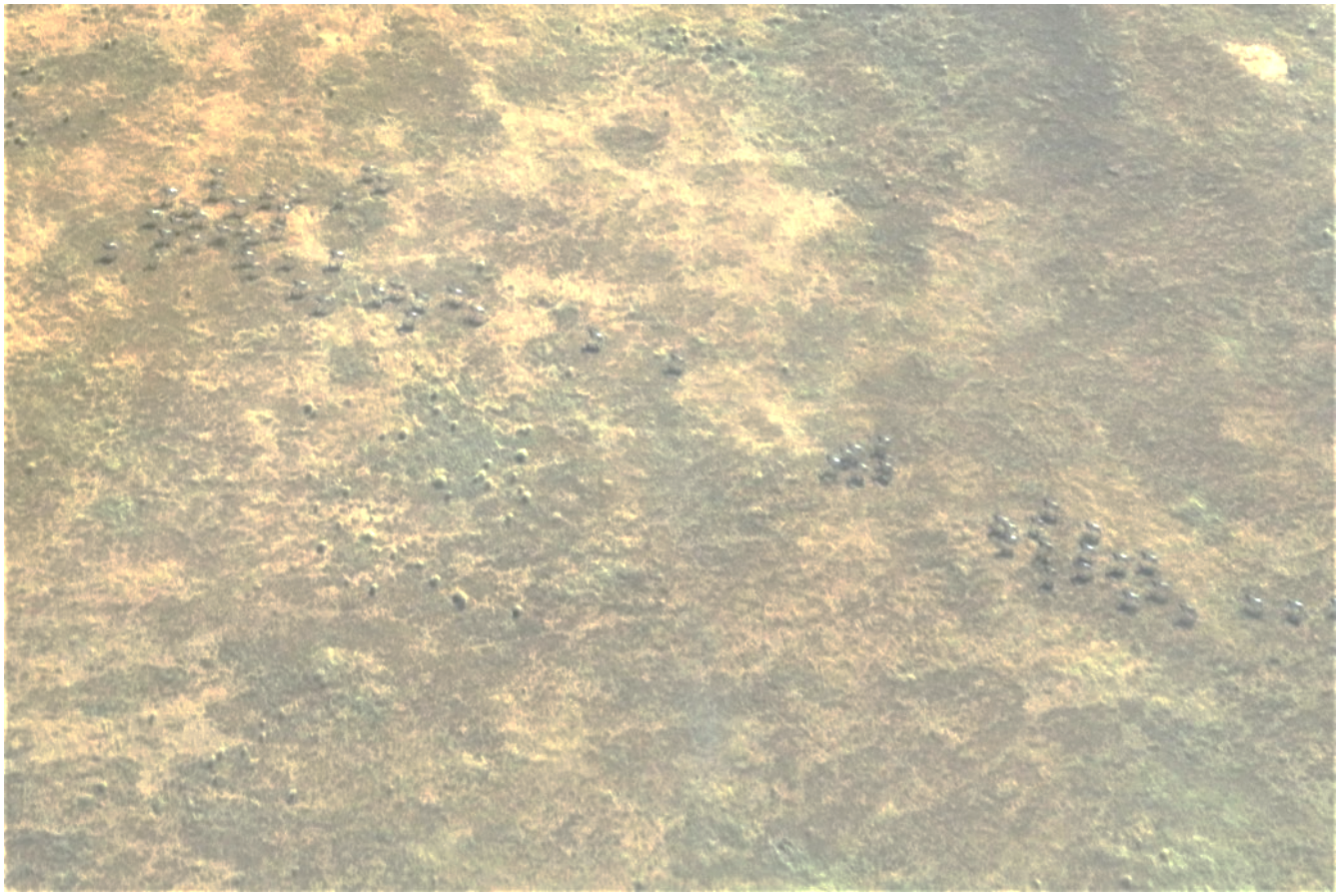
Aerial sample count

Tim Wacher, Marc Dethier, Habib Ali

18-25th November 2021



Co-funded by the European Union

AERIAL SAMPLE COUNT

PROJET OUADI RIMÉ-OUADI ACHIM

18 – 25th November 2021

Published by: ©2022 SaharaConservation

Authors: Tim Wacher, Zoological Society of London
Marc Dethier, SaharaConservation
Habib Ali, SaharaConservation

Recommended citation: Wacher, T., Dethier, M., Ali, H. (2022). Aerial sample count: 18-25th November 2021. Projet Ouadi Rime-Ouadi Achim, SaharaConservation. Ouadi Rimé-Ouadi Achim Game Reserve, Chad

Cover image: Habib Ali

CONTENTS

1. INTRODUCTION

An aerial survey of the Reserve de Faune de Ouadi Rimé-Ouadi Achim (RFOROA), originally planned by the ProJet Ouadi Rimé-Ouadi Achim (POROA) for 2020, but delayed by covid impact, was conducted in November 2021. The objective is to provide updated information on the numbers and distribution of wild ungulates and livestock and record other environmental elements such as human activity and fire impact in the core of the reserve. The results are used to provide recommendations on future management planning needs for the reserve and assess monitoring and patrol requirements to contribute to successful integration of wildlife conservation objectives and other land use activities across the RFOROA (Bemadjin *et al.* 2012).

2. METHODS

Logistics: SaharaConservation (previously named Sahara Conservation Fund) negotiated an agreement with the Mission Air Fellowship de Tchad (MAF) for their pilots to fly the survey using the Cessna 182 operated by MAF. Fuel supplies at the oryx base camp were organised by SaharaConservation in collaboration with MAF. The oryx project airstrip was prepared with white marker points at 20m intervals along one side. Working within the budgetary and logistical constraints of a maximum 30 hours flying time, a strip transect stratified survey design was drawn up by Zoological Society of London. The survey was navigated using twelve flight routes displayed on a Garmin 276Cx unit, including display of distance to 5km marker points along each transect, start and end points and time to sunset (Annex 1).

Survey team: The core survey team of observers and recorder were unchanged through the survey, with a change of pilots mid-survey.

Pilot - 18-22 Nov. 2021	Becki Dillingham - MAF
Pilot - 22-25 Nov. 2021	Phil Henderson - MAF
Left seat Observer	Marc Dethier – SC
Right seat Observer	Habib Ali – SC
Recorder	Tim Wacher - ZSL

Survey method and design: Followed traditional aerial survey strip sampling methods (Norton -Griffiths 1978). This called for flying at 300ft above ground level, ideally managed with radar altimeter, and rods fixed to wing struts to define 150m strips on the ground either side of the aircraft. In practice certification rules for the MAF airplane prohibited the fixing of strip marker rods and a radar altimeter. Tape markers on the wing struts were used as an approximate guide to aid observers. Altitude was managed by the pilots using a conventional pressure altimeter.

In response to the east west orientation of drainage and dune features, transects were aligned north-south. The full survey zone of 10,400km^2 (13% of the 77,950km^2 reserve) was centred around the oryx reintroduction site, covering the principal areas currently used by reintroduced scimitar-horned oryx, Map 1. The zone was stratified into an inner 80km x 40km (3,200km^2) core area where oryx and dama gazelle are most frequently found, sampled by transects at 2.5km separation (12% sample fraction), with a surrounding 7,200km^2 zone, with transects at 5km separation (6% sample fraction).

Training: In preparation for the survey a presentation explaining the methods and principles of aerial strip sampling was given in a discussion session with the monitoring team. The observers took part in the process of identifying marker points on the wing struts (twice – see below) to guide the 150m strip width limits, followed by short test flight to familiarise the pilot, recorder and observer team with working conditions and processes.

Strip width calibration: Through the course of the survey 10 passes at survey altitude, perpendicular to the airstrip over its mid-point, were made for the observers to view and photograph the white 20m marker points along the edge of the airstrip (note Norton-Griffiths 1978 advises against using photographs to count markers), Photo 1. Results were very uncertain, caused by expected difficulty in using the small tape markers on the wing struts. In response the process of determining the position of the tape markers was repeated on the ground for a second time, which confirmed identical results to the first exercise for both observers. The lack of conventional strip marker rods inevitably undermined this survey and results are heavily dependent on each observers' assessment of the 150m strip.

Flight management and data collection: In the aircraft the pilot managed navigation along the GPS displayed transect lines, flying into and out of transect start and finish points (called out to the observers by the recorder) at correct altitude and orientation. On transect the observers called out their observations verbally. Primary targets called by observers were scimitar-horned oryx, dorcas, dama, addax, ostrich, camel, sheep & goats, donkey, horse, and nomad household, with information on how many, and whether 'in' or 'out' of the strip width. Large groups of livestock required rapid visual estimation rather than an exact count. Incidental observations of other wildlife and human activities were also reported. The recorder used software adapted for RFOROA species and conditions on a tablet computer. Verbal reports were given and captured in the sequence *species or observation type/number/observer (left or right)/in or out*, mostly achieved with 4-5 rapid button presses, each sequence automatically labelled by date, time and GPS coordinate on completion (Wildlife Survey ©Darren Potgieter). The tablet screen layout also provided options to record grass/herb layer status (*green/half green/dry* – used at 5km interval markers), types of free-standing water seen, vehicle presence and type, evidence of bush fire (*enter burn, burnt ground, leave burn*) and several other categories and notes. The actual flight path was also recorded automatically. Information on dates of bush fires was collected post-survey from satellite detection data (https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms).

Data analysis: Analysis followed the standard procedure recommended for traditional fixed width strip counting (Norton-Griffiths 1978) to provide population estimates with 95% confidence intervals using an Excel spreadsheet set up for the purpose (Annex II). Distribution maps plotted using SURFER (Golden Software Ltd., Colorado) were provided showing either exact locations, or locally observed density per 10km x 10km grid square of target species after correcting for transect alignment and number of passes through each grid square. Livestock counts were combined as Tropical Livestock Units using standard ratios (FAO 2011).

3. RESULTS

The survey flight plan was completed half a day ahead of schedule and in full, Annex I. Two transects were shortened by 1km to avoid low-level overflights of the community at Donki Fadoul and the newly arrived oryx, addax and wild dama in the oryx base camp pre-release pens respectively.

3.1 Habitat and context

The survey took place at the end of 2021, a year which received the highest annual rainfall, by a significant margin, recorded at the oryx base camp since recording began in 2017, Fig. 1. Rainfall ended relatively late (early October). No free-standing water was seen, but the zone was affected by some of the largest fires recorded by the project, Map 2, Photo 2 & 6. A minimum of 26% (147/548 spot visual habitat assessments from the air, corresponding to >3000km^2) of the survey area showed evidence of recent bush fire. The largest fire crossed the north-west sector in the grassland plains habitats, affecting both the peripheral and core survey blocks, burning from 24th to 29th October 2021, four weeks prior to the survey. Three separate smaller fires occurred in the three weeks before the survey, and two fires took place in the core during the survey.

Much of the remaining pasture was seen to be in good condition, notably in the dune habitats, Photo 3. From the air 232/401 spot records (58%), over unburnt ground were scored as showing significant green vegetation.

3.2 Livestock and people

Agricultural activity in the southern margins of the survey area is by far the most extensive observed since the oryx reintroduction began, Maps 2-11 and Photo 4.

Table 1. Summary results for livestock density, numbers, and numbers of nomad households in the core stratum, the peripheral stratum and combined for both. Red shading highlights data affected by 95% confidence intervals >40%, indicating very low precision.

			Horse	Donkey	Cattle	Sheep & Goats	Camel		Nomad house
Core stratum	Density / km2	R=Σy/Σz	0.16	0.60	1.69	20.22	7.93		0.38
	Population estimate	**Y = R.Z**	**483**	**1858**	**5200**	**62275**	**24425**		**1167**
	95% C.I.		167.4	719.4	3060.9	13581.6	5610.9		476.0
	Coefficient of variation		34.6	38.7	58.9	21.8	23.0		40.8
Peripheral stratum	Density / km2	R=Σy/Σz	0.09	0.27	1.98	19.65	7.51		0.42
	Population estimate	**Y = R.Z**	**633**	**1967**	**14283**	**141467**	**54050**		**3000**
	95% C.I.		245.5	702.1	6413.9	47185.0	12666.6		1220.7
	Coefficient of variation		38.8	35.7	44.9	33.4	23.4		40.7
Combined strata	**Population estimate**		**1117**	**3825**	**19483**	**203742**	**78475**		**4167**
	95% C.I.	95% c.i	297.1	1005.2	7106.8	49100.8	13853.7		1310.2
	Coefficient of variation	CV	26.6	26.3	36.5	24.1	17.7		31.4

Summary results for observations of livestock numbers and people are shown in Table 1. Full analysis is shown in Annex II.

The results show small stock to be numerically dominant, with more than 200,000 estimated present. But the 78,000 odd camels, being much larger, represent more than double the metabolic equivalents of the combined small stock. Combined numbers of cattle, donkeys and horses are also important in terms of grazing pressure in the region. But the more patchy distribution of cattle, with a focus around the borehole at Donki Fadoul, has resulted in particularly low precision for their estimate.

Importantly the overall density estimates for small stock, camels and nomad presence in the core zone and peripheral zone are very similar. The distribution of livestock species and nomad camps is shown as densities per 10km^2 grid cell, Maps 3-8.

3.3 Reintroduced species, dorcas and dama

The primary target wildlife species for aerial survey are dorcas gazelles *Gazella dorcas*, dama gazelles *Nanger dama*, and reintroduced scimitar-horned oryx *dammah*. Re-introduced Addax *nasomaculatus* and re-introduced Ostriches *Struthio c. camelus* were also searched for, but there were only 75 and 8 individuals to find respectively. One sighting of 2 male ostriches together was made, but none of the 75 or so addax known to be present were detected.

Summary results for gazelles and oryx are shown in Table 2. Full analysis is available in Annex II. Distributions are shown in Maps 9-11.

Table 2. Summary results of scimitar-horned oryx, dorcas and dama estimates for the core stratum, the peripheral stratum and combined for both. Red shading highlights data affected by 95% confidence intervals >40%, indicating very low precision.

			Oryx	Dorcas	Dama
Core stratum	Total seen inside the sample strip		97	2044	4
	Total seen outside the sample strip		103	932	20
	Density / km2	R=Σy/Σz	0.26	5.53	0.01
	Population estimate	Y = R.Z	808	17033	33
	95% C.I.		1019.4	4006.5	61.3
	Coefficient of variation		126.1	23.5	183.8
Peripheral stratum	Total seen inside the sample strip		1	1616	0
	Total seen outside the sample strip		0	362	0
	Density / km2	R=Σy/Σz	0.0023	3.74	0.0
	Population estimate	Y = R.Z	17	26933	0
	95% C.I.		29.3	10359.0	0.0
	Coefficient of variation		175.8	38.5	0.0
Combined strata	Total seen		201	4954	24
	Population estimate		825	43967	33
	95% C.I.	95% c.i	1019.8	11106.8	61.3
	Coefficient of variation	CV	123.6	25.3	183.8

The results indicate that the survey design returned very low precision for both oryx and dama gazelles. It is significant that more than half the oryx detected in the sample strips were found in one herd, reported at the time as 61 individuals, Photo 5. The formal population estimate for oryx is much higher than believed plausible from results of the ground monitoring that has been maintained consistently since 2016. The confidence intervals signal that this estimate should not be quoted as the population size for oryx in 2021. Just as it makes no sense to quote the formal population estimate that this survey has provided for addax as zero. Both species are rare and difficult to sample precisely, so this type of issue is expected.

The dorcas gazelle population estimate of nearly 44,000 individuals in the survey zone achieved a reasonable precision (CV 25%), comparable with results for camels and small stock. Strikingly the dorcas gazelles showed higher densities in

the core area close to the oryx reintroduction project than in the surrounding areas.

3.4 Other wildlife observations

- Bustards sighted 101 times:
  - 146 individuals most unidentified; largest group 6 Nubian bustards .
- Vultures sighted 23 times:
  - 32 individuals, mostly unidentified ; most sightings on nests.
- 1 flock of white storks flying.
- 1 short-toed eagle flying.
- 6 single jackals reported.
- 53 multiple burrow fox dens typical of pale fox *Vulpes pallida* noted.

3.5 Other observations

- 4 4x4 vehicles were sighted (1 ranger patrol and 3 unknown).
- 8 motorbikes were sighted.
- 1 tented camp selling water from a plastic reservoir in the dunes 4.5km ESE of oryx base camp.
- The enlarged firebreaks created by the SaharaConservation/EAD oryx project staff were seen to be effective, though protecting a relatively small area (Map 2 and Photos 6 & 7).

4. CONCLUSIONS & RECOMMENDATIONS

The first aerial survey in the Ouadi Rimé-Ouadi Achim Game Reserve has produced valuable insight into the general numbers and distribution of livestock and key wildlife species. The direct sighting of over 200 oryx in a limited sample of the area is a notably positive result for a species still classified as Extinct in the Wild. The method also vividly illustrates the spatial interactions between wildlife, livestock and ecological processes affecting the conservation initiatives of the reserve, notably conversion of grassland to seasonal agriculture, human settlement, very high livestock numbers and huge bush fires.

Recommendation 1

Aerial surveys should be continued on an annual or twice-yearly basis as a tool to provide feedback on ungulate and human population processes in relation to reserve management initiatives and objectives.

1. The population estimate results for abundant species (dorcas, small stock and camels) have returned reasonable levels of precision. But the survey has not produced useful precision (c.i. less than 20% to allow reasonable probability of detecting significant change) for the rarest species, scimitar-horned oryx and dama gazelles, and no observations at all of addax.
2. The reasons for low precision estimates for scimitar-horned oryx and dama are very clear; encounter rates are very low; only 7 groups of oryx seen within in the sample strips, 61/97 of them in one group (Photo 5). Only one of the four groups of dama seen was within the sample strip. Distribution of sightings between transects was consequently very inconsistent, with very high variability in group sizes observed. Accordingly, the formal population size estimates derived are not reliable indicators for these two key species. But with clear independent evidence (ground survey work) that the oryx population is still growing, these issues can be expected to diminish in future aerial surveys of oryx and hopefully for addax, dama and ostrich as well.
3. Also supported by contemporary observations on the ground, it was clear that at the time of the November 2021 aerial survey, the scimitar-horned oryx were gathered into some of the largest herds recorded since the reintroduction began. This also compromises the sample survey approach which works best when animals are evenly distributed within each sample stratum rather than highly clustered. This observed clustering may be related to the growing population size, but it is also the case that east

African oryx are known to form some of their biggest group sizes at times of abundant grazing. The Chad population may now be sufficiently large to exhibit a similar response. Only ongoing monitoring will confirm if a seasonal pattern of groups size change emerges.

Recommendation 2

Continue to monitor seasonal change in oryx group size and consider options for running aerial surveys in dry conditions if group fragmentation and dispersal in this season becomes evident and predictable. But it is noted that visibility and other meteorological conditions are less likely to be favourable to air surveys at such times.

4. Although producing useful results, the survey was handicapped because it was not possible to equip the aircraft fully for aerial strip counting.

Recommendation 3

Future surveys must secure permissions for aircraft to fly at 300ft agl, rigged with radar altimeter, strip marker rods and suitable navigation equipment as a routine process, with minimum administrative burdens for all authorities involved.

Recommendation 4

Developing capacity for aerial distance sampling should also be considered in future surveys, to better account for detectability and increase precision.

5. The high rainfall may have accelerated the already expanding opportunistic agriculture (millet and sorghum fields) observed along the drainage lines of the Ouadi Haddat floodplain in the south of the survey zone.
6. The increase in borehole sites and permanent dwellings observed near and in the SW of the survey area in the heart of the reserve, underlines that these activities are not just dependent on years of good rain. Agriculture and settlement appear to be stabilising. This must be a challenge to the definition of 'traditional land use' within the statutes of the reserve.

Recommendation 5

The legal status and spatial distribution of agricultural plots, new boreholes and permanent dwelling development within the reserve needs to be reviewed. A significant wildlife and pasture conservation zone between the Ouadi Haddat in the south and the Ouadi Kharma in the north, should be identified in conjunction with stakeholders. Management criteria within the conservation priority zone will be to prohibit new water development, agriculture or permanent settlement.

Traditional mobile livestock grazing can continue. Measures to control fire to be applied inside and outside the zone.

7. The aerial perspective provided evidence that the fire break system being established by the DCFAP/EAD/ SaharaConservation reintroduction project can be effective, Photo 6. It is noted that the firebreaks maintained in 2021 protect an area of approximately 50km x25km (1,250km^2). This is very small compared to the movements and grazing requirements of key wildlife. At least two fires were initiated within it in November 2021.
8. The distribution of livestock and nomad camps shows a clear avoidance of the burnt areas one month after the largest fires. The grazing protected by firebreaks inevitably attracts livestock herders after fires.
9. Wild ungulates also showed evidence of avoiding recent fires though it was clear from the air that dorcas are also more likely to seek out and use small patches of vegetation within the greater burn zones. Dorcas also exhibit relatively low numbers in the east of the zone, probably reflecting pressure from agricultural expansions and other human activity pressures emanating from the towns of Arada and Biltine, (Map 11).
10. The survey has shown how fire caused by people restricts the available grazing and results in compression of both livestock, people and wild ungulates into smaller areas where competition for food and empty space is increased.

Recommendation 6

Options to extend the firebreak system more widely, should be considered, including discussion with stakeholders on potential for use of firebreaks to create a mosaic of protected vegetation zones and so minimise local post-fire grazing pressure compression.

Recommendation 7

Increase stakeholder involvement and responsibility for bush fire control by enforcement of proper campfire management and close management of vehicle access to conservation priority areas.

11. The numbers of livestock estimated by the survey, in excess of 300,000 animals in 13% of the protected area, vastly outnumbering the wild ungulates which total just under 45,000 of which most are dorcas gazelles. Dorcas are much smaller than any of the livestock species that share the pastures, further skewing the grazing offtake in favour of livestock.

12. The results also suggest that vehicle access routes may influence livestock distribution, notably along the general alignment of the main track running from Arada and Biltine in the east towards Batan Al Djenna and Salal in the west. This route is being used by tankers to support temporary plastic bladder reservoirs selling water to pastoralists; one such was observed 5km from the oryx release site. The potential for firebreaks to result in increased vehicle access should be born in mind in considering further development of a fire break system (Recommendation 6).
13. The extremely high abundance of livestock relative to the comparatively modest numbers of wild ungulates must be leading to direct disturbance and elevated levels of grazing competition compared to historical conditions.
14. Livestock density results indicate that the immediate zone around the oryx reintroduction site experiences no reduction in livestock grazing pressure relative to the surrounding areas.
15. Small stock as a group match wild ungulates closely in dietary selection for the grasses and herbs favoured by gazelles and oryx; camels and cattle also take these resources in bulk, though camels also access wider choice of diet selection from higher level browse.

Recommendation 8

Observations 12 to 16 all reinforce Recommendation 5, that a wildlife and pasture conservation priority zone amounting to some 10% of the reserve area be established. In this zone livestock density and grazing pressure is managed by prevention of further water development, permanent settlement is banned and fire control operational. The objective is to assure the reserve is functional as a grazing zone operating in line with national conservation and environmental objectives. Stakeholder support for fire control and grazing pressure management throughout the reserve should also be sought.

5. ACKNOWLEDGEMENTS

This product is co-financed by the European Union through the grant FED/2017/388-558 awarded to SaharaConservation to implement the project "Support for the development of the Ouadi Rimé-Ouadi Achim Wildlife Reserve and the sustainable management of its biodiversity (POROA)" which is part of the support program for the preservation of biodiversity and wildlife and fragile ecosystems of Central Africa (ECOFAC VI) funded by the 11th European Development Fund (EDF)."

We thank colleagues at SaharaConservation, in particular Arrachid Ahmat Ibrahim (POROA project), John Watkin, John Newby, Violeta Barrios, Firmin Dingamtebeye (Project Oryx), for their support and involvement in setting up and executing the logistics and fuelling. We thank as well the DFAP guards for protection of the aircraft, and pilots Becki Dillingham and Phil Henderson at MAF for their strong collaboration.

6. REFERENCES

Bemadjim, N.E., Newby, J., Desbiez, A., Lees, C. & Miller, P. (eds) (2012) *Technical Workshop on the Reintroduction of the Scimitar-Horned Oryx to the Ouadi Rimé-Ouadi Achim Game Reserve, Chad*. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, USA

FAO (Food and Agriculture Organisation of the United Nations) (2011) *Guidelines for the Preparation of Livestock Sector Reviews*. Animal Production and Health Guidelines No. 5. Food and Agriculture Organisation of the United Nations, Rome, Italy.

Norton-Griffiths, M. 1978: Counting Animals, *African Wildlife Leadership Foundation*, Nairobi, Kenya.

ANNEX I

Table 1. Initial aerial survey planning document submitted with a map to SaharaConservation and MAF.

CORE 40X70KM SURVEY BLOCK 30 NORTH-SOUTH TRANSECTS AT 2.5KM SEPARATION : Outer blocks 36 transects at 5km separation									
Day No.	**am/pm**	**Transect length km**	**N Transects**	**Activity**	**Direct km**	**Av. Speed**	**Est. Hrs.**	**Depart**	**Return**
				Introductory Powerpoint presentation on survey methods given to survey team. : Plane prep hangar (rods, cameras, altimeter). Map calibration strip and airstrip. Prep. calibration route.					
Day 1	am			MAF transfer flight N'Djamena -> Oryx base	625		3.8	N'Djamena	Oryx Airstrip
Day 1	pm			Aircraft set-up on the ground					
Day 2	am	To be decided		Training flight		171	2.00	Oryx Airstrip	Oryx Airstrip
Day 2	pm	20	10	PB_SW	367	171	2.15	Oryx Airstrip	Oryx Airstrip
Day 3	am	20	12	PB_S	350	171	2.05	Oryx Airstrip	Oryx Airstrip
Day 3	pm	1X20km & 4X40km	5	PB_SE	270	171	1.58	Oryx Airstrip	Oryx Airstrip
Day 4				Pilot rest - Data management at base camp					
Day 4				Pilot rest - Data management at base camp					
Day 5	am	40	6	PB_W	407	171	2.38	Oryx Airstrip	Oryx Airstrip
Day 5	pm	40	6	Core West (6x40km @ 2.5km)	347	171	2.03	Oryx Airstrip	Oryx Airstrip
Day 6	am	40	8	Core Centre W (8x40km @ 2.5km)	397	171	2.32	Oryx Airstrip	Oryx Airstrip
Day 6	pm	40	8	Centre Centre E (8x40km @ 2.5km)	359	171	2.10	Oryx Airstrip	Oryx Airstrip
Day 7	am	40	8	Core East (8x40km @ 2.5km)	361	171	2.11	Oryx Airstrip	Oryx Airstrip
Day 7	pm	1X20km & 4X40km	5	PB_NE	296	171	1.73	Oryx Airstrip	Oryx Airstrip
Day 8	am	20	10	Pilot rest - Data management at base camp					
Day 8	pm	20	12	Pilot rest - Data management at base camp					
Day 9	am			PB_NW	396	171	2.32	Oryx Airstrip	Oryx Airstrip
Day 9	pm			PB_N	398	171	2.33	Oryx Airstrip	Oryx Airstrip
Day 10	am			MAF transfer flight Oryx Base -> N' Djamena	625		3.80	Oryx Airstrip	N'Djamena
				Estimated survey flight time Istraightline)			25.09		
			90	Straightline flight time estimate N'Djamena -? N'Djamena	5198.00		32.69		
				Corrected Flight time estimate (+ c. 12.5%)*			**41**		
				*Based on real data from 19 flights at Ennedi (If applied only to survey flight time then total estimate is 40 hours N'Djamena-> N'Djamena					

Table 2. Summary of realised dates and times, distances and average overall speed for each survey flight derived from Garmin 276Cx GPS unit used for navigation in the aircraft.

Date		Block	Elapsed time hrs.	GPS moving time hrs.	Distance km	GPS Avg moving Speed km/hr	MAF Pilot	Left Seat observer	Right seat observer	Recorder	Alt. ft.
18/11/2021	pm	Training	00:54:46	00:51:28	128.00	149	Becki Dillingham	Marc Dethier	Habib Ali	Tim Wacher	500
19/11/2021	am	Block South	02:37:19	02:32:49	405.00	159	Becki Dillingham	Marc Dethier	Habib Ali	Tim Wacher	500
19/11/2021	pm	Block SE	01:58:29	01:49:44	297.00	162	Becki Dillingham	Marc Dethier	Habib Ali	Tim Wacher	300
20/11/2021	am	Block West	02:44:27	02:35:22	458.00	177	Becki Dillingham	Marc Dethier	Habib Ali	Tim Wacher	300
20/11/2021	pm	Block SW	02:14:30	02:12:08	396.00	180	Becki Dillingham	Marc Dethier	Habib Ali	Tim Wacher	300
22/11/2021	am	Core West Centre	02:34:33	02:31:08	440.00	175	Becki Dillingham	Marc Dethier	Habib Ali	Tim Wacher	300
22/11/2021	pm	Block NE	01:30:09	01:30:09	276.00	184	Phil Henderson	Marc Dethier	Habib Ali	Tim Wacher	300
23/11/2021	am	Core East Centre	02:16:27	02:13:05	386.00	174	Phil Henderson	Marc Dethier	Habib Ali	Tim Wacher	300
23/11/2021	pm	Core West	02:02:38	02:01:52	367.00	180	Phil Henderson	Marc Dethier	Habib Ali	Tim Wacher	300
24/11/2021	am	Core East	02:31:11	02:18:08	386.00	168	Phil Henderson	Marc Dethier	Habib Ali	Tim Wacher	300
24/11/2021	pm	Block NW	02:30:28	02:29:48	442.00	177	Phil Henderson	Marc Dethier	Habib Ali	Tim Wacher	300
25/11/2021	am	Block North	02:31:50	02:23:33	428.00	179	Phil Henderson	Marc Dethier	Habib Ali	Tim Wacher	300
Total			**26.45**	**25.49**	**4409.00**	**172**					

ANNEX II

Ouadi Rime-Ouadi Achim

Transect data and analysis of aerial survey observations, November 2021.

CORE STRATUM

Transect km	1232
Stratum area km^2	3080
Total sample units N	258.33
Samples n	31
Sample fraction %	12

Stratum	Transect	km	Strip	Area (z)	Oryx	Dorcas	Dama		Horse	Donkey	Cattle	Shoat	Camel	Ferrik
Core	C01	40	0.3	12	0	68	0		6	24	83	353	93	27
Core	C02	38	0.3	11.4	0	12	0		4	14	64	15	140	2
Core	C03	38	0.3	11.4	0	79	0		1	5	20	185	25	3
Core	C04	40	0.3	12	0	26	0		0	5	119	280	94	6
Core	C05	40	0.3	12	0	82	0		5	29	92	183	112	10
Core	C06	40	0.3	12	0	30	0		0	0	99	170	63	0
Core	C07	40	0.3	12	0	69	0		2	4	73	360	101	14
Core	C08	40	0.3	12	0	166	0		0	0	30	40	110	0
Core	C09	40	0.3	12	0	156	0		2	0	0	195	116	11
Core	C10	40	0.3	12	29	69	0		4	16	33	370	133	5
Core	C11	40	0.3	12	2	125	0		1	4	0	315	94	8
Core	C12	40	0.3	12	0	116	0		0	0	0	0	249	4
Core	C13	40	0.3	12	61	104	0		1	0	0	310	24	4
Core	C14	40	0.3	12	5	82	0		0	0	0	60	129	4
Core	C15	40	0.3	12	0	136	0		5	25	0	400	60	2
Core	C16	40	0.3	12	0	103	0		5	21	0	294	293	11
Core	C17	40	0.3	12	0	30	0		0	0	0	450	115	0
Core	C18	40	0.3	12	0	86	0		4	3	1	590	152	3
Core	C19	40	0.3	12	0	50	0		4	6	0	443	202	1
Core	C20	40	0.3	12	0	136	0		2	1	2	230	97	5
Core	C21	40	0.3	12	0	27	0		0	0	5	350	104	2
Core	C22	36	0.3	10.8	0	51	0		0	6	0	10	19	2
Core	C23	40	0.3	12	0	19	0		2	10	0	515	56	0
Core	C24	40	0.3	12	0	93	0		0	0	0	100	58	0
Core	C25	40	0.3	12	0	9	0		0	5	0	31	98	2
Core	C26	40	0.3	12	0	38	0		3	11	0	371	50	2
Core	C27	40	0.3	12	0	9	4		2	16	3	60	21	6
Core	C28	40	0.3	12	0	34	0		1	9	0	150	8	0
Core	C29	40	0.3	12	0	12	0		0	0	0	100	44	1
Core	C30	40	0.3	12	0	14	0		4	7	0	335	67	5
Core	C31	40	0.3	12	0	13	0		0	2	0	208	4	0
					Oryx	Dorcas	Dama		Horse	Donkey	Cattle	Shoat	Camel	Ferrik
			Σz	369.60	369.6	369.6	369.6		369.6	369.6	369.6	369.6	369.6	369.6
			Σy		97.0	2044.0	4.0		58.0	223.0	624.0	7473.0	2931.0	140.0
			Σz^2 or Σy^2	4408.56	4591.0	201352.0	16.0		224.0	3735.0	51168.0	2579099.0	408441.0	1570.0
			Σz.y		1164.0	24412.2	48.0		693.0	2657.4	7437.6	89544.0	35050.2	1674.6
	Density / km2		R=Σy/Σz		**0.3**	**5.5**	**0.0**		**0.2**	**0.6**	**1.7**	**20.2**	**7.9**	**0.4**
			s_y^2		142.9	2219.3	0.5		3.8	71.0	1286.9	25920.8	4377.3	31.3
			s_z^2		0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1
			s_{zy}		0.3	1.4	0.0		0.0	0.0	-0.1	14.9	3.5	0.2
	Population estimate		**Y = R.Z**		**808.3**	**17033.3**	**33.3**		**483.3**	**1858.3**	**5200.0**	**62275.0**	**24425.0**	**1166.7**
			Var Y		270506.3	4178562.3	977.4		7295.7	134705.7	2438792.2	48016148.5	8195155.0	58974.4
			SE Y		520.1	2044.2	31.3		85.4	367.0	1561.7	6929.4	2862.7	242.8
	95% C.I.		**95% c.l.**		**1019.4**	**4006.5**	**61.3**		**167.4**	**719.4**	**3060.9**	**13581.6**	**5610.9**	**476.0**
			CV		**126.1**	23.5	**183.8**		34.6	38.7	**58.9**	21.8	23.0	**40.8**

Transect data and analysis of aerial survey observations, November 2021.

PERIPHERAL STRATUM

Transect km	1440
Stratum area km^2	7200
Total sample units N	433.33
Samples n	26
Sample fraction %	6

Stratum	Transect	km	Strip	Area (z)	Oryx	Dorcas	Dama		Horse	Donkey	Cattle	Shoat	Camel	Homes
Periphery	P09	80	0.3	24	0	84	0		1	3	7	517	293	2
Periphery	P10	80	0.3	24	0	60	0		4	16	25	334	198	23
Periphery	P11	80	0.3	24	0	52	0		5	19	102	396	98	22
Periphery	P12	80	0.3	24	0	161	0		3	0	69	685	369	4
Periphery	P13	80	0.3	24	0	372	0		3	15	229	435	110	27
Periphery	P14	80	0.3	24	0	157	0		1	0	31	227	195	2
Periphery	P15	40	0.3	12	0	18	0		2	6	45	260	130	3
Periphery	P16	40	0.3	12	0	27	0		0	2	0	80	92	2
Periphery	P17	40	0.3	12	0	22	0		2	1	30	310	39	7
Periphery	P18	40	0.3	12	0	106	0		5	2	0	69	116	1
Periphery	P19	40	0.3	12	0	10	0		0	5	0	200	114	0
Periphery	P20	40	0.3	12	0	66	0		0	2	0	30	98	3
Periphery	P21	40	0.3	12	0	100	0		0	0	0	100	177	2
Periphery	P22	40	0.3	12	0	41	0		0	0	0	150	196	1
Periphery	P23	40	0.3	12	1	61	0		0	0	67	0	165	0
Periphery	P24	40	0.3	12	0	12	0		0	6	10	430	74	6
Periphery	P25	40	0.3	12	0	29	0		0	5	5	480	202	2
Periphery	P26	40	0.3	12	0	23	0		0	1	0	450	24	2
Periphery	P27	40	0.3	12	0	39	0		1	4	4	230	94	4
Periphery	P28	40	0.3	12	0	29	0		3	1	23	155	142	23
Periphery	P29	40	0.3	12	0	32	0		0	7	9	280	18	0
Periphery	P30	40	0.3	12	0	24	0		2	2	4	80	63	0
Periphery	P31	80	0.3	24	0	20	0		2	9	38	1821	38	11
Periphery	P32	80	0.3	24	0	48	0		1	1	48	4	142	1
Periphery	P33	80	0.3	24	0	11	0		2	2	71	463	16	4
Periphery	P34	80	0.3	24	0	12	0		1	9	40	302	40	28
					Oryx	Dorcas	Dama		Horse	Donkey	Cattle	Shoat	Camel	Homes
			Σz	432.0	432.0	432.0	432.0		432.0	432.0	432.0	432.0	432.0	432.0
			Σy		1.0	1616.0	0.0		38.0	118.0	857.0	8488.0	3243.0	180.0
			Σz^2 or Σy	8064.0	1.0	243390.0	0.0		118.0	1224.0	87811.0	5895056.0	584467.0	3354.0
			Σz.y		12.0	31116.0	0.0		732.0	2304.0	18204.0	164064.0	56904.0	3648.0
	Density / km2		**R=Σy/Σz**		**0.002**	**3.7**	**0.0**		**0.1**	**0.3**	**2.0**	**19.6**	**7.5**	**0.4**
			s_y^2		0.0	4765.0	0.0		2.1	22.9	1985.4	104135.0	5998.8	70.3
			s_z^2		29.5	29.5	29.5		29.5	29.5	29.5	29.5	29.5	29.5
			s_{zy}		-0.2	142.2	0.0		3.4	11.4	132.2	767.8	100.7	21.9
	Population estimate		**Y = R.Z**		**17**	**26933**	**0**		**633**	**1967**	**14283**	**141467**	**54050**	**3000**
			Var Y		223.5	27933316.4	0.0		15686.4	128307.2	10708430.1	579556906.3	41764578.1	387871.9
			SE Y		15.0	5285.2	0.0		125.2	358.2	3272.4	24074.0	6462.6	622.8
	95% C.I.		**95% c.l.**		**29.3**	**10359.0**	**0.0**		**245.5**	**702.1**	**6413.9**	**47185.0**	**12666.6**	**1220.7**
			CV		175.8	38.5	0.0		38.8	35.7	44.9	33.4	23.4	40.7

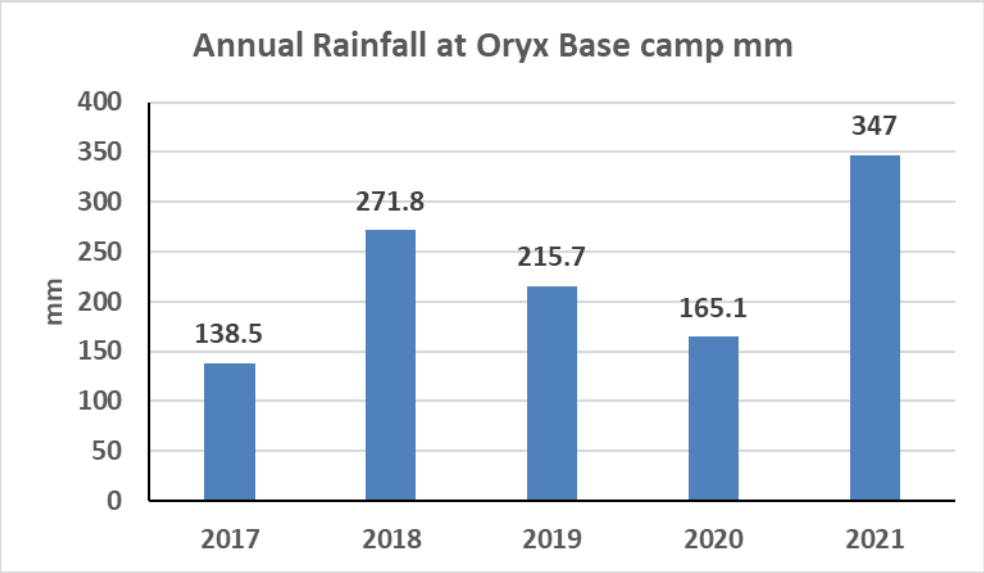
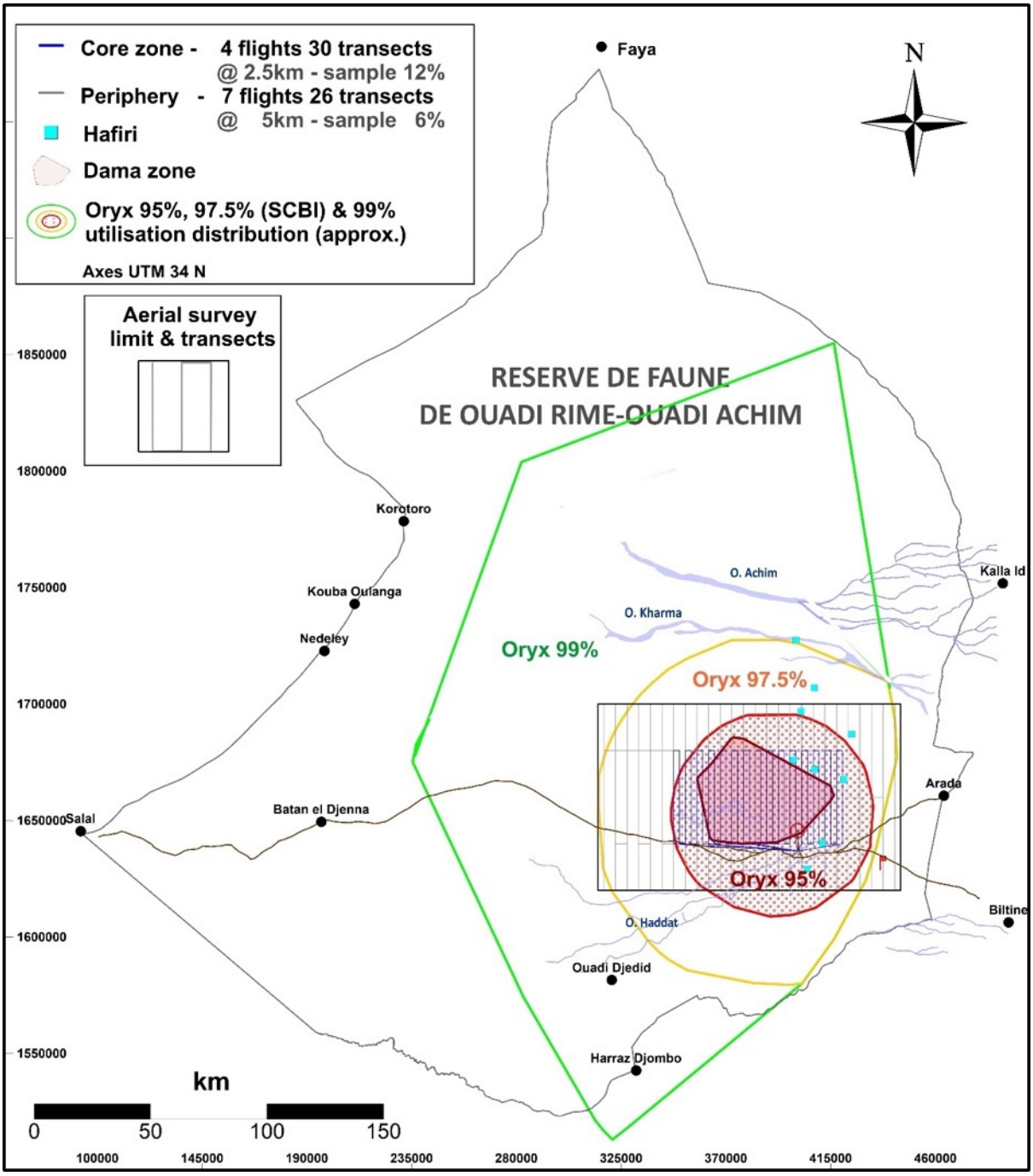
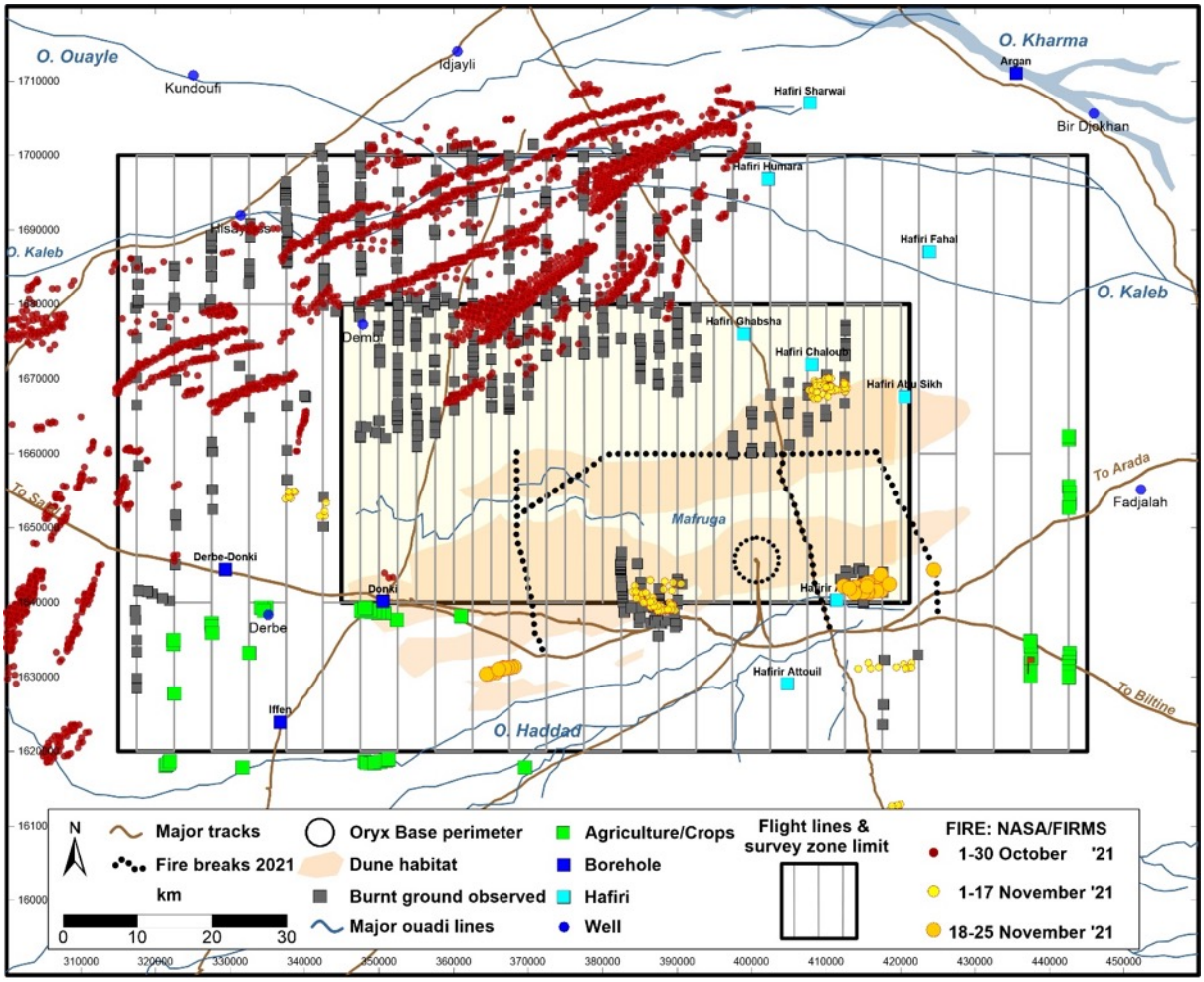


Fig. 1 Annual rainfall totals recorded at oryx project base camp; 2017-2021.

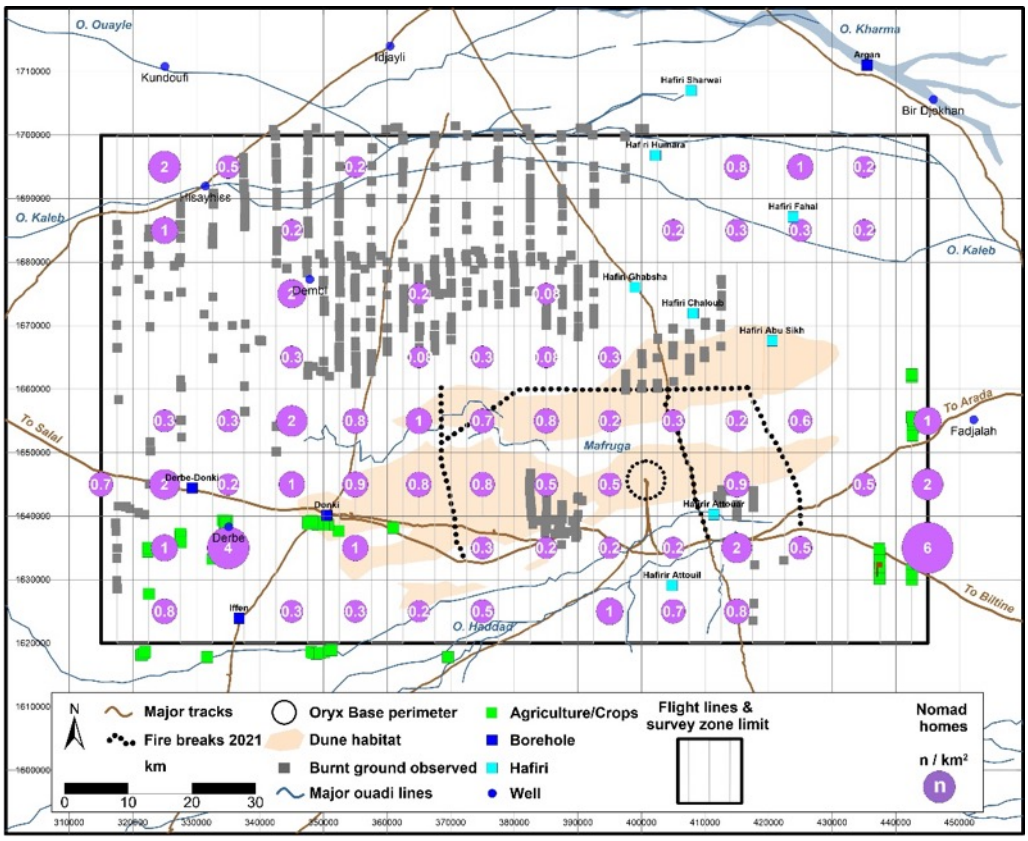
FIGURES AND MAPS



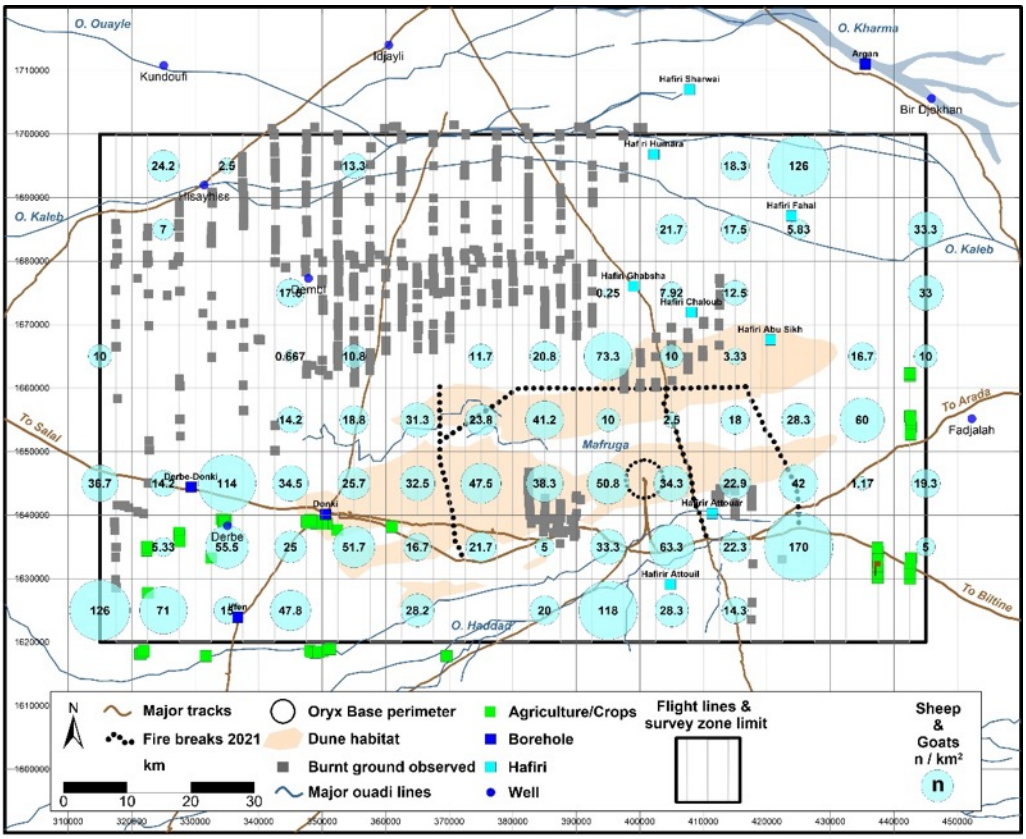
Map 1. Aerial survey zone showing high sample fraction core stratum surrounded by peripheral stratum, overlaid on the dama gazelle and scimitar-horned oryx utilisation zones within the Ouadi Rimé-Ouadi Achim Game Reserve.



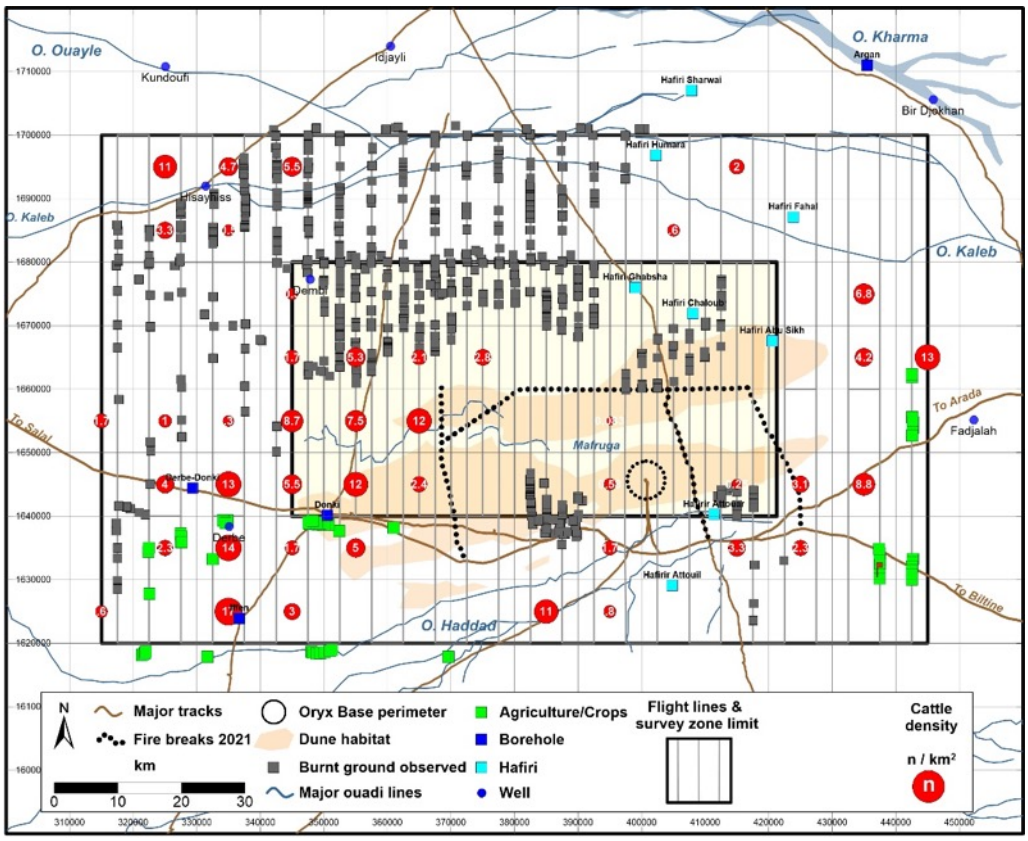
Map 2. Detail of aerial sample transects showing inner core stratum (shaded pale yellow), surrounding peripheral stratum and flight lines in relation major habitat features, seasonal agriculture, fire locations detected by satellite October and November 2021, directly observed burnt ground during the survey, and firebreaks operational in 2021.



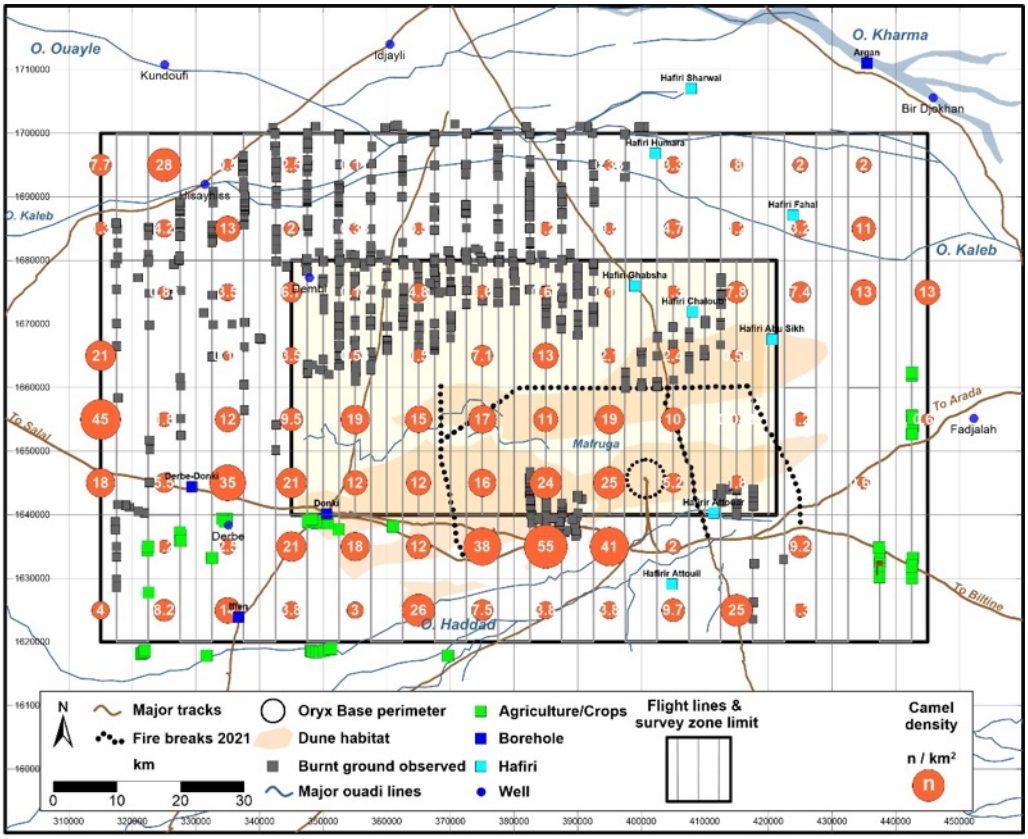
Map 3. Distribution of nomad homes counted from the air and displayed as local density of homes by 10km x10km grid square, November 2021.



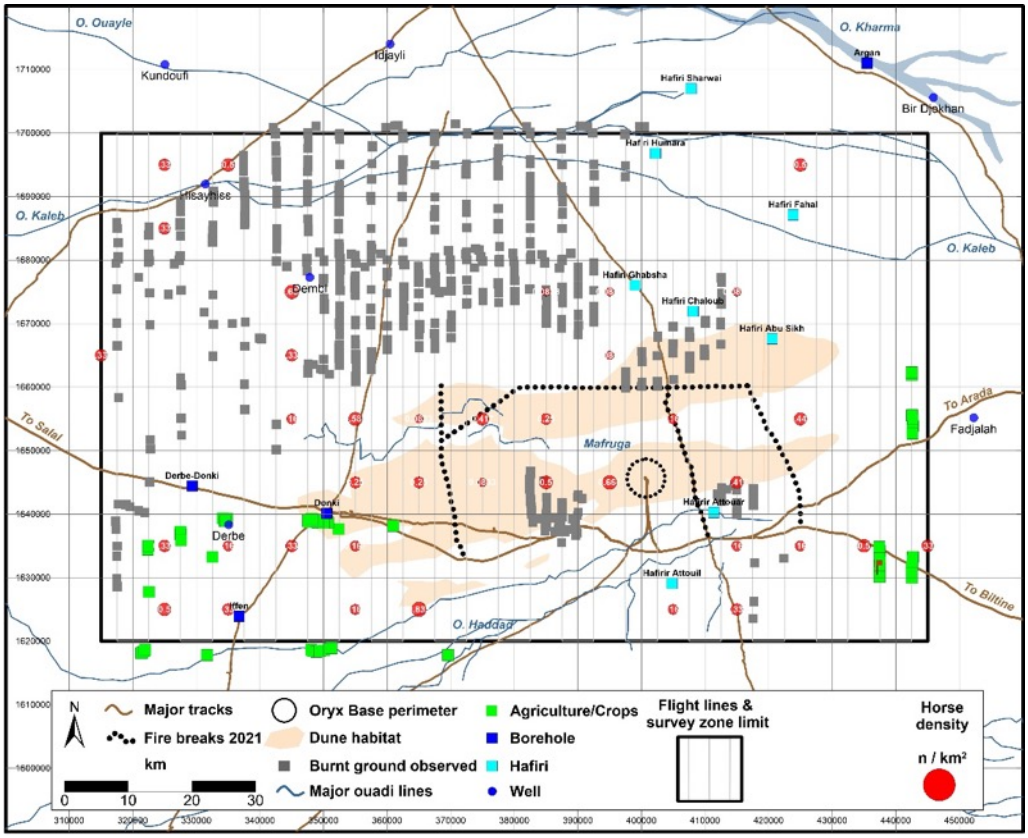
Map 4. Distribution of small stock counted from the air and displayed as local density in each 10km x10km grid square, November 2021.



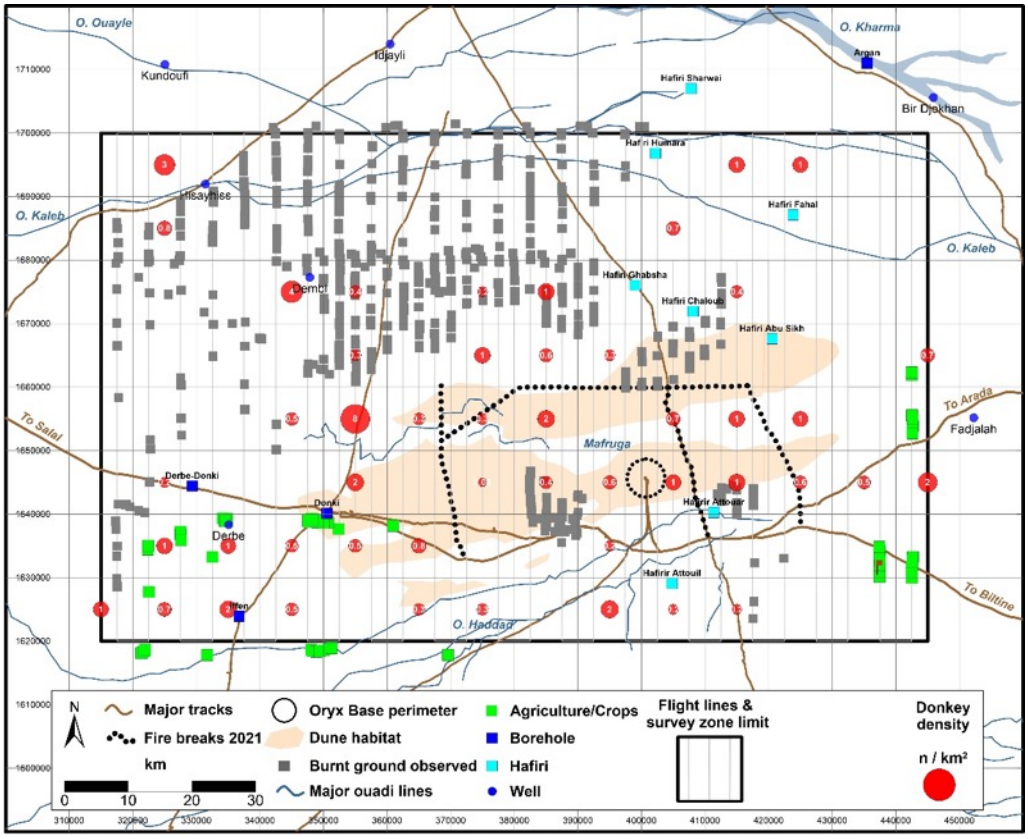
Map 5. Distribution of cattle counted from the air and displayed as local density in each 10km x10km grid square, November 2021.



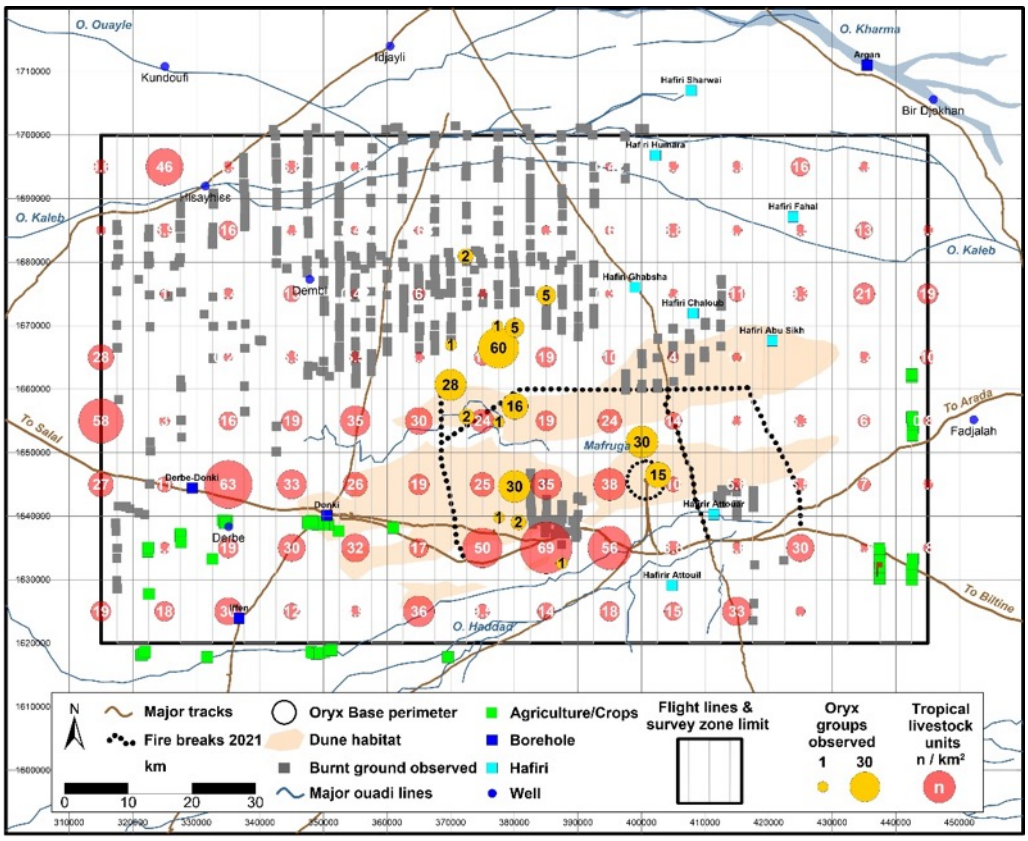
Map 6. Distribution of camels counted from the air and displayed as local density in each 10km x10km grid square, November 2021.



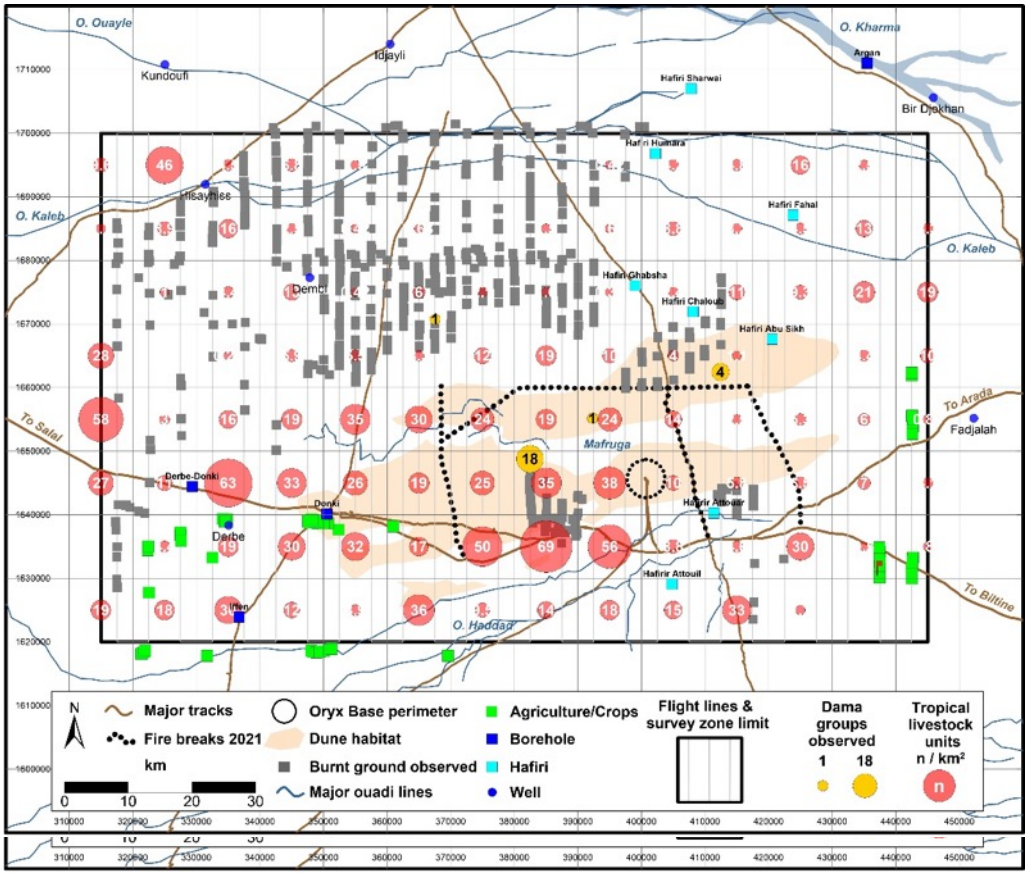
Map 7. Distribution of horses counted from the air and displayed as local density in each 10km x10km grid square, November 2021.



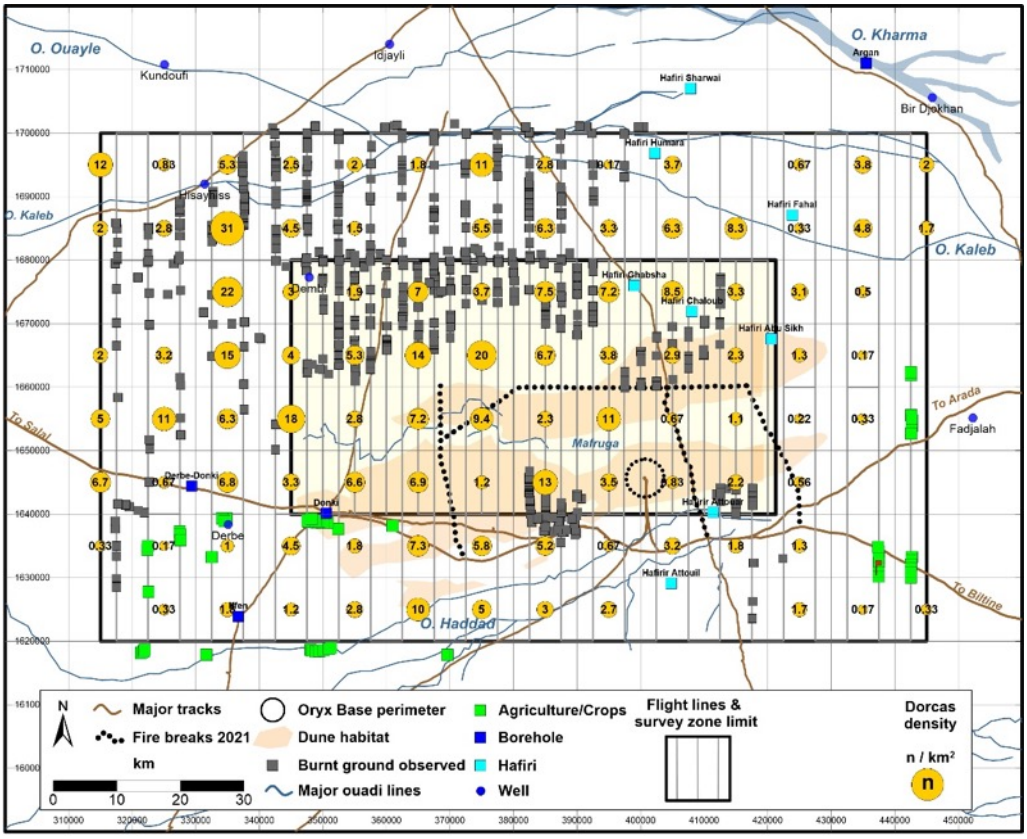
Map 8. Distribution of donkeys counted from the air and displayed as local density in each 10km x10km grid square, November 2021.



Map 9. Location of all scimitar-horned oryx groups seen from the air overlaid on distribution of livestock concentrations, fire and agriculture, November 2021.



Map 10. Location of all dama gazelle groups seen from the air overlaid on distribution of livestock concentrations, fire and agriculture, November 2021.



Map 11. Distribution of dorcas gazelles shown as local density in 10km x 10km grid cells, in relation to burnt ground and agriculture, November 2021.

Photo 1. Photo illustrating the difficulty of using a band of tape on wing strut to assess strip width. White markers on edge of airstrip are set at 20m intervals.

Photo 2. View looking south towards the cement-lined well at Dembi in the north-west corner of the core stratum, showing effects of the fire of late October and heavy livestock trails radiating from the well, November 2021.

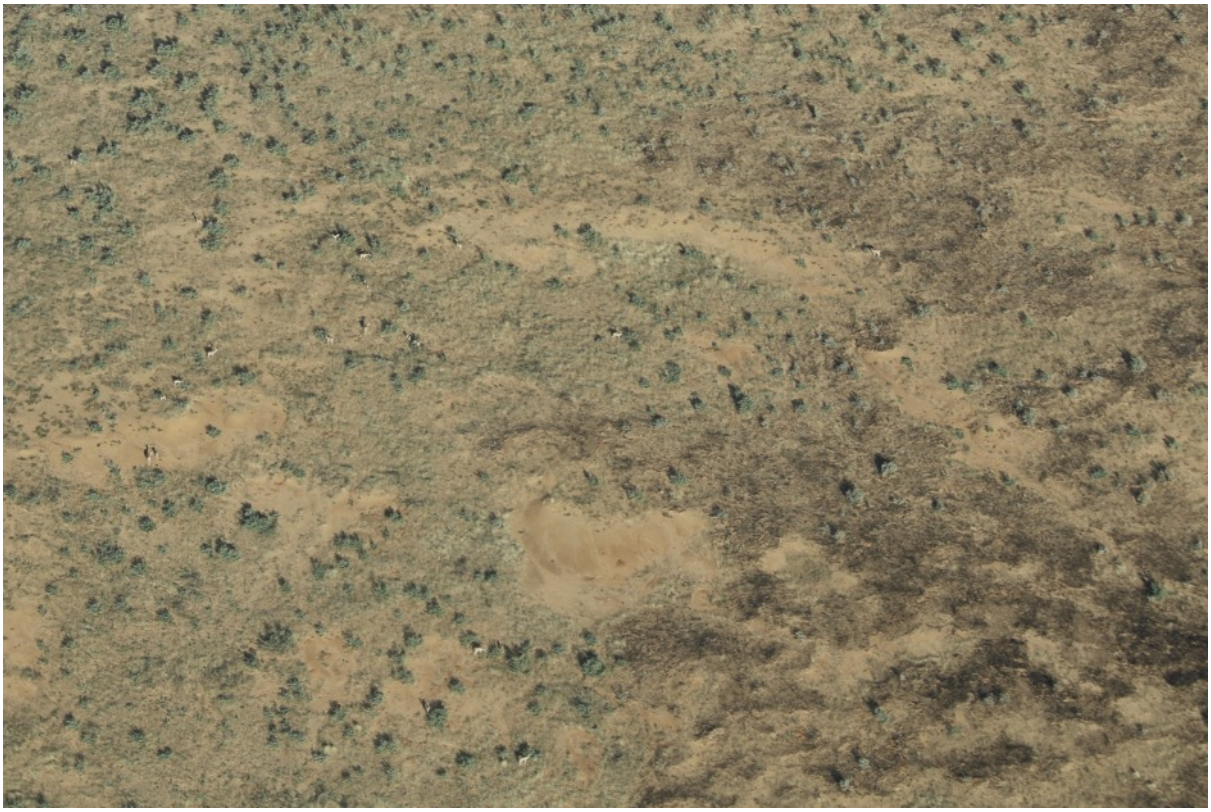


Photo 3. Typical 'dune' vegetation in the core stratum, showing vigorous green *Chrozophora* sp. There are also 21 dorcas gazelles visible, November 2021.

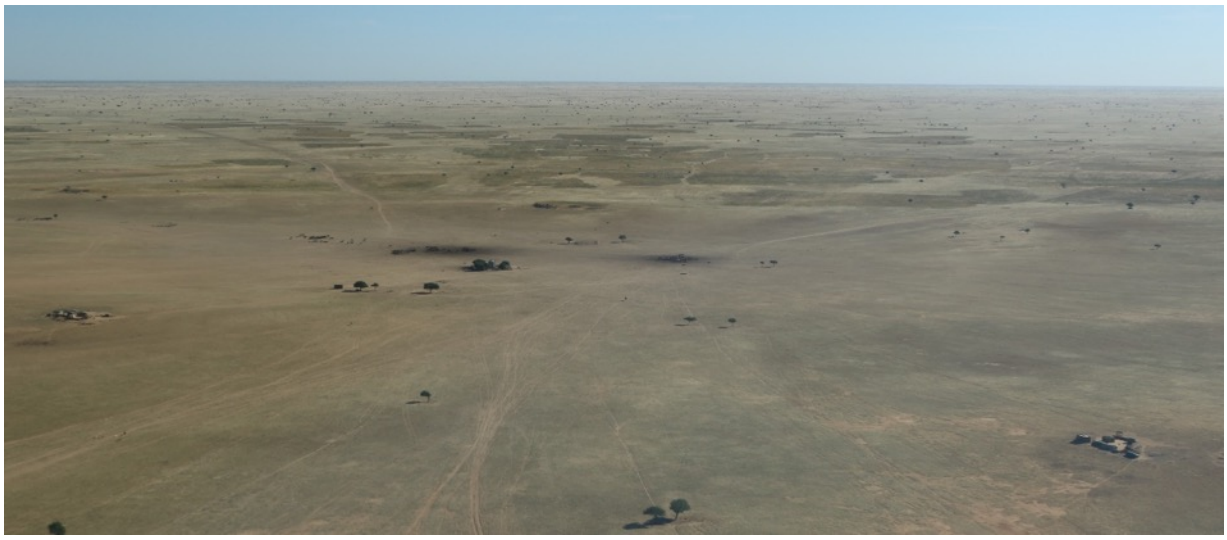


Photo 4. Part of the settlement at Donki Fadoul. The squared off dark patches on the plains beyond are fields of grain crops, which have increased in extent significantly along the Ouadi Haddat generally since the start of the oryx reintroduction and protected area restoration, November 2021.

Photo 5. Herd of scimitar-horned oryx reported at the time as 61 oryx in the transect; with 62 or 63 individuals visible in this picture. Core stratum November

Photo 6. View showing where one of the smaller bush fires was successfully arrested by the east-west fire break (Map 2) having burnt downwind SW from its origin in the vicinity of Hafiri Chaloub.

Photo 7. Detail of fire break; strips are first harrowed at the outer margins using tractors supplied by Ministry of the Environment, before implementing a controlled burn in between.