ten, air temperature, wind speed, and picture numbering. A photo software editor (for example, Adobe Photoshop CS5) is used for counting the individuals and taking their measurements. Each seal image is allotted an individual serial number within one picture. By flying over and photographing a rookery at different times of the day, quadcopters allow for an assessment of the daily dynamics of the seal numbers to be made. In cases when the groups under assessment are numerous, counts are recommended to be performed along transects. Knowing the angle of the field of vision (FOV) of the multicopter and the altitude it operates at, the following formula can be applied, "A cathetus lying opposite the angle equals the product of the second cathetus multiplied by the tangent angle," to calculate the distance between the extreme points of a picture's diagonal in the International System of Units (m, cm, or mm) (SI). As the resolution in pixels is also known, calculating the size of a pixel in SI can be performed per picture. The measurements of individual seal images in the pictures are converted from pixels into SI units. As a result, the length and the maximum width of the seals can be established, this being of importance for identifying the size structure of the seal concentrations on rookeries. Subsequently, having compiled a size–age key, the age structure of the groups of seals on rookeries can be calculated.

Keywords: *Pusa caspica*, accounting, rookery, photograph, pixels, International System of Units (SI)

DOI: 10.1134/S1062359021070062

In order to determine the species and count the number of animals, unmanned aerial vehicles are increasingly being used (Belikov et al., 2018).

This paper describes a method for processing photographs taken from multicopters to determine the number and linear dimensions of overlying Caspian seals. The studies were carried out during 2015–2017 on rookeries in the Kazakh zone of the Caspian Sea, and the quadrocopters used were Phantom Professional 3 and Phantom Professional 4. The above drones are on sale, have a relatively low cost, and small dimensions with a weight up to 1.5 kg. For the technical specifications, refer to the respective manuals (Phantom Quick Start Guide, Phantom 4 Pro Quick Start Guide). Quadrocopters have a short flight range, up to 2–3 km in one direction. The recommended temperature range is from 0 to 40°C, which allows one to use these drones in all seasons of the year except winter. It is not recommended to fly at wind speeds above 10 m/s. Before each flight, researchers must measure the wind speed with an anemometer, while experience shows that the wind speed at a height of 2 m should not exceed 6–7 m/s. During rain or in conditions where the probability of their falling is high, flights should not be performed.

Due to these restrictions, researchers drove up to the supposed places of accumulation of seals and launched a quadcopter for search work. These exploration flights took place at an altitude of 35–40 m and a speed of 10 m/s with the video camera included and the ability to view video images on the display of the control panel. The indicated speed at a sufficiently low altitude makes it possible to see the seals from a certain place without frightening them. With such flight parameters, dead seals can also be taken into account.

When a rookery is found, research flights are carried out, and the drone can be directed to the place of accumulation of animals at an altitude of 100–130 m or higher with a maximum speed of up to 15–20 m/s. To reduce the disturbance factor from the noise of the propellers, the approach to the clusters is made from the leeward side (Fig. 1).

The drone is mounted above the cluster, and the camera lens is directed as far down as possible (–90°). The shooting mode is set for photographing, and then a decrease is made with photographing every 10 m.

Fig. 1. Caspian seal rookery on an island in Kendirli Bay (groups of seals are marked with circles).

When the drone descends below 40 m, the seals begin to react strongly to the noise from the propellers, so it is not recommended to go below this height. To even out the possible blurring of the images, three photographs are taken each, while the operator's assistant records the height of the shooting and the number of each frame, or the height is determined by viewing the metadata of the photograph using the ExifTool program.

If the operator notices that the seals are anxious and begin to exit the rookery into the water, he must stop the descent and, having taken pictures from the height at which the drone is located, raise it higher and return to the take-off point. When calculating the total number of individuals in the rookery, the researcher must also take into account those single individuals that were filmed at a higher altitude, including those that were currently in the water.

A special protocol is being developed, through which the place (coordinates), date, time and height of filming, cloudiness on a 10-point scale, air temperature, wind speed, and numbers of the frames captured are entered.

Flights to study the daily dynamics of the number of seals in the rookery are carried out according to the schedule three times a day: morning (at 07:00), noon (at 12:00–14:00), evening (at 18:00–20:00), but the time of each takeoff is adjusted taking into account weather conditions and sufficient light for morning and evening photography.

After taking pictures at a certain height, the operator raises the drone to a height of at least 100 m and makes a return flight, or, when he is near another group, he approaches it and takes pictures according to a similar scheme.

In the course of this work, the frames with clearer images of seals are selected. In office conditions, the number is counted and the length and width of the bodies of seals are measured from the photographs.

The selection of photographic materials is carried out according to the following criteria: the static position of the group of seals, the coverage of the whole group, and the clarity of the photograph. Counting of individuals and processing of the frames are carried out in a graphics editor (for example, Adobe Photoshop CS5). Within a given photograph, each seal image is assigned an individual serial number. The data on the number of seals of individual groups (Fig. 2), located close to each other, are then summarized to reflect the total number of animals in a given rookery. In this case, the serial numbers of seals belonging to different groups are numbered continuously.

In the case of assessing the number of numerous groupings, which include thousands of individuals, it is recommended to make a count by flying along transects and taking photographs at one selected height

Fig. 2. Numbering of seals in the photograph.

and after a certain flight interval. Flying and counting along transects will then make it possible to estimate the total number of animals in the rookery by extrapolating the density of lying animals calculated from photographs to the entire area of the rookery.

In order to assess the dynamics of the number of seals objectively, it is recommended to search for rookeries and counts covering the entire period of occurrence in the spring and autumn seasons. Counting the number of seals in rookeries to estimate the size of the population as a whole is relative. With detection and constant monitoring of the main rookeries over a number of years, it will be possible to identify trends in the population size (stable, increase, or decrease) and to assess the order of fluctuations in the number.

In the future, specialized tagging of animals will allow us to calculate the individual periods of stay of seals in rookeries. At the same time, it will be possible to make a more accurate assessment of the absolute size of the population and to compare and combine data obtained by aerial photography on the number of animals during the ice period. In addition, it will be possible to obtain information about the sex structure of the seal population.

Along with taking into account the number of the photographs obtained, it is possible to determine the size structure of seal accumulations.

Please note that, according to the technical characteristics set forth in the above-mentioned manuals, the vertical hovering accuracy (GPS Mode) of the Phantom 3 Professional is 0.8 m and that of the Phantom 4 Professional is 0.5 m. Therefore, with the specified error, we know the height at which photographs are taken, which is displayed on the drone control panel.

Also referring to the known FOV of the lens (for Phantom 3 Pro 94°, Phantom 4 Pro 84°), according to the formula "The leg opposite to the angle is equal to the product of the second leg and the tangent of the angle," the distance included in the photograph from a known height is calculated, or

$$b = a\tan\alpha,$$

where b is 1/2 the distance included in the photograph, diagonally (m, cm, or mm), a is the height from which the photograph is taken in the MCE, and α is 1/2 angle of field of view of the lens (for Phantom 3 Pro 47°, Phantom 4 Pro 42°).

The resolution of the photograph, expressed in pixels, is also a known quantity. For example, the highest resolution for a Phantom 3 Pro camera is 4000 × 3000 or 5000 pixels diagonally. Therefore, 1/2 of the diagonal distance included in the photo is 1/2 of 5000 or 2500 pixels. From here, the size of 1 pixel is calculated from a photograph at a certain height. The measure-

Table 1. Comparative data of measurements of two-meter boards based on photographs from a quadcopter Phantom 3 Pro from different heights

Height, m	Average, pixels	Error of mean, pixels	The coefficient of variation	Size of 1 pixel, cm	Reconstructed board length, cm	Measurement error,%
Board 1						
100	46.81	0.24	1.46	4.29	200.78	0.39
90	51.54	0.30	1.65	3.86	198.96	–0.52
80	58.67	0.17	0.82	3.43	201.35	0.67
70	67.22	0.10	0.42	3.00	201.84	0.92
60	78.61	0.29	1.06	2.57	202.32	1.16
50	95.43	0.32	0.96	2.14	204.67	2.33
40	119.88	0.50	1.17	1.72	205.69	2.84
Board 2						
100	47.14	0.12	0.70	4.29	202.22	1.11
90	52.16	0.30	1.61	3.86	201.38	0.69
80	59.40	0.20	0.93	3.43	203.83	1.91
70	67.62	0.13	0.56	3.00	203.05	1.53
60	79.01	0.34	1.21	2.57	203.34	1.67
50	96.87	0.35	1.02	2.14	207.76	3.88
40	121.28	0.62	1.45	1.72	208.09	4.05
Board 3						
100	47.4	0.20	1.19	4.29	203.17	1.59
90	53.0	0.26	1.41	3.86	204.61	2.31
80	60.0	0.19	0.91	3.43	205.88	2.94
70	67.9	0.15	0.64	3.00	204.00	2.00
60	79.8	0.17	0.59	2.57	205.33	2.66
50	97.4	0.31	0.90	2.14	208.85	4.42
40	122.7	0.69	1.59	1.72	210.61	5.31

ment data obtained for one pixel are given in Tables 1 and 2.

Having determined the size of one pixel, it is easy to measure the length or width (or another parameter) of the seal image using the pixel ruler of the Adobe Photoshop program and to find out the required parameter in SI units:

$$\text{Seal parameter in SI units} = \text{Seal parameter in pixels} \times \text{size of one pixel in SI units.}$$

In order to determine the measurement errors, the lengths of three two-meter boards were measured in photographs from different heights. These boards were positioned as follows: no. 1, directly under the drone camera (shooting axis); no. 2, parallel to no. 1 at a distance of 10 m; no. 3, at no. 2, but perpendicularly (Fig. 3). Three flights were made, in each of which photographs were taken every 10 m from a height of 100 to 40 m. The measurements of the boards from the photographs obtained were made by three operators independently of each other; thus, each board was measured nine times.

The measurement results and the main statistical parameters calculated using the Excel program are summarized in Tables 1 and 2. The formula for calculating the measurement errors is shown below:

$$\text{Measurement error (\%)} = (\text{reconstructed board length} - \text{true board length})/\text{true board length} \times 100.$$

Table 2. Comparative data of measurements of two-meter boards based on photographs from the Phantom 4 Pro quadcopter at different heights

Height, m	Average, pixels	Error of mean, pixels	Variation coefficient	Size of 1 pixel, cm	Reconstructed board length, cm	Measurement error, %
Board 1						
100	72.15	0.24	0.94	2.87	206.95	3.48
90	80.29	0.22	0.79	2.58	207.27	3.63
80	90.25	0.14	0.43	2.29	207.09	3.55
70	103.42	0.29	0.79	2.01	207.65	3.82
60	121.06	0.28	0.65	1.72	208.34	4.17
50	145.52	0.30	0.59	1.43	208.70	4.35
40	183.08	0.28	0.43	1.15	210.05	5.03
Board 2						
100	72.09	0.29	1.12	2.87	206.77	3.38
90	80.47	0.24	0.83	2.58	207.74	3.87
80	90.53	0.26	0.80	2.29	207.74	3.87
70	103.31	0.23	0.63	2.01	207.42	3.71
60	120.89	0.14	0.33	1.72	208.04	4.02
50	145.28	0.32	0.63	1.43	208.36	4.18
40	182.92	0.47	0.73	1.15	209.87	4.93
Board 3						
100	72.61	0.25	0.97	2.87	208.26	4.13
90	80.88	0.20	0.71	2.58	208.78	4.39
80	90.65	0.17	0.54	2.29	208.00	4.00
70	103.91	0.26	0.70	2.01	208.64	4.32
60	121.38	0.33	0.78	1.72	208.89	4.44
50	146.18	0.45	0.87	1.43	209.65	4.82
40	183.52	0.44	0.68	1.15	210.56	5.28

Fig. 3. Arrangement of boards (*1*–*3*) for experimental surveys from quadcopters.

Table 3. Categories of the location of seals in photos

Category	Location Description
1	Measurement of body length in a straight line and maximum width of a straight-lying individual
2	Measuring the length of the body of a curved individual “along the trajectory” and maximum width
3	Body length is not measurable
4	Maximum width not measurable

As is clear, the coefficients of variation of measurements have small values and do not exceed 2%. The measurement errors are also low. It was found that, for boards located at a distance from the survey axis, due to the optical aberration (Grammatin, 2002), the measurement errors are higher when calculating the restored length. Measurement errors increase with decreasing survey height. Obviously, this is due to an increase in the number of pixels when measuring boards at a lower height; therefore, there is an accumulation of errors from a larger number of pixels. Paradoxically, it seems that a similar phenomenon explains the higher measurement errors when shooting from the Phantom 4 Pro drone, which is characterized by a higher camera resolution compared to images obtained from the Phantom 3 Pro. At the same time, pairwise comparison of the average measurement data of different boards in pixels, taken at the same heights, according to the t-test can show a significant difference in photos with the Phantom 3 Pro when comparing boards 1 and 3 ($p<0.05$), while photos taken with the Phantom 4 Pro do not show a significant difference. However, the maximum difference between board length measurements with the Phantom 3 Pro is 6 cm (comparing the average measurements for boards 1 and 3 with 90 m) or about 3% of the true length of the board, and the minimum is 0.95 cm (comparing the average data measurements of boards 2 and 3 from 90 m) or 0.47% of the true length of the board.

It is worth noting that the seals in the photographs are located in different poses; therefore, a subdivision is made according to the suitability of images for measurements and symbols by category are accepted (Table 3).

Note that the total body length (L) was determined from the tip of the nose to the end of the hind flippers,

Fig. 4. Measurements of upright seals (category 1) lying on the belly (no. 289) and on the side (no. 288).

Fig. 5. Measurement of the curved body of a seal (no. 54) “along the trajectory” (category 2).

Table 4. Comparison of length measurements of seals of categories 1 and 2 of two operators (S and L)

Categories	1		2	
Operators	S	L	S	L
Min.–max.	58.83–72.24	59.77–72.09	52.18–82.14	52.35–80.93
Number of measurements	15	15	15	15
Average	65.69	65.33	67.24	67.28
Error of mean	1.02	1.09	1.86	1.85
Variation coefficient	5.82	6.25	10.33	10.30
t-test	0.40		0.49	

while the maximum body width (B) was determined mainly at the level of the middle of the body. Measurement of these two characteristics is important for finding correlations between them and, subsequently, for restoring the body length of animals belonging to category 3.

Category 1 seals may lie eithr on the stomach and on the side (Fig. 4).

The total body length of bent seals (category 2) can be measured along the trajectory, for example, as the sum of measurements of the head and neck length, body length, and back flippers. Their maximum body width is also measured (Fig. 5).

In the rookery, some individuals may overlap part of the body of others (categories 3 or 4), and may also be located in positions completely unsuitable for measurement. Such individuals belong to categories 3 and 4 at the same time (Fig. 6).

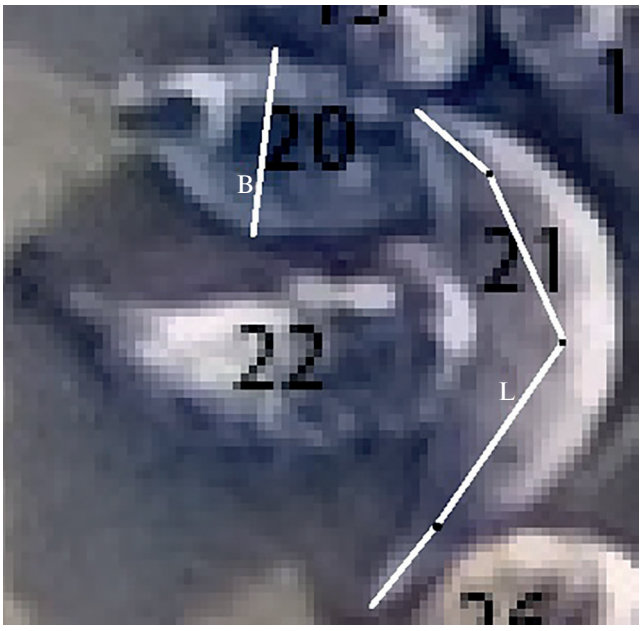

Fig. 6. Measurement of category 3 (no. 20) and category 4 (no. 21) seals and an example of an image of a seal (no. 22) not subject to measurement in categories 3 and 4 at the same time.

Comparative analysis of measurements of the body length of individuals of categories 1 and 2, carried out independently by two operators (Table 4), showed a lack of reliability of differences in the mean values of the trait.

Thus, the methodology developed for recording and measuring the linear dimensions of Caspian seals based on photographs from cameras of the Phantom Professional 3 and 4 quadrocopters makes it possible to count the number of seals and carry out their measurements with known errors. This technique can be used for studies of other pinnipeds (*Pinnipedia*) during the periods of their occurrence on land. The advantage of multicopters over other unmanned aerial vehicles is that they can stop and hover over the selected subject and provide high-quality photography. The choice of brands of multicopters depends on the tasks and the remoteness of the rookeries of pinnipeds. But to determine the linear dimensions of animals when calculating the pixel size in SI units, you can use this method.

ACKNOWLEDGMENTS

This work was carried out under a contract with the Kazakh Research Institute of Fisheries LLP within the framework of a state order of the Ministry of Agriculture of the Republic of Kazakhstan to estimate the number of Caspian seals on island rookeries in the Kazakh part of the Caspian Sea in 2015–2017.

REFERENCES

Belikov, R.A., Prasolova, E.A., Krasnova, V.V., Litovka, D.I., and Bel'kovich, V.M., Experience of using remotely piloted and tethered unmanned aerial vehicles for the study of the White Sea and Anadyr beluga whales, in *Morskie mlekopitayushchie Golarktiki. Sbornik nauchnykh trudov* (Marine Mammals of the Holarctic: Collection of Scientific Papers), Moscow, 2018, vol. 1, pp. 45–50.

Grammatin, A.P., *Metody sinteza opticheskikh sistem. Uchebnoe posobie* (Methods for the Synthesis of Optical Systems: Tutorial), St. Petersburg: St.-Peterburg. Gos. Inst. Tochnoi Mekhaniki i Optiki, 2002. Phantom Quick Start Guide. https://www.icover.ru/manuals/DJI_PHANTOM_RUS.pdf.

Phantom 4 Pro. Kratkoe rukovodstvo pol'zovatelya (Phantom 4 Pro Quick Start Guide).

SPELL: 1. OK