FULL TEXT: Everard, M. (2021). Migration: a systemic consideration. *Environmental Scientist*, October 2021 (special edition Animal Migration), p.10-15. https://www.the-ies.org/resources/animal-migration.

Migration: a systemic consideration

Mark Everard looks at the importance of migration for the wider ecosystem services that animals and humans rely on for survival.

That organisms move on a regular, semi-predictable basis may not appear revelatory from our contemporary world view. However, in reality, this insight is profound, built from successive discoveries through the environmental sciences. It also remains an insight we are very far from embedding into how we manage the world.

Of birds and fish

Before the phenomenon of migration began to be understood, the disappearance, reappearance and breeding of many organisms was a thing of mystery from which many ingenious theories emerged.

One example is the life cycle of the swallow (*Hirundo rustica*), a charismatic and graceful summer visitor to northern latitudes. Prior to vanishing in the autumn, swallows mass over ponds, streams and damp meadows to hawk for insects, feeding up before they disappear. Just as suddenly, they reappear in large numbers as a harbinger of spring, swooping and feeding voraciously on emerging insects from those same waterbodies. It was not such a massive intuitive leap for our forebears to surmise that swallows lay dormant during the winter in the beds of the waterbodies over which they massed in autumn and from which they reappeared in spring. This view prevailed right up to the 18th century. So, too, did a common belief that barnacle geese (*Branta leucopsis*), arriving suddenly in flocks, were born of the sun's heat on long-necked and admittedly goose-like goose barnacles (*Lepas* spp.) washing ashore on drifting wood.

The sudden appearance of wriggling masses of tiny translucent eels in the margins of the lower reaches of rivers in spring attracted similar myths. Aristotle (384–322 BCE) considered

that this was because eels were born '...of nothing' and that 'They are produced from what are called the entrails of the earth, which exist spontaneously in mud and wet earth'.[1] The sudden appearance of small, hair-like elvers often found in depressions made by horse hooves in river margins after rain led Pliny the Elder (AD 23–79) to speculate that elvers grew from horsehair dropped into the water, or that 'They [horses] rub themselves against rocks, and their scraping comes to life'.[2] In *The Compleat Angler* Izaak Walton and Charles Cotton's 'Piscator' notes:

'*… some say they breed by generation, as other fish do; and others, that they breed, as some worms do, of mud; as rats and mice, and many other living creatures, are bred in Egypt, by the sun's heat when it shines upon the overflowing of the river Nilus; or out of the putrefaction of the earth, and divers other ways.*'

Walton and Cotton continue:

'And others say, that as pearls are made of glutinous dewdrops, which are condensed by the sun's heat in those countries, so Eels are bred of a particular dew, falling in the months of May or June on the banks of some particular ponds or rivers, apted by nature for that end; which in a few days are, by the sun's heat, turned into Eels...'[3]

In fact, no eel with testes has ever been found. A lesser-known fact is that Sigmund Freud, the Austrian founder of the psychoanalytic school of psychiatry, researched the mysteries of eel reproduction at the outset of his long career. After dissecting many eels, Freud concluded that '...all the eels which I cut open are of the fairer sex', before abandoning biology in favour of working on the human mind.[4] This observation only served to deepen the mystery of eel reproduction. Even when eel larvae were found in marine plankton, they were for many years misidentified as a new species, *Leptocephalus*, a name that persists for the migratory eel larvae borne on oceanic currents before they metamorphose on making landfall. There remain missing links and unfounded, albeit oft-repeated, assumptions related to migration in the life cycle of the European eel (*Anguilla anguilla*).

Survival strategies and ecosystem impacts

As we learnt more from observations of marked birds and other organisms, our awareness grew leading to our current – and still partial – understanding of migration. With it came the realisation that species exploit different habitats at different life stages to further their survival and fitness to reproduce.

The longest known regular migration is undertaken by the Arctic tern (*Sterna paradisaea*), a bird that migrates between breeding areas in the Arctic and sub-Arctic regions and wintering areas in the Antarctic. Tracking studies have found that these birds make annual journeys averaging 70,900 km.[5]

Many birds and flying insects also require mosaics of different roosting, feeding and loafing habitats that they exploit on daily, seasonal and other cycles of movement. Break the links between habitat units at even fine scales and life cycles are compromised. Just one local-scale example is the importance of adjacent dry, short grassland for nesting and wet pasture for the feeding needs of hatching chicks of many wading birds such as the northern lapwing (*Vanellus vanellus*).

On a greater scale, the movements of whales from the Antarctic's krill-rich circumpolar regions carries nutrients northwards on their seasonal migrations. Furthermore, as whales feed in deep oceanic waters, they bring nutrients to the surface waters into which they return to breathe. These nutrient pumps add substantially to planktonic photosynthesis, making tangible contributions to ocean productivity and climate regulation.

Various species of salmon migrate to sea to feed on small fish and large invertebrates, returning to spawn in nutrient-poor upland river reaches with a productivity too low to otherwise sustain them. Many species of Pacific salmon die upon spawning, their corpses liberating embodied nutrients obtained from rich sea feeding into natal streams, boosting productivity and supporting hatching fry. In fact, these salmon function as substantial nutrient pumps bringing large amounts of marine nutrients from the ocean to the headwaters of otherwise low-productivity rivers.

These nutrients become incorporated into food webs in rivers and surrounding landscapes by the activities of a wide variety of mammals, birds and other fish. In south-eastern Alaska, spawning salmon contribute up to 25 per cent of the nitrogen found in tree foliage, resulting in tree growth rates nearly three times higher than in areas without spawning salmon. As the trees grow and age, they fall to create log jams in the streams, providing shelter for juvenile salmon and helping scour gravels in which adult salmon spawn. Whole catchments and their ecosystems depend upon the migratory habits of these salmonid fish.

Many large animals, mostly terrestrial but also some aquatic, migrate over daily cycles differentiating latrine from feeding areas. This serves both to enhance overall landscape productivity and diversity, but also, importantly, to break parasite life cycles.

Ecosystem processes and services

The many types of migration highlighted here and throughout this edition of the *Environmental Scientist* are fascinating in their own right. However, they also play vital roles in ecosystem processes, transferring nutrients, carbon, energy and genes, and supporting cultural resources and traditions.

They do so from scales as local as the seasonal movements of fish and invertebrates as they travel from river channels into adjacent floodplains; as regular as the journeys of whales into surface waters as they move from deep oceans to excrete after feeding at depth; and as long-term as their final journeys, sequestering embodied carbon as they decompose. Migratory species perform these fluxes by lateral and longitudinal movement across linked aquatic and terrestrial systems and major global flyways. Herds of large herbivores migrate across broad savannah landscapes, contributing to the heterogeneity and vitality of whole ecosystems and their processes. Migration is as functionally important at the staging posts between the pole-to-pole migration of the little Arctic tern and the oceanic travels of the great whales as it is in the daily vertical movements of plankton.

The timing of migration and interactions with the ecosystems through which species migrate also matter a great deal. The study of the timing of plant and animal life cycle events is known as phenology. Well-known, long-term phenological records – for example, the first springtime emergence of leaves, flowers and butterflies, the call of the cuckoo, and the reappearance of swallows and martins – highlight natural rhythms and synchrony linked to the seasons, but also indicate longer-term shifts in a time of profound climate change.

These longer-term shifts are concerning, as the myriad interconnections within nature are elaborately co-evolved. The seeds and berries of plants feed birds and mammals in preparation for overwintering or migration, while emerging aquatic insects in springtime feed juvenile fish, post-hibernation bats and arriving summer-migrant birds. Flooding cycles enable fish migrating over both short and long distances to run over obstructions in river channels and to access marginal wetlands. Break the timings and, for all of nature's evolved adaptive capacities, natural processes are inevitably compromised, including the capacity of migratory species to access different habitats to complete their life cycles and play their important roles in ecosystem functions.

People and nature

All these movements and the processes they perform have tangible and significant importance for humanity.

At a basic biophysical level, the return of migratory birds and animals can form an important basis for local cultures and spiritual beliefs as well as serving as sources of food. As just one illustration of significance, the Grand Coulee Dam on the Columbia River in the United States, developed between 1933 and 1955, took no account of impacts on migratory fish, particularly salmon, or of the ramifications on the livelihoods of upstream Native Americans and Canadian First Nations. Production of salmon and other fish had been a centrepiece of the area's indigenous economy and culture. In 1951, the Colville Confederated Tribes filed a lawsuit against the United States Government which was finally settled 27 years later, in 1978, entitling the tribes to full compensation for all income losses associated with the dam.

A total of US$66 million was paid as historic compensation, including annual payments of US$15 million to offset ongoing reduced income opportunities.[6]

Without the fluxes of nutrients and productivity enabled by migration, many marine and freshwater fisheries would collapse. Enclosure of land preventing free movement of herbivores on savannah and other formerly open grassland landscapes has been significant in changing the ecology of these systems. Furthermore, restriction of wider-ranging migratory behaviours of fenced grazing domestic animal herds results in the dual problems of persistent parasite issues – as latrine and feeding areas cannot be segregated – but also sward depletion as animals are no longer free to move with the availability of fresh grass. As a result, grazed areas are unable to regenerate and replenish longer roots to aid gas and water permeation, carbon storage and nutrient cycling in depleting soils.

Instead, inputs of energy, nutrient, biocidal and other agrochemicals to enclosed farmed land or aquaculture systems are intensified to compensate for the loss of nutrient regeneration, parasite regulation and other processes naturally replenished by migratory behaviours, at the same time resulting in alarming rates of global soil degradation and aquatic eutrophication.

Protection of nature and people

The protection of intercontinental flyways for migratory birds was one of the foundational purposes of the 1971 Ramsar Convention (on wetlands of international importance), now with 169 Contracting Parties globally. The Ramsar Convention has since evolved to address the wider functional roles of wetland systems, including the contributions from, as well as support for, migratory birds, fish and other organisms. The Convention on the Conservation of Migratory Species of Wild Animals, also known as the Convention on Migratory Species (CMS), was signed in 1979, entering into force in 1983 and now with 131 signatory Member States.

But the fact that many species migrate over varying scales is still far from adequately acknowledged. There remain naive assumptions that there are migratory and non-migratory

species, simplistically overlooking the varying habits and needs of many organisms, their life stages, the different spatial and temporal scales over which they move together with their functional importance. Migratory needs are certainly not reflected in management relating to the permeability of landscapes that are heavily fragmented by economic uses. This, in turn, affects ecosystem processes and, with them, delivery of ecosystem services vital for the sustainability of ecosystems and the diverse human needs and socioeconomic benefits they support.

As we progress within the UN Decade on Ecosystem Restoration (2021–2030), also recognising the importance of retaining or restoring ecosystem functionality for meeting the UN Sustainable Development Goals, there is a pressing need to remove these blinkered views about the migratory needs of species and acknowledge their importance. Only this way can we take appropriate management actions to protect species, ecosystems, natural processes and the many human needs that depend on them.

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