

Ornithology from the Flatlands

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Ornithology from the flatlands

SATELLITE SENSING OF GREENNESS AND THE RESOURCE LANDSCAPES OF BIRDS

That we, inevitably, all have our biases, is implicated in this beautiful line of Geertz (1973): “We all begin with the natural equipment to live a thousand kinds of life but end in the end with having lived only one.” Growing up scientifically in the 1980s in the family of investigators around Rudi Drent, one such bias in my own development as a biologist is the constant concern about proper measurement of food availability to explain the distribution of animals eating that food. Drent instilled in us the conviction that not only should we know precisely what birds eat, if necessary up to the level of individual birds, to explain bird distributions we should always take into account the birds’ sensory capacities and limitations, their digestive physiology and the behavioural or other characteristics of their prey species. To try to answer the sort of questions about distribution and movement that still keep us busy today, under Drent’s influence Leo Zwarts developed advanced concepts of food ‘harvestability’ for different prey types and their shorebird predators (e.g. Zwarts & Dirksen 1990, Zwarts & Wanink 1993), whilst Jouke Prop was making painstakingly detailed field and laboratory observations on the characteristics of food plants as well as the feeding behaviour of the geese eating them (Prop & Deerenberg 1991, Prop & Vulink 1992). This tradition carries on to the present day (e.g. Oudman *et al.* 2018).

At the end of an introductory lecture in late 1977, Drent asked our class of biology students whether any of us would be interested in joining him for a weekend on the island of Schiermonnikoog. He needed hands to calibrate a new instrument, a ‘green-meter’ to measure standing stocks of food plants for geese on the salt-marsh. His research technician was to take a local reading with the instrument, collect that quadrant of vegetation, whilst we were instructed to sort the plant samples and separate the green and the non-green parts. These would be dried and weighed, and I do

remember a graph showing a positive correlation between the reading on the green-meter and the biomass of the green parts. We had a wonderful weekend. However, it also had the effect that I realized that ‘research on geese’ would actually mean ‘research on plants’. Being more interested in organisms that move and behave faster than plants do, I eventually opted to put my own focus on Red Knots *Calidris canutus*, exceptional migrants that during the non-breeding season habitually eat snails and bivalves. As shown by Zwarts & Blomert (1992), these shorebirds had well-defined food availability characteristics (to which we added a few later; van Gils *et al.* 2005, Yang *et al.* 2013), which we should be able to measure widely.

The instrument to be calibrated that fateful weekend on Schiermonnikoog measured ‘greenness’, technically known as the Normalized Difference Vegetation Index or NDVI (Pettorelli *et al.* 2005, 2011, Didan *et al.* 2015). Even by then, similar instruments mounted on satellites were available to measure NDVI across much of the Earth (Rouse *et al.* 1974). I cannot remember whether this hugely exciting prospect was discussed during the weekend. The measure of greenness, NDVI, is a ratio of the reflected amount of near-infrared light minus the amount of red light divided by the sum of these two parts of the light spectrum. This works because green leaves, to power photosynthesis, reflect much of the incoming near-infrared light and absorb much (and reflect little) of the red light, thus yielding high ratios (high NDVI or greenness) when there is a lot of photosynthesis going on at a location, indicating that there is a lot of photosynthetically active plant biomass (Pettorelli *et al.* 2011). The NDVI has values below zero for water surfaces and it is close to zero for clouds, snow, bare soils and concrete (Neigh *et al.* 2008). Clouds obstruct the view of what is happening below, but with clear blue skies NDVI is a good measure to

monitor agricultural fields where vegetation is killed by the application of glyphosate-based herbicides (Pause *et al.* 2019).

The use of NDVI has become a veritable ‘scientific cottage industry’ as well as a concern for major academic players. As a keyword, NDVI meanwhile assembled 14,000 citations in Web of Science, with clear exponential growth over the last decade. NDVI is obviously a fantastic measure to describe the seasonal greening and browning of whatever part of the world one is interested in (Verbyla 2008). Mueller *et al.* (2008) were able to capture 85% of the actual distribution of Mongolian Gazelles *Procapra gutturosa* on the basis of NDVI values of their potential grazing habitat in the eastern steppes of Mongolia. They could then explain why the gazelles had to be on the move all the time: only 15% of the area was consistently good enough (and only 1% was formally protected). Examining six species of large North American mammalian herbivores, Merkle *et al.* (2016) showed that the seasonal migrations of seven of 10 study populations were well explained by them tracking the highest instantaneous rates of green-up (calculated as the rate of change in NDVI over time), hence, ‘surfing the green wave’.

Of course, as envisioned by Drent, NDVI has much to offer students of migratory avian herbivores as well. Although he let his own opportunity for this go, instead relying on hard-won sequential food plant sampling at various localities along the Russian flyway of Barnacle Geese *Branta leucopsis* to find patterns of site and forage use consistent with the ‘green wave hypothesis’ (van der Graaf *et al.* 2006), almost a decade later, a team, including some of his students, were the first to apply NDVI measures to avian herbivores, again on Barnacle Geese migrating along the same and two other flyways (Shariatnajaabadi *et al.* 2014). They confirmed that all three populations tracked high quality food during the migrations from temperate wintering to tundra breeding areas.

Now there are smaller animals than geese and bison that eat plants, herbivorous insects of various life stages for example, and then there are flying animals eating these insects! A first such study bringing NDVI and secondary consumers together involved Drent himself. Trierweiler *et al.* (2013) examined the movements of Montagu’s Harriers *Circus pygargus* in the Sahel. Over the winter season these harriers appeared to track areas of low NDVI which, on the basis of field observations, was associated with high grasshopper densities, their main food. Using this and other successes as an inspiration, an increasing number of investigators began to publish about patterns of correlations, but often at the

cost of ignoring the ‘Drent principles’ to greater and lesser degrees. Thorup *et al.* (2018), for example, examined the seasonal migrations from Europe into and across Africa in three insectivorous birds, two passerines and the Common Cuckoo *Cuculus canorus*. They found a match between local seasonal maxima for greenness and then state in the Results section that “population patterns consistently matched the high levels of food supply throughout the birds’ migration routes”. Thorup *et al.* really believed this interpretation, as they called their paper: “resource tracking within and across continents”. The question is, as none of the three birds eat plants, which resources were tracked here? Adult Common Cuckoos, for example, eat invertebrates, especially the large, aposematic and hairy larvae of moths (Lepidoptera; Wyllie 1981, Cramp 1985). They do so during northward migration in East-Africa (Prins 1986) and in a study in the UK, Denerley *et al.* (2019) were able to correlate breeding Common Cuckoos to where “later in the summer, higher numbers of moths were captured whose larvae are cuckoo prey”. Let me offer you an alternative hypothesis to Thorup *et al.*’s interpretation of resource tracking. During their seasonal migrations, Common Cuckoos use a sequence of places with lots of photosynthesizing vegetation for reasons of safety. Open areas are dangerous, cuckoos simply have no defences against raptors except to hide among foliage (Davies 2015).

In the meantime, Fernández-Tizón *et al.* (2020) took the trouble to assess whether the arthropod biomass of dry semi-natural grasslands in Germany correlated with NDVI. With an increase in photosynthesizing plant biomass in spring, there was indeed an increase in arthropod biomass, both NDVI and arthropod biomass following the spring increase in temperature. However, it seems that spatial variation in arthropod abundance cannot be so easily captured. At the level of entire agricultural landscapes, this would seem an unlikely goal, as ‘more green’ no longer correlates with ‘more insects’ (Newton 2017, De Felici *et al.* 2019). To do justice to the specific requirements of particular animals, and yet tap into the incredible fountain of global, satellite-based Earth-observations, additional measures will be necessary.

Building on the products of a new generation of orbiting satellites employing radars to screen, unhindered by clouds, the surface of the land, we have recently explored measures of ‘surface roughness’ to ascertain the intensity of (agricultural) land use. If vegetation grows slowly in the course of spring, temporal variability of ‘surface roughness’ is small, whereas in areas with fast growing crops like ryegrasses

Lolium sp. which are harvested repeatedly, or with Corn *Zea mays* which grows fast and high even if harvested once per year, variance is high. It turns out that Black-tailed Godwits *Limosa limosa* stick to areas with relatively low values of variability in surface roughness, both across parts of The Netherlands (Howison *et al.* 2018) and on the wintering grounds in West-Africa (Howison *et al.* 2019). Although variability in surface roughness is still a 'magic number' to explain the distribution of godwits, ongoing field work is likely to bring us squarely back to the 'Drent principles': when trying to explain numbers and distributions, make sure you understand the sensory and digestive capacities of your study species as well as the characteristics of the foods they eat (and don't forget about the predators that eat the study species).

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