Using an unmanned aerial vehicle for environmental research and monitoring at Sea Lion Island

Project report - Update 2016/2017

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**Summary**

There is an increasing interest in the use of unmanned aerial vehicles (UAVs) for environmental research and monitoring. The widespread recreational use of UAVs is producing an exponential increase in their technical specifications, and a corresponding drop in their price. UAVs permit to acquire aerial imagery on demand and at a very low cost compared to alternatives (aerial surveys, satellite imagery). Even recreational UAV cameras can now produce high resolution pictures and high quality video footage. If combined with mission planning software and picture processing software, UAVs can carry out semi-automatic surveys, and final products like orthorectified images and digital terrain models can be obtained with a semi-automated software pipeline.

Having been involved in research of wildlife of Sea Lion Island in the past twenty years and more, we are interested in testing equipments and methodologies that can improve our capability to carry out not only our specific research projects but also general environmental monitoring of the island. Sea Lion Island is a National Nature Reserve, an Important Bird Area, an Important Plant Area, a RAMSAR convention site, and the premiere destination of nature oriented tourism in the Falkland Islands. Although some specific monitoring programmes are carried out at Sea Lion Island, including marine birds surveys by Falklands Conservation and research on elephant seals, killer whales and Falklands skua by the Elephant Seal Research Group, and although spot environmental surveys were carried out in the past, the island lacks an integrated environmental monitoring programme.

In 2016-2017 we made extensive trials to determine the effectiveness of a semi-professional UAV in helping our specific research projects and the general environmental monitoring of the island. In particular, we used the UAV for: 1) assessment of colonial marine birds nesting and breeding success; 2) monitoring of bird species that are particularly affected by human disturbance, and, therefore should not be surveyed directly; 3) counts of southern sea lions, that breed in an area that is difficult to access; 4) study of the spatial structure of elephant seal harems; 5) study of killer whale social behaviour and organization; 6) monitoring of landscape changes, in particular in the coastal and sand dune areas; 7) general mapping of the island; 8) assessment of management interventions.

All together, the results were very positive. Our main concern was the effect of UAV flights on wildlife. UAVs can produce a significant low frequency noise, can be attacked by territorial birds, and can adversely affect flying birds at large. We observed null to scarce reaction to the UAV from all the monitored species, and territorial birds (e.g., caracaras) showed a very scarce interest in the flying UAV, much below our own expectation. Our UAV proved very useful to reduce count disturbance in colonial marine birds, permitted us to count affectively the breeding southern sea lions, and produced a quantum leap in our understanding of orcas behaviour, in particular during predation events. With just a small number of flights we were to obtain a full imagery coverage of the Sea Lion Island coastline.

We hope to be able to fly our UAV in the future, if our research licence will be renewed. We plan to adopt mission planning software that will permit us to regularly carry out semi-automated surveys, and we are working on a picture post-processing pipeline that should streamline and simplify the production of results that can be useful both for our research projects and for the management of the island.
Introduction

In recent years there has been an increasing interest for the use of unmanned aerial vehicles (UAVs) for environmental monitoring and research. UAVs have the potential to produce a methodological revolution in spatial and landscape ecology (Anderson and Gaston 2013) and in wildlife biology (Chabot and Bird 2015; Christie et al. 2016), permitting the on-demand collection of accurate, high resolution imagery at a very low cost compared to alternatives (traditional aerial surveys, satellite imagery). UAVs are being used for general environmental monitoring (Gonzalez et al. 2016), vegetation mapping (Salami et al. 2014), and census of indicator species (Zmar et al. 2015).

The Elephant Seal Research Group (ESRG, www.eleseal.org) begun wildlife research at Sea Lion Island (Falkland Islands; SLI hereafter) back in 1995. For more than twenty years we carried out a long term research project on the behavioural ecology of southern elephant seals (*Mirounga leonina*), that have at SLI their main breeding colony of the Falklands. More recently (2013) we begun a study of killer whales (*Orcinus orca*), focusing on killer whale sociality and impact of killer whale predation of the demography of their potential preys (southern elephant seals, southern sea lions *Otaria byronia*, and various species of penguins). In 2014, we begun a study of the Falklands skua (*Catharacta antarctica antarctica*), to assess nesting and breeding success, and to study their vocal communication system. Moreover, we are monitoring nesting and breeding success of various bird species of the island, including various species of ducks and geese, king cormorants (*Leucocarbo albiventer*) and caracaras (*Phalcoboenus australis*), and we are carrying out regular counts of southern sea lions. All these research and monitoring activities can potentially be improved by using UAVs imagery.

UAVs have been shown to produce more accurate counts of colonial birds than human observers (Hodgson et al. 2016) and to reduce biases due to the different accessibility of different colonies of birds and seals (Pomeroy et al. 2015). Moreover, they have been shown to have a great potential in the monitoring of elusive species (Goebel et al. 2015), that are greatly affected by human distance and are difficult to be located and counted with traditional approaches. UAVs have been frequently used to carry out marine mammal surveys (Koski et al. 2009; Koski et al. 2010), and to study their demography (Koski et al. 2010), size and development (Durban et al. 2016), and behaviour (Fiori et al. 2017). UAVs have been also used in very creative manners to sample marine mammals at sea (Acevedo-Whitehouse et al. 2010).

Objectives

We tested the usability, advantages and negative impacts of UAVs for the following environmental monitoring tasks:

1) aerial surveys of marine bird breeding colonies to count nests, adults and chicks, with a specific focus on gentoo penguins, rockhopper penguins, and king cormorants
2) aerial survey of breeding colonies of species that are much affected by human disturbance, with specific focus on gull species
3) counts of southern sea lions in their breeding colony, that, due to the local topography, is very difficult to count accurately and safely
4) surveys of elephant seal harems, to assess UAV use in mapping of individual (marked) seals
5) observations from the air of killer whales, to study their sociality and predation behaviour
6) monitoring of landscape changes in coastal and sand dune habitats
7) general mapping of the island, targeted at producing a full coverage of the coastline
8) evaluation of management policies, and tussac re-planting in particular

Methods

Field work was carried out at SLI between September 2016 and March 2017. We used a semi-professional four-engine UAV, the Phantom 3 Professional (DJI, http://www.dji.com/product/phantom-3-pro; Figure 1), which is a small UAV (weight = 1280 g, diagonal size = 350 mm excluding rotors), fitted with a 20mm high resolution camera, capable to take 12.4 megapixels pictures and 4K videos. The UAV was operated from an Android phone or tablet with the DJI Go software.

Figure 1 - The UAV platform, a DJI Phantom 3.

A peculiar aspect of UAVs is that they require good weather conditions, and in particular rather low wind, to be flown safely. The Falklands are surely not an ideal place for UAV flying, due to the common high winds. Therefore, we were in an ideal position to test UAVs because we spent the whole spring and summer at SLI, and we were, therefore, able to operate the UAV only on days with optimal weather conditions. Our UAV was used only when the wind and weather conditions were optimal to safely fly. In particular we avoided
flying the drone when it was raining of very wet, when there was fog or mist, and when wind and gust speed were above 15 knots. When surveying wildlife UAV was always launched far from the subject animals, usually more than 50 meters and always more than 20 meters.

Although the use of UAVs can produce notable benefits to environmental and wildlife research, it has drawbacks that should be taken into account. In particular, UAVs can produce stress and fear on the study subjects, often in subtle ways that are not easy to be recognized (e.g., increase in heart rate, Ditmer et al 2015). The impact of UAVs on marine mammals is not well established (Smith et al. 2016). Assessment of noise effect on some marine species showed that UAV disturbance is modest, and is a minor factor compared to other sources of disturbance (Christensen et al. 2016; Erbe et al. 2017). We strictly applied best practice guidelines for the use of UAVs in wildlife research (Hodgson and Koh 2016) and followed the suggestions for flying UAVs on bird colonies based on the results of previous studies (Vas et al. 2015), but we also carefully evaluated ourselves the effect of UAV flying on each of the species and colonies that was monitored. During each flight a second operator observed and recorded ad libitum notes about the reaction of the subjects. These notes were reviewed with the UAV pilot after each flight. Summary flight logs were saved using the UAV control software (Go, DJI) at the end of each flight, and detailed logs were regularly downloaded from the UAV memory, to document the application of best practice guidelines. Logs were decoded to CSV files, and analyzed using custom scripts. Details of the methods used for each objective of the project follow.

Survey of marine birds colonies

We used the UAV to obtain counts of gentoos penguins, rockhopper penguins, and king cormorants that nest in high density colonies. Direct counts of these species are difficult due to the large number of nests densely packed in space. Moreover, gentoos nest in colonies with different topography and, therefore, the accuracy of counts changes from one colony to the other, mostly because sometimes it is difficult or impossible to see all nests together from the same location. The accuracy of counts can be greatly improved by taking pictures of the colony from the air, assembling them in a composite pictures, and carrying out the counting in these pictures, using image analysis software that permits to mark and number the counted nests (Goebel et al. 2015). UAVs have been used previously in the Falklands to obtain counts of penguin colonies (Ratcliffe et al. 2015). We obtained pictures of all breeding colonies of the target species, at different times of the season. Counting in pictures permits to have replicated counts, to estimate intra and inter-operator reliability. For each colony we obtained imagery at peak nesting and at peak presence of chicks, to estimate nesting success and net productivity. Some colonies were small enough to require just a single picture. For colonies covered by multiple pictures, we either counted animals on the different pictures (annotating on the pictures which area was to be counted and which was counted on an adjacent pictures) or we stitched pictures together using Photoshop (version CS6, Adobe) before counting. Stitching can be problematic because it can produce artefacts (deletion or addition of nests/animals), so various trials were made using the different algorithms available in Photoshop, and quality of the stitching was manually checked in all pictures. Usually the “reposition” algorithm, with the “blend images together” option, gave the best stitching result. Counts were carried out using the ObjectJ plugin (https://sils.fnwi.uva.nl/bcb/objectj/) of the ImageJ software (https://imagej.nih.gov/ij/). Pictures were counted by three different
operators. In each picture we counted number of occupied nests, number of adults per nest, number of chicks per nest, and number of adults in the colony but not on the nest. Repeatability was calculated following Lessels and Boag (1987), and its confidence interval was calculated by bootstrap (Many 2007).

Monitoring of species sensitive to disturbance

Kelp gulls are very sensitive to human disturbance while nesting. When humans approach them at close distance they usually leave the nest and fly over it, exposing the eggs and chicks to the predation by other gulls, or other species, including caracaras and skuas. Skua predation can be particularly intense, and in the past we observed mass skua attacks, favoured by the presence on unaware SLI visitors, that produced dramatic drops in kelp gull productivity (unpublished data, ESRG). Kelp gulls often nest together with dolphin gulls, which are also potential predators of their eggs. The use of UAV permitted us to get pictures of gull nesting colonies and, therefore, to obtain counts without any need to have operators approaching the colonies.

Southern sea lion counts

At SLI the southern sea lions have a single breeding colony, with a total productivity of about 100 pups (unpublished data, ESRG). The topography of this colony, that is at the bottom of a steep cliff with unsteady and slipping ground on top, makes direct counts of pups difficult, and variable, depending on how many pups are out of view from the top of the cliffs. Pups tend to aggregate at the very bottom of the cliffs, to stay in the shade and be safe from high tides, and, therefore, can be particularly difficult to count form the top of the cliffs. Repeated counts carried out at different time of the day showed that a single count from the top of the cliffs can underestimate the actual number of pups of up to 25% (unpublished data, ESRG). Although the use of a video camera mounted on a pole can improve the reliability of counts (unpublished data, ESRG), this solution is far from perfect. The UAV permitted to take pictures of the whole colony, with sufficient resolution to count pups in groups, and recognize sex and age classes.

Elephant seal harem structure

One of the main goals of our long term study of elephant seals is the effect of the spatial distribution of seals on their social behaviour. Although we are already collecting data on seal spatial distribution using GPS receivers and laser telemetry, the availability of aerial pictures of harems can greatly help. Therefore, we used the UAV to obtain aerial pictures of harems during the breeding season, and of elephant seal groups during the moulting season. Resolution of pictures was good enough to recognize not only size and age classes, but also individual seals bearing dye marks.

Killer whale sociality and predation behaviour

A great limitation of our killer whale study is that it is land based, and we are carrying out observations only from the coast of SLI. On the other hand, the behaviour of cetaceans can be greatly affected by the presence of boats at close distance (Guerra et al 2014). Boat noise not only may adversely affect killer whales (Williams et al. 2014), but there are clear demonstration that their behaviour is modified by the presence of boats even at long distance (100+ meters; Noren et al. 2009). Therefore, even having a boat at SLI, will not fully solve the limitations of our observation protocol. The UAV permitted us to obtain high resolution images of the killer whales, and high quality video footages of their behaviour. When killer
whales are close to the coast they tend to stay quite close to the surface and, therefore, they can be easily seen in the screen of the tablet or phone controlling the drone, and in the video footage. Individual killer whales can be recognized in both photos and videos. Observations from UAV were carried also during killer whale predation events.

Coastal and sand dune habitats
The study of medium and long term changes in landscape is probably one of the most neglected parts of the environmental monitoring carried out in the Falklands. Starting from an initial interest about the effect of beach changes for our long term study of elephant seals, we are now trying to implement a data collection protocol to study landscape changes at a fast pace. During the 2016-2017 we carried out repeated UAV surveys of the sand beaches and dunes of the eastern tip of SLI. The UAV is obviously an ideal platform to take high resolution aerial pictures on demand and at low cost. The UAV pictures will be integrated with the ground surveys carried out in the past using survey-grade GPS receivers (ProMark3, Magellan), and with reference satellite imagery.

Island mapping
We have a long term plan to set up a semi-automated system that will permit us to automatically fly our drone to produce a full high resolution map of the whole island at least every year, to be able to document long term environmental changes. Not having this system in place, in 2016-2017 we did manual aerial surveys, starting with coastal areas of the whole SLI perimeter, and we tested various approaches to georeference the resulting imagery. The most promising approach was the use of natural control point already present on the ground, which geographic position was accurately determined by using survey grade GPS receivers (ProMark3, Magellan). We also tried to use ad hoc reference points, obtained by deploying on the ground aerial survey targets (1.5 x 1.5 meters). Although effective, because aerial target can be easily located even in pictures taken from high altitude, the approach was definitely more time consuming than natural reference points.

Results and discussion

Survey of marine bird colonies
We flew our UAV over gentoos colonies at an altitude of 15 to 50 meters, depending on the size of the colony, and the number of pictures that were required to cover the full colony (Figure 2 and 3). Pictures taken at 50 meters of altitude over the colony were still useful for nest counting.

We observed no reaction of nesting gentoos when flying the drone at the range of altitudes used for photographic surveys. We made some trials flying at lower attitudes, down to 5 meters, and we did not observe any significant reaction of the nesting penguins. At the end of the season, when the nesting phase was over, gentoos had a stronger reaction the UAV. This change in reaction with the phase of annual cycle is evident also toward airplanes overflying the colonies (ESRG, unpublished data). All together, in the flying range used to takes pictures useful for counting, the impact of the drone was almost null.
Figure 2 - UAV pictures of a gentoo colony that required two stitched pictures to obtain full coverage of the nests. The red line is the limit of the colony. The red circles were used to improve the stitching process.

Figure 3 - Detail of a gentoo penguin colony with count markers. Dots of different colours represent different gentoos classes (e.g., single adult on the nest).

An advantage of the drone is that the flying time over each colony is short, usually < 60 seconds, so the disturbance, if any, is short and concentrate. Moreover, the UAV was launched far away from the colonies, reducing to zero the direct human-subjects interaction. This is in sharp contrast with direct counting, in which up to 20 minutes of walking around the colonies is required to the operators to carry repeated counts of the largest colonies. The
short times spent over each colony permitted us to carry out a full survey using just two UAV batteries, i.e., a total of about 40 minutes of flight. To obtain rockhopper penguin imagery we flew our UAV at 10 to 25 meters. We never went below 10 meters, and pictures taken above 25 meters were not useful to count rockhoppers, in particular in mixed colonies in which the rockhoppers nest together with king cormorants. We noted modest rockhopper reaction even at the lowest altitude. To obtain king cormorants imagery we flew our UAV at altitudes between 15 and 50 meters. Due to the size of the largest colony, multiple images and stitching were required. Reaction of king cormorants was the lowest of all colonial birds, probably due to the heavy background noise of their large colonies. As a precaution, we flew the UAV over king cormorants colonies when aerial activity of adults returning to the nests was minimal.

We obtained UAV imagery of the 20 breeding colonies of gentoo penguins. Repeatability of counts was high in all cases (Table 1).

<table>
<thead>
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<th>Count</th>
<th>R</th>
<th>se(R)</th>
<th>LCL(R)</th>
<th>UCL(R)</th>
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<tr>
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<td>0.0033</td>
<td>0.9853</td>
<td>0.9981</td>
</tr>
<tr>
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<td>0.0000</td>
<td>0.9999</td>
<td>1.0000</td>
</tr>
<tr>
<td>Chicks</td>
<td>0.9280</td>
<td>0.0270</td>
<td>0.8751</td>
<td>0.9809</td>
</tr>
</tbody>
</table>

Table 1 - Repeatability of different kinds of gentoo counts. R: repeatability; se(R): standard error of repeatability. LCL(R) and UCL(R): lower and upper limits of the 95% confidence interval of repeatability.

Figure 4 - Improvement of count accuracy with increasing counting experience. The red bar are differences among operators (one experienced operator used as baseline, plus two inexperienced ones) during the first count of all gentoo colonies. The blue bars are differences in second count, and the green bars are the improvement between counts. In parentheses number of nesting pairs in the colony.

First count
Second count
Improvement
We observed an improvement of counts precision and accuracy of inexperienced counters in following counts, and the improvement was greatest for bigger colonies, that are more difficult to count (Figure 4). Therefore, even our field helpers that had no previous experience of penguin counts were able to obtain very good counts after some training. Similar results were obtained for nesting rockhopper adults, but not for chicks, that aggregate in crèches and hide below rocks, rendering very difficult to obtain accurate counts. Therefore, UAV pictures are an effective option to determine rockhopper nesting success, but not net productivity of the colonies. Counting of nesting king cormorants in UAV pictures was very easy, they were definitely the easiest species for UAV surveys among the ones that we examined. Even in composite pictures of the main SLI colony (about 1300 nests) it was very easy to obtain accurate counts even by inexperienced field helpers, and even using imagery taken at the highest altitude of 50 meters. The only drawback was the stitching of the pictures, that requires careful manual validation to avoid the creation of artefacts like the duplication of nests in the stitching areas.

Monitoring of species sensitive to disturbance

In 2016-2017 we had a single mixed kelp and dolphin gull breeding colony, located in a flat grass area close to Sea Lion Lodge and, therefore, much exposed to human disturbance. We refrained to carry out direct counts in this sensitive situation, and we conducted just UAV surveys. The UAV was flown at 15 to 30 meters of altitude over the colony (Figure 5).

Figure 5 - A mixed kelp and dolphin gull breeding colony. Taken from 15 meters of altitude. The two species can be easily discriminated, and resolution is higher enough to permit identification of chicks.
In all surveys none of the nesting gull, either kelp or dolphins, left the nest, so impact of breeding birds was minimal. In the pictures taken we were able to recognize the two species and count adults, occupied nests, and chicks all along their development. Pictures taken at altitude above 30 meters were not useful because in those pictures it was difficult to recognize nesting adults, and almost impossible to accurately count chicks.

**Southern sea lion counts**

Sea lion surveys were carried out by lunching the UAV from the top of the cliff, and flying it at 10 to 30 meters of altitude (Figure 6).

![UAV picture of the southern sea lion colony](image)

**Figure 6 - UAV picture of the southern sea lion colony.** It is possible to count accurately individuals of the different sex and age classes, including pups (red dots). Moreover, it is possible to determine territorial limits (red lines) and, therefore, assign females and pups to the different territorial males.

On imagery taken above 30 meters of altitude it was still possible to count sea lions, but the accurate counting of pups was more difficult, and the safe recognition of sex and age classes was not fully possible. In particular, it was difficult to discriminate females from juvenile males. Sea lions showed no reaction to the UAV during counting survey. We made trials flying the UAV over specific group of sea lions to obtain footage to be used for a pilot behavioural study, and we were surprised by the lack of sea lion reaction. We flew the UAV
at 5 meters distance over groups of pups playing in shallow water, to obtain footage to be used to determine play behavioural modules, and the pups had a totally natural behaviour, never directing attention to the UAV. With the UAV we were able to survey places previously totally inaccessible to us. In the case of sea lions, we were able to fly over Rum Island, and we identified on pups born there.

**Elephant seal harem structure**
To obtain imagery useful to study southern elephant seals harem structure we flew the UAV at an altitude between 20 and 50 meters (Figure 7).

![Figure 7 - Group of moulting elephant seals, directing their attention toward the UAV. Taken at 15 meters of altitude.](image)

At these altitudes, it was possible to safely count all sex and age classes, and to safely discriminate males. It was often possible to identify seals by reading their dye marks. At lower altitude of 15-20 meters it was possible to determine standard body length of individually identified seals, by using the altitude information recorded in the EXIF record of each picture. A similar approach to body length estimation was tried in other species of Antarctic seals (Goebel et al. 2015). Contrary to expectation reactivity of elephant seals to the UAV was higher than in sea lions (Figure 7). Often, elephant seals directed their attention to the UAV and, on average 10% of the seals raised their head towards the UAV when it was flown at low altitude. Reaction was brief and limited to oriented alert, and no seal moved away or interrupted resting. We made some trials flying the UAV at very low altitude, down to 2 meters over the seals, and in no case reaction was stronger that oriented alert. The higher reactivity of elephant seals is probable due to their acoustic sensitivity for low frequency
sounds (Kastak & Schusterman 1998), similar to those produced by the UAV engines. An added value of the UAV use with elephant seals was that we were able to regularly survey Rum Island, confirming that there is no breeding of elephant seals there, and being to count seals there, and identify dye marked individuals, during the molting season.

**Killer whale sociality and predation behaviour**

UAV was a very effective tool to study killer whale sociality and predation events. In fact, the use of the UAV produced a quantum leap in our understanding of killer whale behaviour and activity at large. The UAV was flown at 10 to 50 meters of altitude. Killer whales have a highly structured social organization and a complex activity pattern, so it was normally not possible to follow all individuals at the same time and, therefore, video footages were obtained by concentrating on a single pod or individual. Due to the limitation of our UAV, which batteries last about 20 minutes, we were able to obtain just short video segments, but we combined more than one flight obtaining an almost full coverage of events, e.g., up to many hours of follow up during predation events. Reactivity of killer whales to the UAV was null, and we found no sign of UAV disturbance both in the behavioural sequence of each individual and in the global activity of the group. It was possible to individually recognize killer whales in almost all the pictures and footages that we obtained (Figure 8).

![Figure 8 - Identification of killer whales in UAV footage. Calf Pinnino (3 years old) is still suckling from its mother Puma, a behaviour that we were never able to observe from land.](image)

The overall picture of killer whale activity and association was very different from the one obtained by land observation. In particular, killer whale video footage showed more variable association patterns than the ones observed from land. Moreover, in the videos we observed complex behaviours that are impossible to observe from the coast, like calf suckling (Figure 8), underwater manipulation of the prey (Figure 9), prey sharing, and help and support by
adults to the younger individuals, e.g., to keep prey carcass close to the sea surface (Figure 10).

Figure 9 - Killer whales with sea lion prey. During this predation event the prey was never seen at the surface and, therefore, it would have been impossible to classify the event as a sure predation event by observing it from land.

Figure 10 - Prey sharing between adult and calf. The adult (top animal) is passing a piece of the prey to the calf (bottom animal).
Coastal and sand dune habitats
We did regular surveys of the sandy beaches and dunes of the east side of the island. By using a combination of natural and artificial control points we were able to document the significant short term changes of these habitats, e.g., the notable variation of the sand beach coastline after rough seas periods (Figure 11).

Figure 11 - Effect of storm and high seas on the sand beach extent. The two pictures show the same portion of a sand beach before and after a storm. By using the tussac dune marked by the red circle is possible to appreciate the large change in beach extent. UAV is the ideal platform to take imagery to document such rapid habitat changes.
Island mapping
We were able to obtain high resolution imagery of the full coastline of SLI. This required a rather large number of flights due to the intrinsic limitations of our UAV platform (batteries about 20 minutes). Even images taken at 500 meters of altitude (Figure 12 top) had enough resolution to permit counting of individual tussac plants (Figure 12, bottom).

Figure 12 - UAV picture of the Sea Lion Lodge and airstrip area. Taken at 500 meter altitude. Top: full image, bottom: enlargement showing the maximum resolution of the image.
Conclusion and perspectives

Our extensive trails of UAVs to carry out a diverse array of environmental research and monitoring were, all together, successful. It was possible to obtain accurate counting data for most species, and the disturbance of the UAV was low, and lower or equivalent to direct counts. The UAV produced a quantum leap in our understanding of killer whales behaviour, showing behavioural and association patterns that were impossible to observe from land. Although results are still very preliminary, the UAV proved to be an effective platform to map both specific habitats and the whole island.

In the coming 2017-2018 season, if our UAV research licence will be renewed, we would like to concentrate on the standardization of our survey protocol. The final goal is to run semi-automated surveys, in which the UAV will follow an established route, taking pictures and video following a programmed protocol, with the least human intervention possible. This will permit to repeat survey along years producing comparable imagery.
Acknowledgments

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Literature cited


