Creating a frame of reference for conservation interventions

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A B S T R A C T

Understanding the context within which conservation interventions take place is critical to effective implementation. The context includes baseline status of conservation targets, and most likely counterfactual given recent trends in those targets i.e. what would have occurred in the absence of intervention. The baseline and counterfactual together provide a ‘frame of reference’ for judging conservation outcomes. It has recently been demonstrated that, since conservation interventions take place within dynamic systems, and involve either encouraging or discouraging changes in those systems, the reference frame against which interventions are evaluated fundamentally determines how much effort is required to achieve objectives, and whether they are deemed successful. In turn, this makes frames of reference crucial to planning and policy development. Counterfactuals are difficult to estimate, however, and subject to considerable uncertainty. They are consequently not widely specified in practice.

We analyse the historical context, baseline and trends for Uzbekistan’s semi-arid Ustyurt plateau, as a case study development of a frame of reference for policymaking. Our framework incorporates physical, social, economic and institutional considerations. We conduct analyses of socio-ecological trends relevant to conservation targets in the region over the last 100 years – particularly the iconic, critically endangered saiga antelope Saiga tatarica – based upon primary data sets (e.g. vegetation surveys), secondary data sets obtained from collaborators (e.g. meteorological data), and satellite imagery.

We demonstrate that an informative frame of reference can be developed even in the absence of exhaustive data on land use and landscape ecology. This is because the broader historical context, drivers of change, and interactions between these drivers are so influential upon the necessary design of conservation interventions. The approach taken here – of dividing trends and drivers of change into those that are physical, social, economic and institutional, and considering conservation targets in light of each in turn – provides a manageable structure for building a frame of reference. Additionally, it provides a means for making assumptions about the counterfactual explicit, leaving them open to critical evaluation.

Finally, by developing alternative feasible counterfactuals, testable hypotheses can be outlined and used to improve future iterations of management plans—essentially, an adaptive management approach.

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1. Introduction

An understanding of the existing context within which conservation interventions take place is critical to effective conservation. The specification of appropriate baselines, which express the current status of a conservation target, would support more rigorous evaluations of conservation success and failures, and thus, a more scientific approach to developing conservation policies themselves (Ferraro and Pattanayak, 2006; Maron et al., 2013). However, a baseline understanding of the current status of the target is not adequate in itself. There is also a need to project counterfactuals based upon ongoing trends, i.e. expectations for what would have occurred in the absence of the intervention (Gordon et al., 2011a). It is the choice of counterfactual, which can be thought of as a dynamic baseline, that enables measurement of true conservation impact (Ferraro and Pattanayak, 2006). Although a range of possible counterfactual scenarios exist for any given region, all of which are subject to a number of sources of uncertainty (Gordon et al., 2011a),

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they allow the calculation of the net outcome of interventions rather than merely reporting observed gains (McDonald-Madden et al., 2009).

Baselines and counterfactuals are particularly pertinent in relation to the development of biodiversity offset policies, as a result of offsets requiring the achievement of ‘no net loss’ of biodiversity alongside development (Bull et al., 2013a). Few biodiversity offset schemes include the development of both a baseline and a counterfactual as part of a systematic approach to the calculation of true conservation benefit (Quétié and Lavorel 2012; Maron et al., 2013). We refer to the calculation of a baseline and counterfactual by which to calculate net conservation benefit of an intervention as the development of a ‘frame of reference’ for conservation (Bull et al., 2014). A robust frame of reference should not only consider the ecological status quo, but also incorporate physical, social, economic, and institutional factors (Ferraro and Pattanayak, 2006). Further, it is insufficient to consider factors within these domains in isolation, as interactions and feedbacks between them can be important (Nicholson et al., 2009). These factors, both in isolation and in interaction, drive the trajectory of overall biodiversity value in the ecosystem in question (Bull et al., 2014). Finally, a historical perspective is necessary—not only for evaluating the success of potential offset schemes, but also to prevent shifting baseline syndrome (Pauly, 1995), and to provide the social and economic context to which any conservation intervention should be sensitive (Pooley, 2013).

A key reason that counterfactuals are not always developed for conservation interventions is that it is considered difficult to do so, especially where there are inadequate data (TEEB, 2010). Examples do exist of the retrospective evaluation of interventions using a counterfactual, which both emphasize the need for data and show that the use of an appropriate counterfactual change perceived outcomes (Andam et al., 2008), but few examples exist of counterfactuals being developed at the initial intervention design stage. The common outstanding problems with developing counterfactual scenarios for conservation include that it is not done at all, that the assumptions are not made explicit, or that the assumptions made are demonstrably wrong (Maron et al., 2013). In this exploration, we attempt to partially address these obstacles by developing a counterfactual for a case study for which there are very limited data, in which we make our assumptions clear, and in which we compare counterfactuals developed under different assumptions.

The case study used is of biodiversity offsets for the residual ecological impacts of oil and gas extraction on the Ustyurt plateau, in Uzbekistan, which is home to the critically endangered saiga antelope (Fig. 1). The feasibility of a biodiversity offsetting policy covering the Ustyurt to compensate is currently being explored (UNDP, 2010a), and the Ustyurt plateau exemplifies how dynamic an ecological and political system can be, and how difficult data can be to obtain (Bull et al., 2013b). The approach here is to look at the relatively recent past and identify as far as possible the drivers and patterns of change relevant to management and conservation of the Ustyurt ecosystem. This includes compiling historical datasets and identifying key variables that have been monitored through time.

Because biodiversity offsets tend to use either habitat-based (floral) or species-based (faunal) metrics to calculate no net loss (Quétié and Lavorel, 2012), we define conservation targets either as the Ustyurt vegetation (habitat-based metric) or the status of particular species of interest (species-based metric). This study provides insights into the drivers of ecological change for a unique and relatively neglected region, and highlights some of the practical and theoretical challenges that arise when developing frames of reference for conservation interventions.

2. Methods

Information was gathered on trends in primary conservation targets in the Ustyurt, categorized into the habitat and species targets. The two conservation targets selected, vegetation cover and the saiga antelope, were chosen as they are the focus for ongoing biodiversity offset policy development in the Ustyurt region (Bull et al., 2013b). Statistical and spatial analyses were performed upon these data. Subsequently, we explored the drivers of ecological change in the region, and developed a conceptual map of the main interactions between these drivers. We explicitly considered the drivers of change in four domains (physical, social, economic, institutional). Finally, the numerical analyses and assessment of trend interactions were used to develop a frame of reference (a baseline and feasible counterfactual) that could be used to assess the effectiveness of the planned intervention in the region; a biodiversity offset for gas infrastructure. Since socio-ecological systems are complex and multi-faceted, various possible counterfactuals could be projected from existing data and historical trends—so we also developed an alternative counterfactual scenario, in part to make our assumptions explicit. The data were collected and analysed over a period of 27 months (2010–2013), incorporating primary and secondary data sets acquired during three field trips (Gintzburger et al., 2011; Jones et al., 2014), as well as information available online (Table A1). The ecological and technical rationales for the methods used are included in the Supplementary materials, and only the trends in ecological status and drivers of change in status are presented in the main text.

2.1. Habitat target: green vegetation cover

Habitat-based metrics for biodiversity offsetting generally measure area and condition of vegetation (Quétié and Lavorel, 2012). In the Ustyurt, a measurable component of condition important both for rangeland management purposes and for conservation is the amount of green vegetation cover (Opp, 2005; Gintzburger et al., 2011). To gain a landscape scale assessment of trends in green vegetation cover over recent decades, we used remotely sensed datasets, with the Normalized Difference Vegetation Index (NDVI) as the focal metric.

The spring and summer seasons are the time at which vegetation cover is extensive enough to permit use of the NDVI. Bekenov et al. (1998) give seasons in the Ustyurt as: spring (early/mid-March to early June), summer (early/mid-June to early/mid-September), autumn (mid/late September to early November) and winter (November to early/mid-March). These definitions are used throughout. We used spring and summer NDVI from three different satellite data sets to examine vegetation dynamics during the growing season over the period 1982–2012 (Robinson, 2000; Singh et al., 2010a).

For trends in the distribution of vegetation cover, we created a raster layer of the average spring NDVI values for each year, stacked these raster layers, and completed a linear regression analysis pixel by pixel. This allowed calculation of a gradient for the approximate trend in NDVI values for each pixel for the years in question, in turn permitting the creation of a spatial map of NDVI trends across the region. Standard least squares regression was used to calculate the gradient by pixel, with NDVI as the dependent variable and time as the independent variable.

2.2. Species target: saiga antelope

Species-based metrics for biodiversity offsets are designed either to maintain or enhance overall abundance of a species itself, or to manage habitat for that specific species. We explored trends
in both the abundance and spatial distribution of the region’s flagship conservation target species—the saiga antelope Saiga tatarica. Saigas are Critically Endangered, and only 5 populations remain in the wild (Milner-Gulland, 2010). The Usturt plateau population predominantly spends the summer in Kazakhstan but overwinters in northwest Uzbekistan (Beknov et al., 1998). Abundance data for the saiga population for Uzbekistan and for the Usturt plateau as a whole (1980–2012) were compiled from reports of aerial and vehicle surveys undertaken by the Institute of Zoology in Kazakhstan, participatory monitoring efforts and sources in the literature (Beknov et al., 1998; Milner-Gulland et al., 2001, 2010). Abundance data were used to explore trends as a result of direct saiga mortality (e.g. poaching), while distributional data were used to shed light upon changes in habitat use based on anthropogenic (e.g. Singh et al., 2010b) and environmental factors.

2.3. Drivers of change in conservation targets

Secondary datasets were analysed for trends in those factors hypothesised to drive change in conservation targets. Drivers were identified for each of the four categories proposed by Ferraro and Pattanayak (2006), which we chose as the structure for our assessment. Specific drivers were selected for inclusion where they were considered material to conservation interventions in the region, based upon literature review and expert consultation (see Supplementary materials for more detail). Where appropriate, relationships between variables were analysed using generalised linear models in the statistical package R v2.15.1 (R Development Core Team, 2012).

2.3.1. Physical drivers

Climate change is potentially a driver of ecological trends in the Usturt (Singh et al., 2010a; Bull et al., 2013b), so data were obtained from meteorological stations at the Jasilk and Karakalpakia settlements on the Usturt. Data included mean/maximum/minimum temperature, rainfall, snowfall, and snow cover. These are all potentially influential both for vegetation growth and as drivers of saiga distribution and migration. Dust deposition, carried by strong desert winds, is known to have an impact on both ecological systems and the health of the human population in the Usturt (Micklin, 2007), hence we also included analyses of wind direction (Aslanov, unpublished data). Desertification and status of faunal and floral species are partly determined by water availability, in conjunction with other drivers of change, and so we included information on water resources where available.

2.3.2. Social drivers

Human population data for the region were obtained from the administrative centre in the town of Nukus. Censuses for Uzbekistan are available online (UN, 2011). Human population trends are relevant to the development of a counterfactual as the number, density and distribution of people will influence natural resource use on the plateau as well as demands on natural resources and the extent of development and infrastructure.

We tracked unemployment rates, using a combination of official socio-economic data online (Dynamic Lines, 2011) and socioeconomic surveys completed in the region (Bykova and Esipov, 2004; Kühl et al., 2009; Phillipson and Milner-Gulland, 2011). Poaching is known to be the primary cause of saiga decline (Milner-Gulland et al., 2003), and is linked to socioeconomic factors such as poverty.
2.3.3. Economic drivers

Agriculture, primarily animal husbandry, is an important regional economic activity. Livestock require water and forage resources, which are potentially limited in this environment, and agriculture is therefore relevant for this study. Similarly, extensive agricultural land use may disturb wild faunal habitat use. Data on livestock and agricultural land-uses from 1990 to 2006 were taken from the report “Livestock raising in Uzbekistan” (UNDP, 2010b), and obtained in hard copy from the Ministry of Agriculture, Karakalpakstan.

The primary industry on the plateau is oil and gas extraction, and biodiversity offsets have been proposed as a means to bring biodiversity into the mainstream of planning by this sector. Industry has a range of direct and indirect negative impacts upon biodiversity in the Ustyurt, including habitat clearance and species disturbance (UNDP, 2010a; Mott-Macdonald, 2012). We collected field data on the spatial configuration of oil and gas infrastructure on the plateau, and vegetation impacts associated with this infrastructure (Jones et al., 2014).

2.3.4. Institutional drivers

Compliance is crucial to the outcomes of biodiversity offset projects (Bull et al., 2013a). We considered the current national legislation with respect to biodiversity conservation and, in particular, legislation that could facilitate offsetting. Further, we evaluated the administrative structure available to manage any offset scheme, as well as the influence of non-governmental organizations. We also explored where possible the land tenure system, which determines land ownership and use rights (Robinson et al., 2013).

2.3.5. Interactions

We also explored the main interactions between the important drivers identified within the system. We used a combination of qualitative and quantitative analyses (reasoning or expert opinion, and simple regression analyses, respectively) to evaluate the effects of selected drivers captured within our study in combination with other drivers. Key findings are reported in the Results, but these are not intended to represent a comprehensive interaction assessment, as this would be unnecessarily involved. Rather, the aim is to highlight some known key interactions, and demonstrate the importance of considering interactions in developing a frame of reference.

3. Results

3.1. A brief recent history of the Ustyurt

We set the context with a brief history of the Ustyurt plateau over the last 100 years. This is approximately how long the republic has existed as a defined international entity, albeit originally under Soviet rule. The last century has been a time of political, social and environmental upheaval in the Ustyurt (Fig. 2, Micklin 2007; Asimov et al., 2009; UNDP, 2010a; Robinson et al., 2013). The 1920s saw the creation of the Uzbek Socialist Republic (SR), the first time that a republic with those borders categorized as ‘Uzbek’ had existed. The decade saw the collectivisation of farms across the Soviet Union with ramifications for farming practices and land tenure in Uzbekistan to this day, but also the creation...
of the earliest national nature reserve. In the 1930s the area now
known as Karakalpakstan, containing the Ustyurt plateau and part
of the Aral Sea, was merged with the Uzbek SR. The Aral Sea was
clearly being heavily fished at this time, as the endemic Aral Trout
was last recorded in the 1930s (Asimov et al., 2009). As part of the
Soviet Union, Uzbekistan was pulled into World War II to provide
resources, and the remote Ustyurt was used as a weapons testing
facility—an activity that intensified in the 1950s, and on into the
Cold War.

The background loss of charismatic species in and adjacent to
the Ustyurt continued with the extirpation of the Caspian Tiger in
the 1950s (Asimov et al., 2009). A policy with severe ramifications
for conservation in Karakalpakstan was implemented in the 1960s:
the use of widespread irrigation for cotton along the banks of the
Amu Darya, which by the early 1980s caused the Aral fishing indus-
tory to collapse entirely, and by the late 1980s reduced the extent of
the Aral so much that it split into two smaller lakes (Micklin, 2007).
The 1960s also saw a boom in extractive activity in and around
the Ustyurt plateau. In the early 1970s, large trunk gas pipelines
commenced construction. At this stage a suite of nature reserves
were designated, but the Asiatic cheetah was still extirpated in the
1970s. In 1991, the Soviet Union collapsed, precipitating indepen-
dence for Uzbekistan for the first time. The following two decades
saw a proliferation of environmental legislation alongside increas-
ings natural gas activity in the Ustyurt, and the catastrophic decline
of the saiga antelope population, which has consequently become
one of the flagship species for conservation in the Ustyurt. In the
early 2000s, the state farms began to be dismantled (Robinson et al.,
2013), but land has yet to be privatised. The mid 2000s were partic-
ularly notable for a well-publicized incident in the town of Andijan
in the south of Uzbekistan, the response to which resulted in all
external NGOs being required to leave the country—a situation that
has not changed since.

3.2. Trends in conservation targets

3.2.1. Habitat

The annual NDVI pattern tends to a minimum over winter and a
maximum around May, with a drop in July/August and secondary
peak in September (Fig. A2). This coincides with the pattern of
actual vegetation cover that might be expected for the northern
hemisphere, and which can be observed in the field. No decadal
trends were apparent in mean NDVI across the Ustyurt during the
period 1982–2006 (Fig. A3).

Changes in the distribution of NDVI can be observed at a finer
scale, however, and are indicative of spatially heterogeneous habi-
tat change (Fig. 3). Areas of either dramatic increases or decreases
in NDVI correspond with irrigated agricultural activities, both in
the Amu Darya river delta and Aral Sea region. As is the case here,
NDVI can be used to highlight those areas in which changes in ve-
getation are occurring most rapidly and in which green vegetative
cover seems to be decreasing, which we interpret as being those
that require the most urgent conservation attention. Note that
cautions should be taken in interpreting changes in the NDVI value
of a pixel, as the index is based upon reflected light rather than a direct
measure of vegetation cover or condition.

Upon visual inspection, NDVI across the Uzbek Ustyurt gen-
ernally increased from 1991 to 2003, but remained stable or decreased
from 2001 to 2012 (Fig. 3). It is not clear if the increase over the first
decade would have been related to climatic factors, or a change
in land use following the collapse of the Soviet Union, or some
other factor. The Aral Sea region appeared to increase in NDVI more
recently, which may be due to the gradual vegetation of the exposed
seabed. The Amu Darya river delta is characterised by patches of
both steep increase and decrease in vegetation, perhaps reflecting
irrigated agriculture in the area. A straight line is partially visible
cutting across the northwest plateau where NDVI has remained
stable since 1991, corresponding to the railway, asphalt road, and
main trunk gas pipeline. Close to this line, NDVI trended upwards
in 1991–2003, and then downwards in 2001–2012. In the far south of
the plateau, NDVI appears to have remained relatively more
stable than further north, apart form one area which corresponds
to the saline lake Sarakamys, where NDVI has generally trended
upwards. It is worthy of note that, throughout the Uzbek Ustyurt,
the lichen Tortula desertorum can be found. The widespread pres-
ence of this lichen is associated with low grazing pressure from
domesticated or wild animals. This could become a concern if it
prevents recruitment of new scrub (Gintzburger et al., 2003; Esipov
and Shomurodov, 2011), and in this case might provide an alterna-
tive indicator of habitat degradation.

Over the last decade, then, the Ustyurt plateau has been charac-
terised by a heterogeneous decrease in NDVI, which is consistent
with the suggestion that desertification is a concern for the region
(Opp, 2005). However, over a longer time period of a few decades,
the case could be made that NDVI, and therefore vegetation cover,
has not shown a clear trend.

3.2.2. Species

The fauna of Uzbekistan includes numerous species of conser-
vation concern, as discussed in detail in the National Red List for
Uzbekistan (Asimov et al., 2009). The sequence of extirpations and
extinctions over the last 100 years (Fig. 2) represents a trend of decline in charismatic vertebrate and other species in the Ustyurt.

Turning to the flagship species of the region, the Ustyurt saiga population as a whole experienced a crash in the late 1990s and early 2000s (Fig. A4). Over the last century, and into the present day, the range of the saiga population in Uzbekistan has remained approximately consistent (Bekenov et al., 1998). The annual saiga migration south is, in part, triggered by temperature or some threshold snow depth (Esipov et al., 2009), which suggests that any upward trend in winter temperature over time could influence how far south into Uzbekistan the species will migrate. An unknown and variable proportion of the population enter Uzbekistan every year. High saiga mortality is recorded in the literature in association with severe winters in the late 1980s and early 1990s (Esipov et al., 2009), but not reflected in broad-scale population data. Indeed, as no consistent or comparable trans-boundary monitoring takes place, it is difficult to know how well the available data for the population as a whole (including Kazakhstan) reflect the situation for saigas in Uzbekistan, beyond that there has been a recent and substantial decline.

A recent hurdle to the persistence of the Ustyurt saiga population is the 2013 construction of a boundary fence by Kazakhstan along the Kazakh–Uzbek border, which largely cuts off the saiga migration route (Salemgareev, 2013). The fence may have severe implications when the population migrates to avoid harsh winters (Milner-Gulland, 2012). GPS collaring data have shown individual saiga moving alongside the fence and eventually passing through, suggesting that it obstructs movement but is not impassable (Salemgareev, 2013).

Recently collected monitoring data do suggest the possibility of small, permanent saiga populations resident in Uzbekistan i.e. those that remain during the summer months (Fig. 4).

![Image](image_url)

**Fig. 4.** Locations of saiga observations, according to all available participatory monitoring data, transect data and general observations from 2006 to 2012. Blue = winter, green = spring, red = summer, grey = autumn. If ‘n’ is the number of saiga observed in the herd, then for full circles n < 500, for empty circles 500 < n < 1000, and for empty diamonds n > 1000. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

**Fig. 5.** (a) Mean annual temperature at Jaslyk meteorological station, 1977–2010 (linear model: \(r^2 = 0.340, p = 0.0003\)). (b) Mean winter temperature at Jaslyk, 1977–2010 (linear model: \(r^2 = 0.249, p = 0.035\)).

### 3.3. Trends in physical drivers

#### 3.3.1. Climate

Monthly mean temperatures over the period 1977–2005 show little variation between years (Fig. A5). Average temperature peaks in July at 28.1 ± 0.5 °C, dropping to −5.6 ± 1.0 °C in January. Peak monthly rainfall (15.1 ± 5.6 mm/month) coincides with peak NDVI in May. There is significantly more inter-annual variation in rainfall than temperature (Fig. A6).

**Temperature:**

Mean temperature has trended upwards at the Jaslyk meteorological station since 1977 (Fig. 5a). Data are available for meteorological stations in other settlements on the Ustyurt plateau for 2005–2010. In these years, the temperature data between settlements show good agreement (Fig. A7). As such, there are grounds
for arguing that the Jaslky data are representative of the plateau as a whole. These data do not necessarily indicate a longer term trend in temperature, but conform with the IPCC data for the Central Asia region, which records a historic temperature rise of 1–2 °C over recent decades (Meethl et al., 2007) and with other analyses of temperature trends across Uzbekistan (Lodumintseva and Cole, 2006; Akcura et al., 2008). The recent rise in annual mean temperature was accompanied by an increase in mean winter temperature (Fig. 5b).

Precipitation:

No significant trend was found in the Jaslky rainfall data from 1977 to 2010. Annual rainfall was variable, both in terms of absolute rainfall and its variability. This is consistent both with Akcura et al. (2008) and IPCC climate predictions for Central Asia (Meethl et al., 2007). Particularly high snowfall was experienced in the late 1980s and early 1990s. Alongside an upwards trend in winter temperature (Fig. 5), there was relatively low snowfall from the mid 1990s onwards (average sum snowfall from 1985 to 1995 was = 514.1 ± 466.5 mm; from 1995 to 2005 was = 72 ± 30.1 mm).

Wind:

There is a highly dominant easterly or northeasterly wind across the Ustyurt (Fig. A8). Large-scale dust deposition, from the desiccated Aral Sea to the northeast of the plateau, is known to have acute impacts upon biological receptors (Micklin, 2007). No localised impacts upon vegetation from dust deposition associated with traffic, in the dominant wind direction, were noted in the field (Jones et al., 2014).

3.3.2. Desertification

Desertification is amongst the main environmental problems facing Uzbekistan (UN, 2010), in conjunction with soil salinisation, particularly in the region adjacent to the Aral Sea (Ji 2008; Micklin, 2007). A gradual depletion of water resources in northwest Uzbekistan (Akcura et al., 2008) is part of this trend. The drying of the Aral Sea is a highly visible outcome of this depletion, resulting from the diversion of water from the Amu Darya and Syr Darya rivers for crop irrigation (Micklin, 2007).

A network of wells is in place across the plateau, and those near settlements and the asphalt road are heavily used. There are approximately 300 wells in the Karakalpak portion of the Ustyurt plateau (Ginzburger et al., 2011). Many in remote areas are no longer operational, consistent with deterioration of infrastructure for livestock since the fall of the Soviet Union (Robinson et al., 2013). The trend in surface salinisation in the Ustyurt accompanies a trend towards salinisation of underground water resources (Akcura et al., 2008). The combination of salinisation and restricted locations of functioning wells (Robinson et al., 2013) means that water could become a concern for livestock raising and agriculture. By extension, this may also be an increasing problem for wild flora and fauna. It should be noted that extensive water abstraction is a requirement of extractive industry.

3.3.3. Interactions between climate and vegetation

A significant amount of the variation in mean spring and summer NDVI can be explained by mean temperature and summed rainfall from the previous month (Table A2). This lagged relationship is consistent with the literature (e.g. Robinson, 2000), and confirms the assertion made in Ginzburger et al. (2003) that temperature and water availability are important factors in shaping species associations found in this habitat. Mean and minimum temperatures are also positively correlated with greater landscape scale variation in NDVI values.

3.3.4. Interactions between climate, vegetation and saiga

Singh et al. (2010a) find that the spatial distribution of saiga populations is driven by climate and forage availability, but that these drivers are relatively weak for the Ustyurt population. Due to the extremely low numbers of saiga even in comparison to two decades ago (Fig. A4), forage is unlikely to be a limiting factor.

3.4. Social trends

3.4.1. Human population

The human population of Uzbekistan has been growing since the 1960s, and is projected to stabilize around 2050 (UN, 2011). This trend is not evident in the Ustyurt region. Official unemployment rates in Uzbekistan are high but the data are uncertain. Official statistics put unemployment at 32% in 2010 for the country as a whole (up from 20% in 1991; Dynamic Lines, 2011). Conversely, a recent socioeconomic study reported an official figure of 25% unemployment in settlements in Karakalpakstan, and that 29% of households surveyed in the Uzbek Ustyurt “contained unemployed inhabitants” ( Phillipson and Milner-Gulland, 2011). Roughly 25% of households surveyed reported that they were in the process of relocating to Kazakhstan due to the promise of better living conditions ( Phillipson and Milner-Gulland, 2011). The ratio of Uzbek to immigrant workers in the Ustyurt is unclear.

3.4.2. Interaction between social and ecological trends

Unemployment and livelihood trends are important in terms of biodiversity conservation, as low household income continues to be the main driver of poaching activity in the Uzbek Ustyurt (Bykova and Esipov, 2004; Phillipson and Milner-Gulland, 2011).

3.5. Economic trends

3.5.1. Livestock numbers

On the Ustyurt plateau, the agricultural sector is primarily pastoral (UNDP, 2010b). In 2007, the UNDP recorded 3,188,800 ha of agricultural land in the Karakalpak republic, of which only 415,700 ha was arable land and the majority of the remainder was pastures. Data on livestock numbers in 2010 are available for the districts of Muynak and Kungrad, which include the Ustyurt plateau (Fig. A9). Detailed data on the proportion or location of livestock kept on the plateau itself are not publically available; however, cattle are largely kept in the Amu Darya river basin to the east of the Ustyurt and graze along riparian habitats, whereas livestock kept on the plateau are primarily sheep, goats and camels (J. Bull. Pers. Obs.).

Cattle numbers in Karakalpakstan in 1990–2010 appeared stable, with an absolute increase in recent years (Fig. A10). Although the majority of cattle are not kept on the plateau, this gives an indication of trends in animal husbandry, consistent with other reports that have discussed livestock in post-Soviet Uzbekistan (Ginzburger et al., 2003; Robinson et al., 2013).

3.5.2. Interactions between livestock and vegetation

Low levels of vegetation cover and the presence of species indicating rangelands degraded by grazing are evident near settlements on the Ustyurt, along the main roads, and along the network of wells (Ginzburger et al., 2011). Near settlements, the vegetation is largely cleared within a perimeter of 8–9 km, approximately the distance that sheep can travel in one day and return for water in the evening (Ginzburger et al., 2011). However, there are few settlements on the plateau, so there is a limited impact overall.

3.5.3. Industry

The main commercial activities on the Ustyurt are extractive industries. These have negative impacts upon regional biodiver-
sity (UNDP 2010a; Mott-Macdonald, 2012) that have yet to be fully quantified. Uzbekistan is also the fifth largest exporter of cotton in the world (NCC, 2012), and the cotton industry is linked to the partial loss of the Aral Sea. This loss has itself directly influenced two other industries in the area: oil and gas, and fishing; there are large gas reserves under the Aral Sea, so the retreat of the shoreline is facilitating access and extraction (EIA, 2012), and the fishing industry has collapsed.

The oil and gas industry in Uzbekistan is large and increasing. Further details on this industry in Uzbekistan and Karakalpakstan are contained in Bull et al. (2013b) and UNDP (2010a). Official government statistics since independence in 1991 show mixed trends. Oil production in Uzbekistan has declined in recent years in part due to the realization of significant gas reserves in Karakalpakstan, and subsequent diversion of resources towards gas exploration/extraction (EIA, 2012). Gas production, conversely, has trended upwards since the early 1990s, (EIA, 2012; Fig. A13), and a number of significant gas developments are planned (e.g. Mott-Macdonald, 2012).

Oil and gas infrastructure is distributed throughout the Ustyurt (Fig. 1; Fig. A12). Uzbekistan as a whole has over 10,000 km of oil and gas pipelines, one of the highest for any country in the world (Goodland 2005), the primary one being the Bukhara–Tashkent–Bishkek–Almaty (BTBA) pipeline that passes through the Uzbek Ustyurt from the southeast, and on into southern Kazakhstan (Yenikeeff, 2008). In addition, the asphalt road and rail crossing the Ustyurt plateau parallel with the BTBA pipeline are used by the industry, and link two of the main settlements in the region: Jasllyk and Karakalpakia. All three main pipeline routes are currently undergoing some form of maintenance, improvement or expansion to meet increasing production capacity (J. Bull. Pers. Obs.). Ustyurt infrastructure is mapped in Jones et al. (2014).

3.5.4. Interaction between industry, socioeconomics and conservation targets

Development and infrastructure remove vegetation almost entirely within the space they directly occupy, but impacts upon vegetation attenuate within 25 m (Jones et al., 2014). The effect of settlement creation or expansion for workers would have a broader footprint, due to the practice of removal of most Vegetative cover through grazing for 6–8 km.

Unemployment and low income has been strongly linked to saiga poaching in the region, as a result of the market value for saiga horn (Phillipson and Milner-Gulland, 2011). A growing natural gas industry in the region means increased work opportunities, if employment is given to resident workers rather than migrants. This interaction presents a good example of why feedback loops within an ecosystem should be considered in conservation schemes: industrial development in the region is exacerbating vegetation loss, and potentially causing some direct mortality of threatened species (Mott-Macdonald, 2012) amongst other environmental impacts (UNDP, 2010a). However, at the same time, industry could provide at least some employment in a region where unemployment is known to drive poaching of one of the main conservation targets. On the other hand, poaching for meat could increase with an influx of new employees and their families, either by locals for sale to industrial employees, or by the workers and their families themselves. This means that if development preferentially employed local people it may contribute towards conservation solutions in the region; if not, it may exacerbate existing problems.

Conversely, anthropogenic presence is also known to disturb saigas (Singh et al. 2010b; UNDP 2010a) and vertebrates in general (Benitez-Lopez et al., 2010); furthermore, associations have been made between the presence of industry and direct saiga mortality, in trenches for example (Mott-Macdonald, 2012) although this has not been quantified. As industry expands further across the Ustyurt, it is likely to come into further conflict with the remaining saigas.

3.6. Institutional context

In this section, we focus on the institutional and legislative context relevant to biodiversity conservation, oil and gas, and biodiversity offsetting in Uzbekistan.

All institutions for the management and conservation of natural resources in Uzbekistan have emerged since independence in 1991. The primary state institution for biodiversity conservation in Uzbekistan is the State Committee for Nature Protection (Goskomririoda). Notable amongst its subsidiaries are Gosbiokontrol, responsible for managing protected areas, hunting and anti-poaching, and Glavcoseoexpertiza, which carries out environmental and ecological impact assessment. Smaller local replicate institutions carry out these same tasks for the region of Karakalpakstan, in partnership with the main state body in Tashkent. Much of the study area is managed by the Ministry of Agriculture, Forestry and Fisheries for natural resources, and this same Ministry would undertake any re-vegetation or habitat restoration activities required as part of an offset scheme.

All issues relating to oil and gas in Uzbekistan are managed through the state organization (Uzbekneftegaz), which partners with international organizations to undertake gas extraction projects (e.g. KoGas, LukOil, Gazprom, CNPC). Two key natural gas extraction sites in the Ustyurt region are Surgil (KoGas) and Shakpakhty (Gazprom). Uzbekneftegaz has a research subsidiary, which would be involved in developing new methodologies for implementation in the sector, such as biodiversity offsetting (Uzlitneftegaz). On the academic research side, the Uzbek Academy of Sciences until recently undertook ecological research through the separate Institutes of Zoology and Botany, although these two have now merged into a larger institute.

Beyond the state organizations for nature protection and management, there are some third and public sector conservation organizations supporting operations in the region. These include international organizations such as the United Nations Development Programme (UNDP, 2010a) and Japanese International Cooperation Agency (JICA, 2011). There are no international NGOs registered in Uzbekistan, but some provide support for activities in the region, such as the Saiga Conservation Alliance (SCA, 2012).

Existing environmental legislation makes provision for the rational and sustainable use of resources such as forestry and soils, the regulation of water abstraction and use, the protection of specific flora, fauna and habitats, the prevention and management of pollutants to soil air and water, and the examination of environmental impacts (including requirements upon Environmental Impact Assessment for industrial developments: Cabinet of Ministers, 2001; UNDP 2010a).

An established network of protected areas exists across the country, divided into a hierarchy aligned with the established IUCN categories for protection. ‘zapovednits’ are State Strict Nature Reserves (IUCN category I); State National Parks and Nurseries for Rare Animals correspond to IUCN category II and III respectively. Also important are ‘zakaznits’ (i.e. State Reserves) that are equivalent to IUCN category IV. Experience of implementing protected areas is extensive, the oldest protected area in the country being the Zaamin Mountain zapovednik, which was established in the 1920s (Fig 2). In the Ustyurt plateau, the only existing protected area is the 1991 Saigachy zakaznik, but this has neither staff nor budget and so is ineffective in protecting the threatened species it contains (Esipov et al., 2009).
3.6.1. Interaction between economic and institutional factors

Livestock on the Usturt are currently under a mixture of state and private ownership (including mixed flocks), although farmers do not generally own land aside from some small household plots (Lerman, 2008). The vast majority of land is owned by the state, as was the case during the Soviet era. There is supposed to be a system of charging for grazing access, but this is only partially implemented (Robinson et al., 2013). The relevance of the land tenure situation to this discussion is twofold: firstly, land tenure influences grazing regimes, which as described have an impact upon the condition of habitat. Secondly, tenure is of importance with regards to designing and implementing biodiversity offset schemes (Gordon et al., 2011b), affecting who has to pay or be paid to maintain restoration areas, and affecting the nature of legal agreements that ensure ongoing management of offset projects.

Discussions with Uzbek legal experts revealed that land can be effectively rented by private sector organisations seeking to explore and extract oil and gas—there is a legal obligation to retain environmental characteristics on such land, but no explicit guidance for biodiversity. Land can be temporarily rented for up to 10 years, or more permanently held, but is never owned. This means there is a lack of opportunity for private landowners to provide offset receptor sites, and for a private market in biodiversity credits. Whilst some speculate about reform to the land ownership system (Robinson et al., 2013), those consulted in Uzbekistan thought it unlikely that reform would take place in the short-term future.

There is an established framework of environmental legislation in place, and Uzbekistan is signatory to both the Convention on Biological Diversity and the Convention on Migratory Species. It is also a signatory to a Memorandum of Understanding and Action Plan on saiga conservation under the CMS, and to a bilateral agreement on saiga conservation with Kazakhstan. The legislation relevant to the implementation of an initial biodiversity offset policy in Karakalpakstan currently contains gaps. These is a requirement to evaluate and monitor the ecological impacts of industrial activities, and a no net loss compensation requirement (UNDP, 2010a). However, institutional capacity already exists to provide a basis for offsetting, particularly in relation to creating protected areas and managing the environmental impacts of industry. Furthermore, it is clear that offsetting may play an important part in conservation in the region, given that industrial expansion will happen, and that economic development may be a pre-requisite for effective conservation.

There currently exist at least three key institutional barriers to robust biodiversity offsetting: a lack of expertise in bringing the topic of biodiversity into the environmental impact assessment process; insufficient resources or capabilities to ensure compliance and enforce regulations in Karakalpakstan; and, a lack of independent organizations, such as environmental NGOs, to monitor offsetting activities.

4. The frame of reference

Having considered elements of the case study in isolation, we now attempt to combine them into a useful frame of reference. To do so, we use the data collated to form a baseline for each of the four categories within our framework, and use the trend and interaction analyses to project the likely system dynamics in the near future in the absence of intervention (i.e. the possible counterfactuals). The baseline and counterfactual scenarios together represent a frame of reference.

The data sets compiled here and in the Supplementary materials constitute the baseline for the case study—one of a landscape containing large areas of relatively intact habitat, with populations of typical Central Asian steppe, desert and riparian species. There are few endemics, because of the contiguous nature of the region’s arid ecosystems. Some species are at very low numbers or extirpated, within and adjacent to the now highly degraded Aral Sea. The area contains a sparse but established human population and industrial infrastructure (Table 1).

4.1. Interactions

We outline what we consider to be important interactions between the main conservation targets and key factors, and then create a set of potential counterfactuals that consist of projections based upon the trends identified above. Finally, we consider the differences between these alternative counterfactuals, and use this to generate questions that remain to be asked for conservation intervention in the Usturt.
A number of interactions fundamental to conservation in the region involve the Aral Sea. It is important to note that, whilst the drying of the Aral Sea interacts negatively with social and ecological components of the system, it interacts positively with industry by enabling new exploration opportunities. Even in the absence of biodiversity offsets or similar mechanisms, industry is inseparable from conservation efforts—this is due not only to causing direct impacts upon ecological targets, but in terms of interactions with the human population, which in turn influences poaching and grazing (Fig. 6).

4.2. Counterfactual

Looking to the future, climate models reported by the IPCC indicate a warming trend in the region, with rises of 3.7–6.6 °C in mean temperature by 2099 (Meehl et al., 2007). This may have implications for vegetation growth. Further, given that the saiga migration itself depends partly upon temperature, being to an extent triggered by snowfall (Esipov et al., 2009), rising temperatures may eventually change migration patterns, especially if interacting with the barrier effect of the Kazakhstan border fence (e.g. rising temperatures and a barrier may encourage the migratory component of the Ustyurt saiga population to stay north, within Kazakhstan). With high interannual variability in snowfall, this influence would be hard to detect in the short term.

The national human population is growing, which is partially reflected in the regional population in Karakalpakstan (Table A3). The main employers on the plateau are the extractive and transport sectors (gas extraction and the railway, respectively), and the extractive sector is currently undergoing growth. As it grows, new or expanded settlements are likely to appear to service and provide labour for new industrial installations—with associated natural resource use expansion, especially water and pastures for grazing. In the long term, evidence suggests that inappropriate grazing regimes can lead to desertification (Savory 1999), and there is visual evidence of this in the Ustyurt (Fig. A11). Localized desertification might therefore be expected to increase across the plateau as a result of expanding industry, overall population growth, and sustained or increasing numbers of livestock. Cotton will probably remain an important component of the economy for the foreseeable future. As a result of the requirements for both cotton irrigation and natural gas exploration on the dry seabed, a purposeful reversal of the drying of the Aral Sea on the shores immediately bordering the study area seems unlikely in the near future. Instead, drying through over-extraction of water resources may continue or accelerate.

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**Fig. 6.** Potential interactions between factors key to conservation planning in the Uzbek Ustyurt. Interactions were hypothesized based on knowledge of the study area, and then tested using available data.
Table 2
Projected counterfactual on the scale of decades, for conservation targets based on analyses in this manuscript, in the context of different drivers of change. Includes an alternative counterfactual projection.

<table>
<thead>
<tr>
<th>Target</th>
<th>Driver</th>
<th>Counterfactual</th>
<th>Alternative counterfactual</th>
</tr>
</thead>
</table>
| Habitat (vegetation cover) | Physical    | • Stable in the near future  
• Some deterioration in the long term | • Reverse of Aral Sea drying  
• Increase in green vegetation cover |
|                         | Social      | Habitat cleared over an increasingly large area near to expanding settlements | Settlements do not grow, additional habitat not cleared |
|                         | Economic    | Habitat cleared over an increasingly large area near to expanding industrial infrastructure | Economic activity moves away from sectors with large habitat impacts e.g. cotton |
|                         | Institutional | No fundamental change in institutional arrangements | Biodiversity becomes key component of impact assessment  
Land tenure reform results in more private ownership |
| Species (Saiga antelope) | Physical    | • Short term, limited effects  
• In the long term, climate change may limit migration | Small resident populations remain, migration no longer relevant |
|                         | Social      | Saigas poached to extirpation | Incentives to poach decrease, saiga population stable |
|                         | Economic    | Industrial activities expand, with some associated saiga mortality | Infrastructure increasingly divides up saiga range and limits movement |
|                         | Institutional | • No increase in protection  
• Political requirements result in maintained Kazakh border fence, increasing mortality and limiting movement | • Protection increases  
• Fence impact is mitigated, reducing barrier effect |

4.2.1. Counterfactual for habitat-based offsets

In physical terms, whilst green vegetation cover appears rather stable across the landscape, it is likely that in the future it will increasingly be influenced by global climatic factors as the Ustyurt becomes warmer and more arid. Social and economic factors are likely to drive an increasing number of areas that feature highly localized vegetation clearance, as a result of livestock grazing and industry. The institutional factor with the greatest potential to influence cover is land tenure reform, although it is not currently thought that this will take place in the near future.

Based on this information, one counterfactual for the Ustyurt habitat could be a stable habitat characterized by small patches of intense clearing and fragmentation, but with some ongoing landscape scale deterioration in the longer term. Pertinently, Bull et al. (2014) find that the use of biodiversity offsetting could be most appropriate for ecosystems that are deteriorating. This suggests that biodiversity offset projects could be required to demonstrate NNL through restoring areas of reduced vegetation cover.

An alternative and feasible counterfactual would be one in which the changing climate caused increased biodiversity and vegetation cover by creating more tolerable winter temperatures, the human population did not grow further (as per the Muyunak region, Table A3) and so resource use did not increase, and economic or institutional factors caused the drying of the Aral Sea to stop or even reverse (Table 2). To achieve NNL against such a counterfactual, it would be reasonable to require biodiversity offset projects to demonstrate larger habitat restoration or creation gains than against the first counterfactual scenario, in order to deliver the same amount of compensation for development losses (Bull et al., 2014). This illustrates how the choice of counterfactual can affect whether interventions are deemed successful, and can guide how much effort would be required to meet objectives.

4.2.2. Counterfactual for species-based offsets

There is no reason to conclude that the causes of species loss in the Ustyurt over the last century are abating or will do so in the near future, i.e. hunting or persecution of fauna to the extent that they disappear or almost disappear, increasing barriers to migration through infrastructure and fencing, and implementation of irrigation practices that drain the Aral Sea with indirect implications for wildlife (Micklin, 2007). In the longer term i.e. over decades, climate change might influence the saiga migration, but otherwise physical factors are unlikely to be of concern. Social and economic factors, conversely, are crucial, and there is a constant threat of extirpation of this population. In the absence of any further conservation intervention, it is likely that the Uzbek Ustyurt population will become extinct over the next decade.

Since the species counterfactual, then, is likely to be one in which the saiga population will remain low or potentially disappear entirely, an offset scheme targeted at saigas would need to realise a continuing viable saiga population to be additional (i.e. by removing poaching pressure and maintaining migratory routes through the border region even if they are unused). Alternatively, the small resident population of saigas could become a focus for an offset scheme, aiming to maintain or increase this population but without the expectation of returning to the very large migratory population of the past. This would conceivably influence conservation planning and biodiversity offset opportunities, as, if the overall objective was to conserve saiga and maintaining migrations into Kazakhstan became untenable; e.g. as a result of the border fence, or climate change; then focus could instead be directed towards management of resident saiga populations in situ (Table 2).

The combination of Tables 1 and 2 and Fig. 6 provides a basic frame of reference for conservation intervention, in terms of historical context, drivers, trends, interactions and projections. A key point, however, is that it is possible to develop alternative and often equally feasible frames of reference based upon analyses such as these (Table 2). Therefore, having developed two possible frames of reference, we now highlight specific questions that would allow the most likely counterfactual to be established.

4.3. Outstanding questions

Again, we structure the set of questions around a framework of physical, social, economic and institutional drivers (Table 3). From a physical point of view, the next stages in the ongoing drying of the Aral Sea will be important, as will monitoring how and if conservation targets respond to climate change. Changes in
Table 3
Outstanding questions relevant to establishing the projected counterfactual, and associated management implications.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Question</th>
<th>Management implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Will climate change limit and eventually stop the saiga migration into Uzbekistan?</td>
<td>Whether intervention focuses on protecting the migration route, or protecting resident Uzbek saigas</td>
</tr>
<tr>
<td></td>
<td>Will overall vegetation cover decrease, remain stable or increase as a result of increasing temperatures?</td>
<td>Whether habitat maintenance or active restoration is needed to demonstrate NNL</td>
</tr>
<tr>
<td></td>
<td>Will the Ustyurt Aral Sea drying be halted, or reversed (as has been demonstrated achieved for the small northern Aral)?</td>
<td>Whether some proportion of conservation effort should go towards reduction of impacts from the loss of the Aral sea</td>
</tr>
<tr>
<td>Social</td>
<td>Will the Ustyurt human population grow or decline?</td>
<td>Influences various components of the counterfactual, as a result of the connection with intensity of natural resource use</td>
</tr>
<tr>
<td></td>
<td>Will income and living standards improve?</td>
<td>May influence saiga poaching and who is carrying it out, and therefore appropriate conservation interventions</td>
</tr>
<tr>
<td>Economic</td>
<td>Will industry increase local employment rates and living standards?</td>
<td>May have an influence on living standards, natural resource use, livestock ownership</td>
</tr>
<tr>
<td></td>
<td>Does industrial activity have direct and significant impacts upon wildlife?</td>
<td>Whether expanding industry will displace wildlife entirely, or merely fragment habitat</td>
</tr>
<tr>
<td>Institutional</td>
<td>Will land tenure reform take place over the coming decades?</td>
<td>How to implement biodiversity offsets as a robust policy option</td>
</tr>
<tr>
<td></td>
<td>Will there be sufficient institutional capacity to ensure compliance with conservation legislation?</td>
<td>Whether biodiversity offsets are a feasibly robust policy option</td>
</tr>
<tr>
<td></td>
<td>Will independent environmental observers eventually be encouraged back into the country?</td>
<td>Whether biodiversity offsets are a feasibly robust policy option</td>
</tr>
</tbody>
</table>

the human population in the Ustyurt will affect natural resource use, and a good case could be made for both a projected increase and a decrease in population. Economic activity is very likely to keep expanding, but the form this will take and the implications for conservation targets are not yet entirely clear. Finally, whilst institutional arrangements do not appear likely to change in the immediate future, there are a number of potential changes (such as land tenure reform and improved conservation capacity) that, if they occurred, would have important ramifications for conservation in the Ustyurt.

5. Discussion

This case study demonstrates, as might be expected, that the collation and analysis of data sufficient to accurately establish the baseline and projected counterfactual necessary for the frame of reference for a conservation intervention can be complicated and uncertain. The availability of robust data, and the ability to analyze and process these data and take account of validity of assumptions, is essential to developing a truly robust frame of reference for conservation interventions. However a reasonable picture can be built even on the basis of limited data, as we have done here—and this is certainly preferable to not developing a reference frame at all. On the basis of the analyses here and in cited literature, we are unable to develop a defensible quantitative counterfactual e.g. a projected curve or distribution map for vegetation cover, or a population trajectory for the saiga antelope. However, useful, the disparate numerical and qualitative analyses have to be drawn together in a qualitative way (Tables 2, 3).

Interactions between drivers of change can be as important as direct drivers themselves. For instance, the influence of ongoing climate change on saigas could be more important for vegetation than the direct impacts of climate change. Further, different forms of interaction could potentially lead to the same driver (e.g. industry) having conflicting impacts on conservation targets (e.g. both promoting poaching and disturbance, and providing alternative employment for current poachers); which must therefore be addressed differently. The framework we have used here, of categorizing drivers into physical, social, economic and institutional domains and considering their interactions, provides a useful way of breaking down the system and understanding its dynamics within a wider context. Many other frameworks exist for categorizing drivers in such a way (e.g. the generic STEEP framework—Social, Technological, Economic, Ecological, Political), but we do not discuss the relative merits of different frameworks here.

In developing the frame of reference, we have attempted to partially address the common problem in doing so that assumptions are either not made explicit or are demonstrably wrong (Maron et al., 2013). The approach taken should make clear by implication where the key assumptions are. Further, by then developing more than one counterfactual, we have highlighted where our assumptions may be wrong (Table 2). The validity or otherwise of these assumptions can only be tested through ongoing monitoring and experimentation, which suggests the need to take an adaptive management approach to conservation when evaluating against a projected frame of reference.

Adaptive management provides a means for management under uncertainty, and involves the development of hypotheses to be tested in practice, which then inform future iterations of the management plan. It is conceptually popular within conservation science, but there are limited examples of it being used effectively in practice (Gregory et al., 2006; Armstrong et al. 2007). The set of questions we develop here (Table 3) could be framed as hypotheses, and thus usefully provides the basis for a form of adaptive management approach. It is noted that this Ustyurt case study does not meet a number of criteria suggested for appropriately implementing adaptive management—particularly the restricted spatial and temporal scale required for management, and the necessary institutional support (Gregory et al., 2006). But elements of the adaptive management approach, particularly the development of hypotheses at the outset that are then monitored for validity, seem highly relevant to the effective development of frames of reference.

6. Conclusion

In conclusion, we consider that understanding historical context, drivers and interactions are so important to the design of conservation interventions that a lack of data is an insufficient reason not to develop some form of reference frame. The approach taken here – of considering conservation targets in light of physical, social, economic and institutional factors – is useful in building a frame of reference. Further, it provides a means for making assumptions explicit, and leaving them open to further critical evaluation. Finally, by developing alternative feasible frames of reference, it is possible to outline testable hypotheses that can be used to improve future iterations of management plans, in a process that shares similarities with the approach of adaptive management.


