Conservation when nothing stands still: moving targets and biodiversity offsets

Joseph W Bull[1*], Kenwyn B Suttle[1], Navinder J Singh[2], and EJ Milner-Gulland[1]

Conservation is particularly difficult to implement for "moving targets", such as migratory species or landscapes subject to environmental change. Traditional conservation strategies involving static tools (eg protected areas that have fixed spatial boundaries) may be ineffective for managing species whose ranges are changing. This shortfall needs to be addressed urgently. More dynamic conservation-based approaches have been suggested but remain mostly theoretical, and so implementation issues and measures of success have yet to be explored. In recent years, however, the concept of biodiversity offsets has gained traction in the conservation community. Such offsets effectively replace biodiversity "lost" during current economic development projects, and are intended to ensure "no net loss" of biodiversity overall. Given their flexibility and unique no-net-loss requirement, offsets provide a platform for testing dynamic new approaches to conservation. Here we explore the potential for offsets to conserve moving targets, using a complex dynamic example: the migratory saiga antelope (*Saiga tatarica*) in Uzbekistan.

Front Ecol Environ 2013; 11(4): 203–210, doi:10.1890/120020 (published online 3 Apr 2013)

Conservation of biodiversity relies heavily on the use of protected areas (PAs) that are "fixed" in place on the landscape or seascape and therefore static in space and time (Rayfield *et al.* 2008). When conservation targets are not stationary on the same scale as their respective PAs – which is common – the effectiveness of PAs may be compromised. For instance, migratory or nomadic species, which might regularly move through a larger area than is feasible for PA designation, may be poorly served over much of their life cycle by static PAs (Singh and Milner-Gulland 2011). Habitats themselves may also "move" in space over longer time scales, driven by environmental change and anthropogenic activities. It is increasingly recognized that, to be effective, conservation planning must account for the dynamic nature of ecosystems (Nicholson *et al.* 2009) and do so at large spatial (eg landscape-level) scales.

In a nutshell:

- Conservation based on fixed protected areas and other static interventions is ineffective in a changing world
- Proposed approaches for dealing with "moving" conservation targets, such as migratory species, include mobile protected areas, which follow their targets across the landscape
- Biodiversity offsets are a promising new conservation mechanism that requires "no net loss" of biodiversity over time; the dynamic nature of biodiversity must be considered in offset design
- By using a case study of Uzbekistan's saiga antelope (*Saiga tatarica*), we show how offsets could provide a framework for dynamic conservation approaches

[1]*Imperial College London, Silwood Park, UK* [*](*j.bull10@imperial.ac.uk*); [2]*Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Sweden*

Various dynamic conservation proposals have been suggested but have yet to be widely tested in practice (Game *et al.* 2009; Milner-Gulland *et al.* 2011). One such method to address the problem of moving targets is the implementation of biodiversity offsets (henceforth "offsets"), which could potentially provide the necessary framework to test more dynamic conservation approaches. Here, we suggest how this system might work, using a case study from Uzbekistan.

Offsets have proliferated globally in recent years (Madsen *et al.* 2011). Their aim is to make "developers" (ie those implementing new economic projects or programs that involve land-use change or natural resource exploitation) fully compensate for any biodiversity losses associated with their activities. The concept of offsetting originated with the US Water Resources Act of the 1970s, which requires that development-oriented wetland loss or degradation in one location is offset by establishing "equivalent" wetlands elsewhere. While this legislation effectively results in the creation of fixed PAs, offsets are delivered through a range of alternative conservation actions. Offset schemes commonly attempt to achieve "no net loss" (NNL) of biodiversity overall (McKenney and Kiesecker 2010), although there is some variation in the outcomes and some even endeavor to achieve a net biodiversity gain. This NNL requirement necessitates specifying a project baseline against which to measure biodiversity losses and gains (Gordon *et al.* 2011).

NNL has been defined not only in terms of space (eg by maintaining the overall area of a given habitat) but also in time (eg by having to establish biodiversity gains before development proceeds; Bekessy *et al.* 2010). Any conservation intervention should, at a minimum, demonstrate NNL in space and time. However, offsets make this requirement explicit, thereby forcing those implementing

Figure 1. *Saiga antelope (*Saiga tatarica*).*

offsets to actively consider the uncertain and dynamic nature of conservation targets when specifying baselines and evaluating future conservation outcomes.

Uncertainty is partially controlled in offset schemes through the use of spatial and temporal "multipliers" (factors by which the amount of offsetting required per unit of projected biodiversity loss is increased, to account for uncertainty in both the biodiversity losses and the success of the offset itself; Moilanen *et al.* 2009). However, there is a difference between uncertainty inherent to ecological dynamics or lack of knowledge (which can be addressed through multipliers) and uncertainty in ecological outcomes as a result of projected external influences (eg human-mediated habitat loss or climate change). To achieve NNL, offsets should therefore be designed so that biodiversity gains are maintained despite external social and environmental trends. This challenging requirement sets offsets apart from more traditional approaches, in that they not only offer an opportunity to test dynamic approaches to conservation but, as a result of the NNL requirement, must incorporate such approaches.

In recent years, offsets have attracted the interest of businesses, governments, and non-governmental organizations, and are rapidly being implemented worldwide; examples include native grassland in Australia, fish habitat in Canada, Natura 2000 sites in the European Union, rainforest in Brazil, and animal species in the US (McKenney and Kiesecker 2010). Consequently, ensuring their effectiveness in an age of change is important to academics, practical conservationists, and policy makers.

Migratory species as a classic example of moving targets

It is not merely the case that many migratory species are endangered; more fundamentally, large-scale migration as a phenomenon is itself under threat (Harris *et al.* 2009). Numerous species migrate across such great distances that protecting their entire range is impossible, due to monetary cost, competing land uses, or complications involving geopolitical boundaries (Milner-Gulland *et al.* 2011). Fixed PAs occasionally benefit a migratory population even though coverage of its range is incomplete (eg wildebeest [*Connochaetes taurinus*] in the Serengeti; Thirgood *et al.* 2004). However, by failing to consider how populations are connected over the course of individuals' life cycles, PAs cannot generally be relied upon to conserve transient species. Martin *et al.* (2007) modeled the migratory American redstart (*Setophaga ruticilla*), predicting that protecting parts of its range could conserve the species, but only if the animals' requirements range-wide were considered. A similar prediction has been made for certain mobile fish species (Apostalaki *et al.* 2002).

As an alternative to fixed PAs, mobile PAs could prove valuable in marine conservation (Game *et al.* 2009) and for migratory species' conservation in general (Milner-Gulland *et al.* 2011). Mobile PAs "move" with the target species itself or temporarily coincide with vulnerable life stages. Although the former Soviet Union once implemented mobile PAs to track calving locations of the migratory saiga antelope (*Saiga tatarica;* Figure 1) in Kazakhstan (Robinson *et al.* 2008), the concept is mainly hypothetical. Mobile PAs have been proposed that change location annually for Canadian caribou (*Rangifer tarandus*; Taillon *et al.* 2012) and in real time for southern bluefin tuna (*Thunnus maccoyii*) off Australia (Hobday and Hartmann 2006). Shillinger *et al.* (2008) recommended temporary marine PAs covering annual migration corridors for leatherback sea turtles (*Dermochelys coriacea*). Notably, the managers of mobile PAs will require the cooperation of resource users (Hobday and Hartmann 2006), availability to and timely processing of data (Taillon *et al.* 2012), and freedom to position reserve boundaries as required by the target species (Rayfield *et al.* 2008).

Environmental change as an emerging driver of moving targets

Species' migratory movements are often a predictable response to regularly fluctuating resources (Dingle and Drake 2007). Environmental change, on the other hand, can drive variation in species' distribution that is open-ended, takes place over a longer time scale, and may affect species that might otherwise be sedentary. Such movement may be more widespread and harder to predict.

Of the many forms of environmental change – including habitat modification and fragmentation, as well as other human-mediated disturbances – that can drive species' movements, climate change may emerge as the most consequential. The implications of climate change for the future effectiveness of PAs are important topics of future research (Hannah *et al.* 2007; Singh and Milner-Gulland 2011). A changing climate not only influences ecological dynamics but also affects the human behaviors

that drive biodiversity loss. Climate sets near-absolute bounds upon where a species could exist and interacts with other factors in determining where and at what abundance that species actually occurs. Climatic forcing can cause physiological, behavioral, numerical, and distributional changes in species, both directly and through effects on ecological interactions (Parmesan 2006; Suttle *et al.* 2007). Furthermore, human adaptation in response to climate change may alter environmental relationships in ways that produce further ecological feedbacks (Nicholson *et al.* 2009). For these reasons, changing climate regimes will influence PA effectiveness. Poiani *et al.* (2011) estimated that, of a sample of 20 existing conservation projects, more than half would require major alterations if climate-change impacts were considered.

In cases where species' ranges are projected to shift in response to climate change, mobile PAs could facilitate conservation. For instance, Rayfield *et al.* (2008) predicted that reserves tracking spatial habitat shifts could be effective for the American marten (*Martes americana*). In this study, models suggested that, over 200 years, such reserves would perform better than static reserves. Discussion has also focused on designing PA networks that are resilient to climate change through the use of dispersal corridors and less vulnerable core refugia (Malhi *et al.* 2008), careful spatial planning based on habitat type (Hannah *et al.* 2007), and projections of habitat suitability (Singh and Milner-Gulland 2011).

Such approaches are difficult to implement because they are subject to future conditions. Predictions regarding ecological responses to climate change involve numerous sources of uncertainty (Walther 2010), thereby necessitating that related conservation efforts take an adaptive-management approach (Heller and Zavaleta 2009). In order to implement successful offsets, consideration must be given to ecosystem dynamics, socioecological trends, and uncertainty, because otherwise NNL cannot be guaranteed. Consequently, offsets provide an appropriate mechanism through which some of the proposed new approaches to conservation might be tested.

Table 1. Examples of biodiversity offset schemes that affect migratory species

No-net-loss target	*Biodiversity offset objective*	*Example*	*Challenges for mobile/migratory species*
Habitat	Any habitat degraded or lost through development is replaced with created/restored habitat (indirect species conservation is assumed).	EU Natura 2000 sites (McKenney and Kiesecker 2010)	Species are not explicitly targeted or conserved, so it cannot be assumed they will be conserved along with their habitat.
Habitat used by migratory species	Any area of habitat used by a migratory species that is degraded or lost through development is replaced with created/restored habitat that is also used by that migratory species.	Pronghorn antelope (Kiesecker *et al.* 2009)	Habitat type/condition may change with time (eg degrade due to climate change). Migratory species may change preference to a different site.
Species' migration route	Any negative impacts of development upon the migration route of a species are offset by actions that preserve that migration route.	Saiga antelope (UNDP 2010)	Species may change migration route. Species migration might stop entirely.
Migratory/mobile species (direct)	Any negative impacts of development upon a population of migratory species are offset by actions that conserve that population.	White-tailed sea eagle (Cole 2010)	Species may begin to be impacted by factors that are outside the scope of the offset scheme. The proportion of the population migrating may change.
Migratory/mobile species (indirect)	Any negative impacts of development upon a population of migratory species are offset by actions that conserve that species elsewhere in its range/life cycle.	Seabirds (Wilcox and Donlan 2007)	Species may begin to be impacted by factors that are outside the scope of the offset scheme. Difficult to demonstrate equivalence between different stages of a species' life cycle.
Ecosystem function	Any loss of functional value provided by a habitat and associated migratory species following development is restored, via the provision of that habitat/species or similar habitat/species elsewhere.	US wetlands (McKenney and Kiesecker 2010)	Habitat/species may cease providing function. Habitat/species may provide function somewhere else.
Combination of the above	Any losses of habitat, species, or ecosystem function following development are compensated for in-kind.		Relationship between species/habitat/ecosystem function might change such that offset goals become incompatible (eg different species might develop conflicting spatial conservation requirements).

Notes: Table contents appear (from top to bottom) roughly in order of increasing consideration given to the mobile nature of migratory species.

Biodiversity offsets and moving targets

Although having already been implemented or proposed in ecosystems involving moving conservation targets, offsets have not necessarily been designed to fully account for such targets.

Biodiversity offsets and migratory species

The appropriate interpretation of NNL for migratory species is beset with challenges, including whether and how to consider influences on the viability of migratory populations outside of the development and offset areas, and how to account for changes in movement dynamics within the project's time scale (Table 1). These issues are not always explicitly considered. For instance, Kiesecker *et al.* (2009) modeled offsets for the Jonah natural gas field in the western US. The field is underneath desert sagebrush, which provides habitat for the migratory pronghorn antelope (*Antilocapra americana*) and various bird species. Models suggest that most of the proposed offset's objectives could be achieved in 30–50 years through the use of fixed PAs. However, the objectives are framed in terms of habitat restoration and protection, under the assumption that transient species will be conserved along with their habitat. As previously discussed, this assumption may not hold for migratory species that do not live exclusively within PAs and that are subject to other threats.

Instead of being targeted by fixed PAs and existing offset methodologies, highly mobile species could be targeted anywhere within their range where they are vulnerable to development-related impacts. Cole (2010) used a European resource equivalency methodology to design compensation for impacts of the Smøla Wind Farm in Norway on white-tailed sea eagle (*Haliaeetus albicilla*) populations. In this case, the units used are "bird-years" (discounted sea eagle life expectancy). Wind farms cause direct sea eagle mortality in the region. The scheme proposes compensation for new farms by retrofitting existing farms with technologies that greatly reduce sea eagle mortality, resulting in NNL of bird-years relative to the status quo.

Alternatively, offsets could incorporate the approach of targeting the most vulnerable stages in a species' life history, rather than the life stages directly affected by development. For example, Wilcox and Donlan (2007) proposed an offset for seabird bycatch among commercial fisheries in which fishermen would pay a levy for unavoidable seabird mortality, to fund the removal of invasive species from island breeding sites elsewhere in the birds' range. Wilcox and Donlan (2007) used a bioeconomic simulation to predict that such an approach would effectively achieve NNL.

Biodiversity offsets and environmental change

Offsets have arguably been most effective when specifically designed to account for environmental change, such as in Victoria, Australia, for example, where legislation requires compensation for cleared native grassland. The original range of native Victorian grassland has greatly contracted, and remnants are now threatened by habitat-degrading invasive species. Offset sites are now being actively managed to suppress or remove invasives and prevent future decline in habitat condition, as well as restoring previously degraded sites. Consequently, because they have been designed with respect to background trends, these offsets could deliver genuine ecological gains in native grassland condition over time (Gordon *et al.* 2011). However, offsets in general are effective only where practical challenges, such as ensuring ongoing monitoring and regulatory compliance, are also being addressed (Bekessy *et al.* 2010); this may in part explain the relative success of the Victorian offsets.

The NNL requirement leads to questions about how the performance of a conservation intervention is defined and measured. The perception as to whether NNL has been achieved changes substantially when outcomes are measured against different baselines (Gordon *et al.* 2011). For instance, if the offsets are evaluated by a "business as usual" baseline of development, grassland conversion, and deterioration, then NNL of Victorian grassland is achieved through offsets. However, the same offset policy with the same absolute ecological outcomes for grasslands might record losses if compared to a fixed historical baseline, because (1) the managed grasslands are only improving relative to declines elsewhere rather than in absolute terms, (2) conversion is still ongoing outside the offset sites, and (3) landscape quality as a whole is deteriorating.

The saiga antelope in Uzbekistan

A situation characterized by contemporary environmental degradation, projected climate-change-related impacts, high uncertainty, and a paucity of available data would complicate conservation efforts for many species, let alone imperiled migratory organisms. Any attempt to define NNL, implement an offset, and report against meaningful baselines under such circumstances could be doomed to failure. Nonetheless, an offset scheme is under development in just such a case: a project to compensate for petroleum and natural gas development impacts in Uzbekistan, with the migratory saiga antelope (hereafter "saiga") as a key conservation target.

Background

The saiga population has declined by 95% since the fall of the Soviet Union, and the species is listed as Critically Endangered on the International Union for Conservation of Nature Red List (Figure 2a). Poaching represents the primary driver of this decline (Figure 2b; Kühl *et al.* 2009), although environmental change and economic development across the species' range may also be responsible (CMS 2010). Here, our focus is the isolated trans-

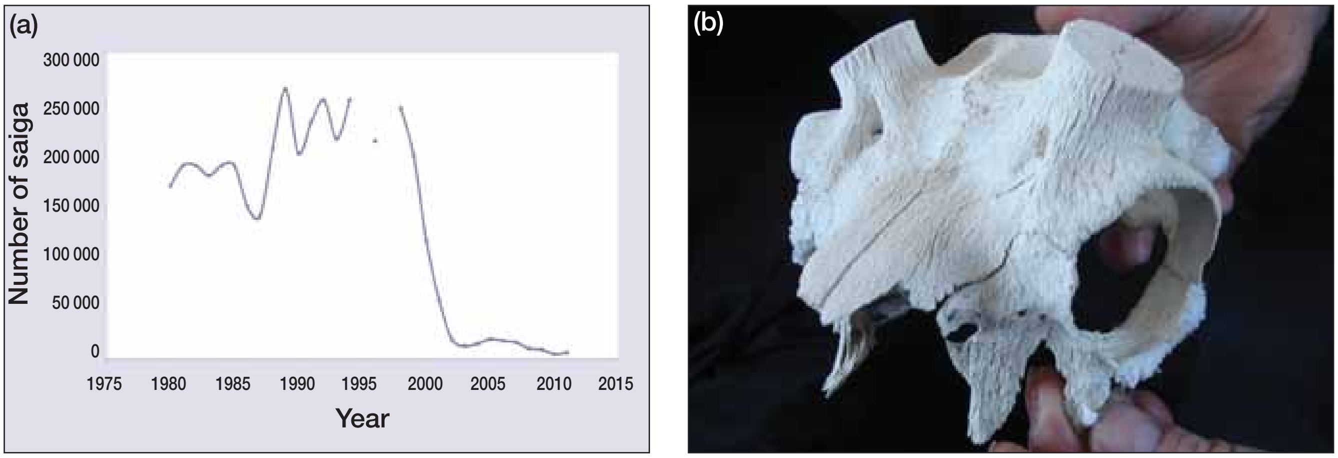

Figure 2. *(a) Recent trends in abundance for the Ustyurt saiga population, which is declining despite the presence of a protected area in the Uzbek portion of its range. (b) A saiga that was poached for its horn in its Uzbek winter range, in an area without effective protection.*

boundary population inhabiting the Ustyurt Plateau, which spans the border between Kazakhstan (where the population summers) and Uzbekistan (where it migrates to during winter).

Saiga migration is driven by climate and forage availability (Singh *et al.* 2010a), and saiga calving sites have shifted northward in recent decades in response to changes in both climate and forage (Singh *et al.* 2010b). The Intergovernmental Panel on Climate Change projects that temperatures will rise considerably during this century, by as much as 6°C in Central Asia (Figure 3a), which would probably force further regional shifts in saiga habitat use. The combined impact of climate change and poaching on the distribution and migratory patterns of the Ustyurt saiga may be substantial (Singh and Milner-Gulland 2011).

Having experienced major environmental change in recent history, the Ustyurt Plateau is bordered to the east by the Aral Sea, the areal extent of which has decreased by ~50% since the 1950s as a direct result of irrigation-related water withdrawals (Figure 4b). More than 40 000 km^2 of its former seabed is now exposed and is a highly saline new desert, characterized by chemical pollution. Prevailing winds deposit substantial amounts of dust from the exposed seabed on the plateau (Ataniyazova 2003). Since the fall of the Soviet Union, domestic livestock husbandry practices have changed; currently, livestock density is highest near human infrastructure but is virtually absent from more distant pastures. Grazing reduction and redistribution processes have led to shifts in plant species composition (Figure 3b; Opp 2005) and will likely continue to influence landscape condition in the future, thereby affecting regional conservation and sustainable development schemes.

The saiga's capacity to respond to this environmental forcing is constrained by growing anthropogenic disturbances on the Ustyurt (Figure 4a). Saigas react strongly to disturbance, which will increase with expanding natural gas development and infrastructure intensification – including new roads – and fencing on the Kazakh side of the border. Uzbekistan is one of the world's top 20 natural-gas-producing nations (Effimoff 2000) and contains 194 confirmed oil and gas reserves with a combined economic potential of US$1 trillion (UNDP 2010). The Ustyurt and Aral regions form one of the country's two main gas extraction areas and contain more than 10 gas fields; there are currently at least five foreign companies in product-sharing agreements with Uzbekneftegaz, the state-owned gas company, and foreign investment for gas extraction and exploration activities totals US$3 billion (UNDP 2010; EIA 2012).

Making offsets a dynamic conservation tool

The Uzbek Government is collaborating with the United Nations Development Programme to investigate mitigation and compensation measures, including offsets, for reducing impacts to biodiversity from the extractive sector. Broadly, offsets would create conservation zones with ecological values equal to or exceeding those lost due to industrial development. These zones would be protected and the habitat within them potentially restored to benefit target conservation species, with varying restrictions on further natural resource use inside the zones by either companies or individuals. One proposal requires companies active in the area to fund 80% of management and anti-poaching enforcement costs in a greatly expanded "Saigachy" PA, as compensation for direct impacts elsewhere on the Ustyurt Plateau (Figure 4a; UNDP 2010). The smaller existing Saigachy PA is effectively inoperative at the present time.

Such a PA would protect the semi-arid desert habitat of the plateau and associated species assemblages, with saigas as the region's flagship conservation target; companies would provide equipment and financing for the reserve for the lifetime of their development activities. In the absence of enforcement, effective protection within the reserve will cease, and illegal hunting of saigas

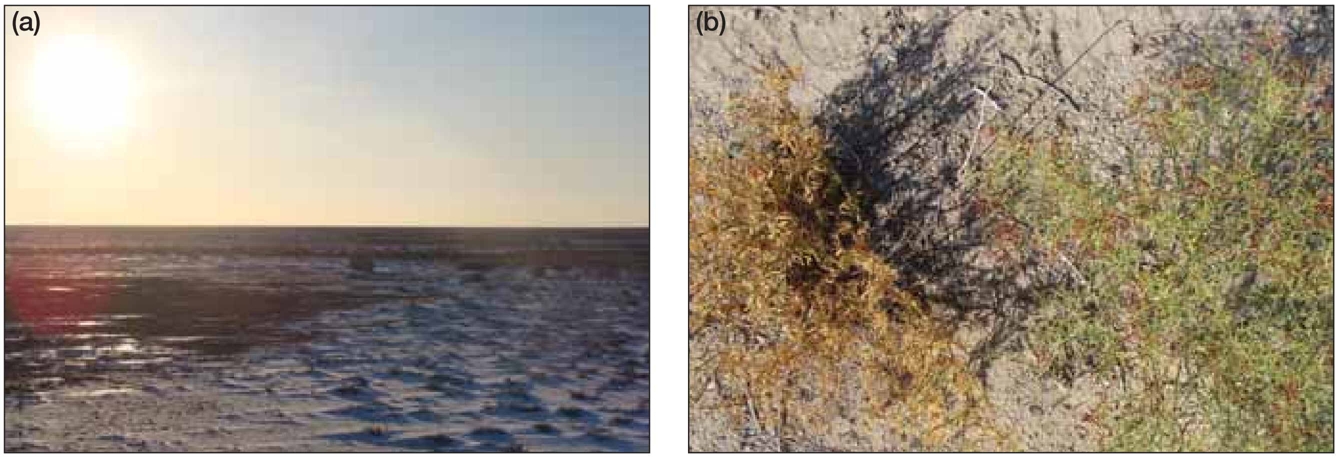

Figure 3. *Evidence of environmental change. (a) The Uzbek Ustyurt Plateau in late winter. Winter temperatures have trended upward over the past 30 years. (b)* Alhaji *spp (right), an excellent livestock forage crop, alongside* Piganum *spp (left), a poor forage crop and an indicator of rangeland degradation.*

throughout their winter range will likely continue. Therefore, while the offset would not promote additional biodiversity, it would prevent impacts from multiple sources unrelated to oil and gas activities, thereby avoiding potentially substantial projected losses.

One key objective for the proposed offset is to prevent further decline and potential extirpation of the saiga in Uzbekistan. To satisfy the NNL requirement, managers must assess current and future species abundance and population dynamics. Simply protecting the saiga in a fixed PA within Uzbekistan is insufficient, given that saigas are also heavily poached in Kazakhstan (Kühl *et al.* 2009). Consequently, as offset actions are not limited to fixed PAs, the offset should incorporate other conservation activities. Clearly, the problem of conserving the saiga along with its habitat must also be viewed in a landscape context, rather than just at the development project level.

One conservation option would be to fund anti-poaching measures in Uzbekistan and Kazakhstan during the winter and summer, respectively. Another option could finance mobile PAs that track the most vulnerable parts of the saiga life cycle (eg calving locations). Studies that clarify the spatiotemporal dynamics of poaching will help to identify areas requiring improved enforcement and to determine where to establish PAs. If PAs must be fixed, then an ecological network approach might be considered (for instance, relying on dispersal corridors and refugia). Alternatively, as discussed by Cole (2010), conservation efforts could be targeted at reducing incentives that result in species' impacts: for example, by preventing poachers from using known saiga-product trading routes (such as the railway) or discouraging human inhabitants in the Ustyurt from poaching. This alternative might include various interventions, from training enforcement dogs (to locate saiga horn) to creating alternative livelihoods for economically disadvantaged families that might otherwise poach. Offsets involving an internationally integrated approach could be possible within the framework of the international Memorandum of Understanding on saiga conservation, signed by both Kazakhstan and Uzbekistan under the Convention on Migratory Species (CMS 2010).

Because saigas may be an inadequate proxy for assessing the condition of biodiversity on the Ustyurt Plateau, offsets could focus on habitat conservation instead. In this case, achieving NNL would also require consideration of regional environmental change. On the plateau, habitat degradation due to salinization and incompatible grazing regimes provides baseline conditions for establishing NNL. Implementing more appropriate grazing practices might then be an effective countermeasure; likewise, on a larger scale, efforts to protect or restore the Aral Sea, as explored in Kazakhstan through improved water and irrigation management, could generate positive conservation outcomes. Since gas exploration opportunities are available under the exposed Aral seabed, this strategy might be unlikely to receive support from those entities funding the offsets. These dynamic conservation options are displayed schematically in Figure 4c.

Although these and other measures (WebTable 1) are theoretically feasible, their practical achievement will require considerable effort. In particular, national legislation in Uzbekistan does not currently contain the measures needed to implement offsets successfully; there is a need to amend the laws on Subsurface Resources, Territorial Planning, and Protection and Use of Flora and Fauna to include a mitigation hierarchy and biodiversity assessment guidelines (UNDP 2010). Furthermore, in Uzbekistan and Kazakhstan, past difficulties in ensuring compliance with anti-poaching legislation must be directly addressed, either within the offset or independently.

Summary

This case study illustrates some of the challenges concerning conservation in a dynamic world. The currently proposed offset scheme would primarily result in a single fixed PA, which fails to cover the target species' entire range and life-cycle components crucial to impede further popu-

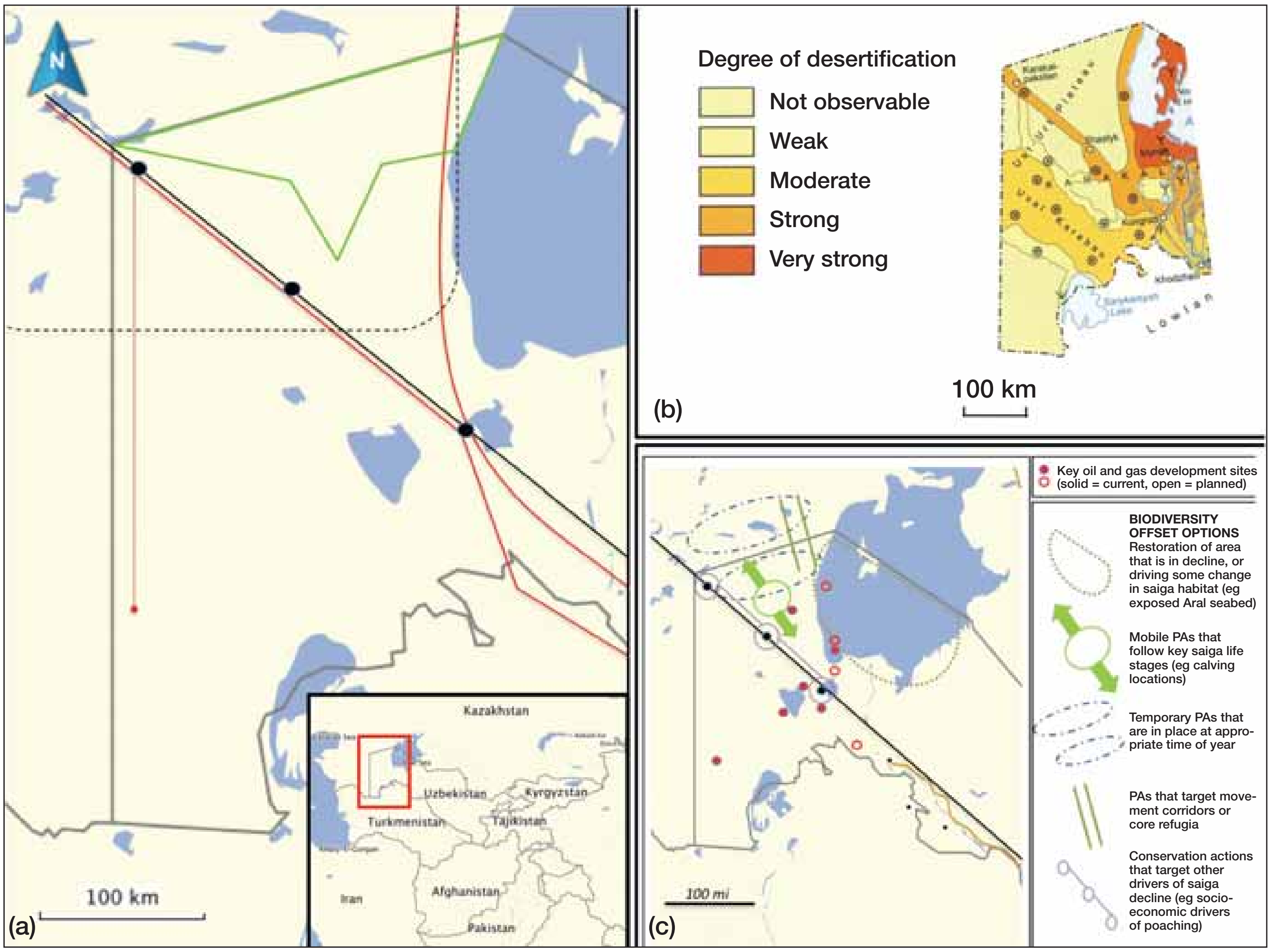

Figure 4. *(a) Schematic of the Ustyurt Plateau in northwest Uzbekistan. Red lines indicate oil and gas pipelines, the black line signifies railways, the dashed area represents the saiga's winter range, and the green area depicts the "Saigachy" reserve. (b) Desertification in the region (modified from Opp 2005). The previous extent of the Aral Sea, now exposed seabed, is indicated in red. (c) Schematic of the area of interest, displaying some of the dynamic conservation actions suggested in the main text.*

lation declines. The relative futility in applying static conservation tools to dynamic targets is exemplified by the saiga, a migratory species within a changing habitat. However, in explicitly considering the mobile nature of both the species and its habitat, proposals for an offset framework to test more dynamic conservation approaches could be explored (WebTable 1). More detailed research and adaptive management would be necessary to establish which of the suggested approaches would be most effective, especially given practical considerations like ensuring regulatory compliance. Likewise, political considerations would inform discussions regarding the use of transboundary offsets. However, this offset scheme offers a framework into which these dynamic approaches can be incorporated, explored, and implemented.

Conclusions

Fixed PAs, which exemplify the still largely static approach to conservation, are insufficient to protect biodiversity in a rapidly changing world. Dynamic new ways to conserve nature (eg mobile PAs, habitat management to prevent declining condition against future baselines, conservation efforts that address vulnerable parts of species' life cycles, and the shifting incentives that resource users face) may prove considerably more effective than traditional static conservation efforts and need to be implemented now.

Offset schemes are supposedly structured in a way that can address the dynamic nature of conservation targets. By requiring NNL of biodiversity within a region and over a specified time period, these schemes account for spatial and temporal dynamics. Because of this requirement and due to their widespread adoption, offsets present an opportunity to implement and test dynamic conservation approaches in the field. Such approaches can be designed into offset schemes in an adaptive manner, with evaluation of their effectiveness as an integral component thereof. Success will require a strong stakeholder commitment to compliance with the underlying rationale of offsets, rather than merely acknowledging the concept of NNL. By exploiting this opportunity, we may

begin to be able to conserve moving targets, a crucial aim in a changing world.

Acknowledgements

JWB acknowledges the support of a Natural Environmental Research Council (NERC) CASE award, NJS was funded by the Thematic programme in Wildlife and Forestry at the Swedish University of Agricultural Sciences, and EJM-G acknowledges the support of a Royal Society Wolfson Research Merit award. We also thank Fauna and Flora International (FFI) for financial support, and P Hotham for support and advice. This research was conducted with funding from the Australian Research Council Centre of Excellence for Environmental Decisions (CEED).

References

Apostolaki P, Milner-Gulland EJ, McAllister MK, and Kirkwood GP. 2002. Modeling the effects of establishing a marine reserve for mobile fish species. *Can J Fish Aquat Sci* **59**: 405–15.

Ataniyazova OA. 2003. Health and ecological consequences of the Aral Sea crisis. Panel III: environmental issues in the Aral Sea Basin. 3rd World Water Forum Regional Cooperation in Shared Water Resources in Central Asia; 18 Mar 2003; Kyoto, Japan.

Bekessy SA, Wintle BA, Lindenmayer DB, *et al.* 2010. The biodiversity bank cannot be a lending bank. *Conserv Lett* **3**: 151–58.

CMS (Convention on Migratory Species). 2010. Overview report: second meeting of the signatories to the memorandum of understanding concerning conservation, restoration and sustainable use of the saiga antelope. www.cms.int/species/saiga/2ndMtg_Mongolia/Mtg_docs/Doc_06_Add1_Rev1_Overview_Report_E.pdf. Viewed 18 Sep 2012.

Cole S. 2010. How much is enough? Determining adequate levels of environmental compensation for wind power impacts using equivalency analysis: an illustrative and hypothetical case study of sea eagle impacts at the Smøla Wind Farm, Norway. European Offshore Wind Conference; 14–16 Sep 2009; Stockholm, Sweden. Epsilon Open Archive Publishing, Swedish Agricultural University. http://pub.epsilon.slu.se/4671//. Viewed 13 Dec 2012.

Dingle H and Drake VA. 2007. What is migration? *BioScience* **57**: 113–21.

Effimoff I. 2000. The oil and gas resource base of the Caspian region. *J Petrol Sci Eng* **28**: 157–59.

EIA (US Energy Information Administration). 2012. Country analysis: Uzbekistan. www.eia.gov/countries/cab.cfm?fips=UZ. Viewed 18 Sep 2012.

Game ET, Grantham HS, Hobday AJ, *et al.* 2009. Pelagic protected areas: the missing dimension in ocean conservation. *Trends Ecol Evol* **24**: 360–69.

Gordon A, Langford WT, Todd JA, *et al.* 2011. Assessing the impacts of biodiversity offset policies. *Environ Modell Softw* **144**: 558–66.

Hannah L, Midgley G, Andelman S, *et al.* 2007. Protected area needs in a changing climate. *Front Ecol Environ* **5**: 131–38.

Harris G, Thirgood S, Hopcraft JGC, *et al.* 2009. Global decline in aggregated migrations of large terrestrial mammals. *Endangered Species Res* **7**: 55–76.

Heller NE and Zavaleta ES. 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biol Conserv* **142**: 14–32.

Hobday AJ and Hartmann K. 2006. Near real-time spatial management based on habitat predictions for a longline bycatch species. *Fisheries Manag Ecol* **13**: 365–80.

Kiesecker JM, Copeland H, Pocewicz A, *et al.* 2009. A framework for implementing biodiversity offsets: selecting sites and determining scale. *BioScience* **59**: 77–84.

Kühl A, Balinova N, Bykova E, *et al.* 2009. The role of saiga poaching in rural communities: linkages between attitudes, socio-economic circumstances and behaviour. *Biol Conserv* **142**: 1442–49.

Madsen B, Carroll N, Kandy D, and Bennett G. 2011. State of biodiversity markets report: offset and compensation programs worldwide. Washington, DC: Forest Trends.

Malhi Y, Roberts JT, Betts R, *et al.* 2008. Climate change, deforestation, and the fate of the Amazon. *Science* **319**: 169–72.

Martin TG, Chadès I, Arcese P, *et al.* 2007. Optimal conservation of migratory species. *PLoS ONE* **2**: e751.

McKenney B and Kiesecker JM. 2010. Policy development for biodiversity offsets: a review of offset frameworks. *Environ Manage* **45**: 165–76.

Milner-Gulland EJ, Fryxell JM, and Sinclair ARE (Eds). 2011. Animal migration: a synthesis. Oxford, UK: Oxford University Press.

Moilanen A, Teeffelen AJ, van Ben-Haim Y, and Ferrier S. 2009. How much compensation is enough? A framework for incorporating uncertainty and time discounting when calculating offset ratios for impacted habitat. *Restor Ecol* **17**: 470–78.

Nicholson E, Mace GM, Armsworth PR, *et al.* 2009. Priority research areas for ecosystem services in a changing world. *J Appl Ecol* **46**: 1139–44.

Opp K. 2005. Desertification in Uzbekistan. *Geogr Rundschau Int Ed* **1**: 12–20.

Parmesan C. 2006. Ecological and evolutionary responses to recent climate change. *Annu Rev Ecol Evol S* **37**: 637–69.

Poiani K, Goldman RL, Hobson J, *et al.* 2011. Redesigning biodiversity conservation projects for climate change: examples from the field. *Biodivers Conserv* **20**: 185–201.

Rayfield B, James P, Fall A, and Fortin M. 2008. Comparing static versus dynamic protected areas in the Québec boreal forest. *Biol Conserv* **141**: 438–49.

Robinson R, Crick H, Learmonth J, *et al.* 2008. Travelling through a warming world: climate change and migratory species. *Endangered Species Res* **7**: 87–99.

Shillinger GL, Palacios DM, Bailey H, *et al.* 2008. Persistent leatherback turtle migrations present opportunities for conservation. *PLoS Biol* **6**: 1408–16.

Singh NJ, Grachev IA, Bekenov AB, and Milner-Gulland EJ. 2010a. Tracking greenery across a latitudinal gradient in central Asia – the migration of the saiga antelope. *Divers Distrib* **16**: 663–75.

Singh NJ, Grachev IA, Bekenov AB, and Milner-Gulland EJ. 2010b. Saiga antelope calving site selection is increasingly driven by human disturbance. *Biol Conserv* **143**: 1770–79.

Singh NJ and Milner-Gulland EJ. 2011. Conserving a moving target: planning protection for a migratory species as its distribution changes. *J Appl Ecol* **48**: 35–46.

Suttle KB, Thomsen MA, and Power ME. 2007. Species interactions reverse grassland responses to changing climate. *Science* **2**: 640–42.

Taillon J, Festa-Bianchet M, and Côté SD. 2012. Shifting targets in the tundra: protection of migratory caribou calving grounds must account for spatial changes over time. *Biol Conserv* **147**: 163–73.

Thirgood S, Mosser A, Tham S, *et al.* 2004. Can parks protect migratory ungulates? The case of the Serengeti wildebeest. *Anim Conserv* **7**: 113–20.

UNDP (United Nations Development Programme). 2010. Mainstreaming biodiversity into Uzbekistan's oil and gas sector policies and operations. www.undp.uz/en/projects/project.php?id=166. Viewed 18 Sep 2012.

Walther GR. 2010. Community and ecosystem responses to recent climate change. *Philos T R Soc B* **365**: 2019–24.

Wilcox C and Donlan J. 2007. Compensatory mitigation as a solution to fisheries bycatch–biodiversity conservation conflicts. *Front Ecol Environ* **5**: 325–31.

