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MIGRATORY ANIMALS CONNECT THE PLANET: THE IMPORTANCE OF CONNECTIVITY AS A KEY COMPONENT OF MIGRATION SYSTEMS AND A BIOLOGICAL BASIS FOR COORDINATED INTERNATIONAL CONSERVATION POLICIES

(Prepared by the Scientific Council)

Summary:

This information document compiles a series of articles on migratory connectivity drafted by participants in two workshops held in Italy in September 2015 and May 2017 respectively, under the auspices of the CMS Scientific Council, to take forward further work on migratory species connectivity. The workshops reviewed available scientific evidence and experiences, and developed recommendations which are the basis of a draft resolution on "Improving ways of addressing connectivity in the conservation of migratory species", submitted to COP12 consideration in document UNEP/CMS/COP12/Doc.24.4.11.

The present compilation of articles aims at complementing the draft resolution, by providing an overview of the science underpinning it.

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Introduction

Fernando Spina[1]

[1] ISPRA, Bird Migration Research Area, Via Cà Fornacetta 9, 40064 Ozzano dell'Emilia (BO), Italy, fernando.spina@isprambiente.it

Migratory animals move across space and time; with their regular and predictable migratory movements they connect continents, countries, sites and habitats. Connectivity is the keyword of CMS, the only global legal instruments devoted to the conservation of migratory animals. Understanding connectivity allows us to appreciate the needs migratory species have in terms of sites and habitats along their migratory journeys and annual cycle. Migration can only be accomplished when animals are able to access the different sites and habitats they are adapted to rely upon along their pathways, from the breeding quarters, through the passage and staging areas, to the non-breeding sites.

Connectivity is key for the identification and planning of the spatial structure of networks of protected areas and other sites managed for conservation purposes, for assessing the functional need for corridors connecting different protected areas, as well as when considering the conservation value of networks of protected areas for the widest range of *taxa* of migratory animals.

Since accomplishing migration is key for the survival of migratory species, connectivity between sites and countries, as mediated by migratory animals, implies and requires sharing of responsibilities for their conservation and survival. Migratory movements of individual animals within migratory pathways lead to the presence of these same individuals in different countries (and often many, including different continents) during the different phases of their journeys.

In order to discuss scientific and applied aspects related to connectivity and thanks to the support offered by: ISPRA, the Veneto Po Delta Regional Park, the Municipality of Rosolina, the Regione Veneto, the Ministero dell'Ambiente e della Tutela del Territorio e del Mare (Ministry of the Environment, and Protection of Land and Sea), the Fondazione CARIPARO and the Marcegaglia Group, two workshops were held in Italy in September 2015 and May 2017 respectively, under the auspices of the CMS Scientific Council, to take forward further work on migratory species connectivity. The workshops reviewed available scientific evidence and experiences, and developed recommendations which are the basis of the draft resolution and draft decision on "*Improving ways of addressing connectivity in the conservation of migratory species*" which are presented to COP12 (UNEP/CMS/COP12/Doc24.4.11).

The resolution aims at flagging CMS as the "connectivity Convention", requesting for special attention to be given to connectivity-related aspects and problems when defining priorities within conservation strategies and when building contacts, cooperation and shared efforts across countries and continents for the long-term survival of migratory animals.

The resolution highlights, among others, the need to express conservation objectives in terms of whole migration systems and functionality of the migration process itself, not just the status of populations or habitats; the need to define conservation actions addressed at the connections between places (or times); the need to correct the most obvious instances of problematic discontinuity in migration systems, such as barriers to migration, fragmented resources, disrupted ecological processes, genetic isolation, altered behaviour patterns, disconnections in distribution caused by climate change or depletion of food or water

resources, inconsistencies in management across and beyond national jurisdictions; the need to work with a wide range of stakeholders in government authorities, local communities, the private sector and others at a variety of scales including the landscape and seascape scale to promote the restoration and management of habitats used by migratory species with particular regard to issues of connectivity; the importance of better understanding the links between connectivity and resilience.

In order to offer an overview of connectivity in migratory species, this document (COP UNEP/CMS/COP12/Inf.20) offers a general overview of the present knowledge on connectivity and the future needs and potential developments, together with a series of case studies and examples from an across-*taxa* perspective. The examples and case studies provided are offered by experts in connectivity from a wide range of species of migratory animals, including insects (butterflies and dragonflies), cartilagineous (Sharks) and catadromous (European Eel) fish, reptiles (marine turtles), birds (albatrosses, geese, swallows and songbirds), aquatic mammals, bats, aridland ungulates. Other contributions deal with key components of whole migratory systems used by large arrays of species and under various degrees of threat through direct human impact and/or climate change (Yellow Sea mudflats, Sahara extension and habitat conservation on Mediterranean island). This interesting list of short contributions complements the draft resolution in providing a good sample of perspectives describing and confirming the importance of connectivity for the conservation of migratory species.

This series of study cases and examples is presented here as a COP information document supporting the draft resolution. The present format will soon be finalized in order to become a brochure on connectivity jointly published by CMS and the Veneto Po Delta Regional Park, thanks to the financial support allocated by the Park administration.

The past, present and future of migratory connectivity

Roberto Ambrosini[1] & Fernando Spina[2]

[1] Department of Earth and Environmental Sciences (DISAT), University of Milano Bicocca, Piazza della Scienza, 1, 20126 Milano, Italy, roberto.ambrosini@unimib.it
[2] ISPRA, Bird Migration Research Area, Via Cà Fornacetta 9, 40064 Ozzano dell'Emilia (BO), Italy, fernando.spina@isprambiente.it

Migratory connectivity refers to the association among individuals in different geographical areas where they spend different phases of their annual life-cycle and on how processes occurring in one area affect populations observed in another area. This concept has been first proposed in 2000 at a workshop on "Connectivity of migratory birds"(Boulet and Norris 2006), and first appeared on a scientific journal two years later (Webster et al. 2002). This was not the first time that a similar concept was proposed, however. Indeed, the concept of migratory connectivity was anticipated by Salomonsen (1955), who entered in the scientific literatures the terms "synhiemy" and "allohiemy", which refer to the tendency of individuals that breed together to, respectively, winter together or not.

Since the seminal work by Webster et al. (2002), migratory connectivity has been defined in several different ways (Table 1). Basically, the main difference in these definition is that they consider migratory connectivity as a property of different entities: geographical areas, individuals or groups of individuals, populations, or even time periods. Importantly, the different perspectives on migratory connectivity may serve different purposes. For instance, considering connectivity as a property of geographical areas may matter for conservation purposes, as it allows identifying areas through which individuals move, and to act to lessen the threats that may hamper survival in each of these areas. In contrast, considering connectivity as a property of individuals may matter for evolutionary or genetic studies of populations as well as for applicative purposes, for instance transmission of parasites and pathogens among individuals that mix at some stages of their annual life-cycle.

An important point of clarification is that the strength of migratory connectivity has been defined in a way that counters that followed for quantifying connectivity in other fields of ecology. Indeed, migratory connectivity has been defined as 'strong' when individuals breeding in one area mostly migrate to one wintering area and vice versa, while when they spread among different areas, then connectivity is 'weak' (Figure 1; Webster et al. 2002). In contrast, ecological connectivity, which can be defined as "the process of movement and how landscape structure can influence the movement of organisms between habitats" (Marra et al. 2006), focuses on the processes that drive individual movements. Hence, strong migratory connectivity in a sense implies weak ecological connectivity, and vice versa. Indeed, strong migratory connectivity suggests that populations are tightly linked and have experienced minimal dispersal or mixing, while strong landscape connectivity predicts high rates of movement and dispersal. Ecological connectivity thus refers to the "ease" of movement across geographical areas, so the easier the movements, the stronger the connectivity. In contrast, migratory connectivity refers to the retention of population structure in the areas where individuals spend different parts of their annual life-cycle and on how conditions and events in one area affect populations in another area (Marra et al. 2006). Thus, it focuses on how processes and events that occur in a geographical area "transfer" into another geographical area, potentially very far away, because these two areas are connected by the movement of individuals between them.

Migratory connectivity can be quantified in different ways, which are rooted, basically, in considering it as a property of areas or of individuals. In the first case, a series of transition probabilities can be defined, which describe how breeding birds from any particular area distribute in different areas of their non-breeding range (Marra et al. 2006). In the latter case, the association between the reciprocal position of individuals in different phases of their annual life cycle (Besag and Diggle 1977) can be used as a measure of the strength

of migratory connectivity (Ambrosini et al. 2009). Importantly, recent theoretical developments (Hostetler et al. 2017) have showed that the quantitative measures obtained by both methods can be easily compared and, under opportune conditions, they converge. This fact will surely boost researches on this topic by facilitating comparison of results and easing comprehensive studies on migratory connectivity across taxa and geographical areas.

Migratory connectivity is thus only one very particular feature of the more general and complex ecological process of migration. For instance, migratory connectivity do not refer to the structure of the migration systems that can determine connectivity. For example, all theoretical types of migration systems proposed by Salomonsen (1955) can lead to strong migratory connectivity, but the individualization of these patterns is not strictly considered as migratory connectivity (Figure 2). However, recent works have questioned whether the field of migratory connectivity has already been thoroughly explored or if further dimensions of this concept exist, but have been neglected so far. For instance, Finch et al. (2017) pointed out that migratory connectivity can arise not only through the mixing of individuals, but also through the spreading of breeding populations in the wintering grounds. They also argue that the relationship between population spread and inter-population mixing should be mediated by the relative size of the species' ranges and showed that variation in population spread is predicted by geography both in the Neotropic and in the Afro-Palerctic migration system. Their theoretical work links directly migratory connectivity to biogeography and macroecology, thus opening new avenues of research in this topic. Another potential dimension of migratory connectivity that has been neglected so far is timing, as it was pointed out by Bauer et al. (2015), which showed that the consequences of migratory connectivity depend not only on which sites are used, but also on when they are used. Finally, migration distance is currently totally neglected in the studies of migratory connectivity, as measures proposed so far do not account for the length of the migration journey, but it may be an important feature to consider.

These examples show that migratory connectivity is still an open field of research, which will probably expand in the near future. Indeed, further developments of the concept of migratory connectivity are possible, for instance, by improving methods for quantifying different dimensions of migratory connectivity or by updating the definition of migratory connectivity in order to include or exclude new dimensions. By linking this concept more deeply with other branches of ecology, it may also be possible to investigate further, for instance, the ecological processes that have determined the evolution of a given degree of migratory connectivity in different geographical areas or in different phylogenetic linages. In all cases, the future of migratory connectivity will be exiting.

References:

Ambrosini R, Møller AP, Saino N (2009) A quantitative measure of migratory connectivity. J Theor Biol 257:203–211. doi: 10.1016/j.jtbi.2008.11.019

Bauer S, Lisovski S, Hahn S (2015) Timing is crucial for consequences of migratory connectivity. Oikos 125:n/a-n/a. doi: 10.1111/oik.02706

Besag JE, Diggle PJ (1977) Simple Monte Carlo Tests for Spatial Pattern. Appl Stat 26:327–333. doi: 10.2307/2346974

Boulet M, Norris DR (2006) The past and present of migratory connectivity. Ornithol Monogr 61:1–13. doi: 10.1642/0078-6594(2006)61[1:TPAPOM]2.0.CO;2

Finch T, Butler S, Franco A, Cresswell W (2017) Low migratory connectivity is common in long-distance migrant birds. J Anim Ecol 38:42–49. doi: 10.1111/1365-2656.12635

Hostetler J, Hallworth M, Rushing C, Cohen E (2017) MigConnectivity: Estimate Strength of Migratory

Connectivity for Migratory Animals. 1–30.

Marra PP, Norris DR, Haig SM, et al (2006) Migratory connectivity. In: Crooks K, Sanjayan M (eds) Connectivity Conservation. Cambridge University Press, New York, pp 1062–1065

Rundel CWCW, Wunder MBMB, Alvarado AHAH, et al (2013) Novel statistical methods for integrating genetic and stable isotope data to infer individual-level migratory connectivity. Mol Ecol 22:4163–4176. doi: 10.1111/mec.12393

Salomonsen F (1955) The evolutionary significance of bird migration. Biol Meddelelser 22:1–62.

Veen T (2013) Unravelling migratory connections: The next level. Mol Ecol 22:4144–4146. doi: 10.1111/mec.12441

Webster MSMS, Marra PPP, Haig SMSM, et al (2002) Links between worlds: Unraveling migratory connectivity. Trends Ecol Evol 17:76–83. doi: 10.1016/S0169-5347(01)02380-1

Table 1: Different definitions of migratory connectivity present in literature (incomplete list to be updated).

Definition	Property of	Reference
The links between breeding and non-breeding areas due to the movement of migrants among them	Areas	(Webster et al. 2002)
The extent to which individuals from the same breeding area migrate in the same non-breeding area and vice versa	Individuals	(Webster et al. 2002)
The geographic linking of individuals or populations between different stages of the annual cycle	Individuals / Populations	(Marra et al. 2006)
Migratory connectivity refers to the degree to which two or more periods of the annual cycle are geographically linked (Boulet and Norris 2006)	Periods	(Boulet and Norris 2006)
Migratory connectivity describes the degree to which individuals or populations are geographically arranged among two or more periods of the annual cycle (Boulet and Norris 2006)	Individuals / Populations	(Boulet and Norris 2006)
Migratory connectivity describes the associations between breeding sites, stopovers and wintering grounds of groups of individuals (Veen 2013)	(Groups of) Individuals	(Veen 2013)
The geographic link between individuals or populations at different stages of their annual cycle (Rundel et al. 2013)	Individuals / Populations	(Rundel et al. 2013)

Figure 1: Conditions defining a) strong and b) weak migratory connectivity (From Webster et al. 2002) (to be redrawn before publication).
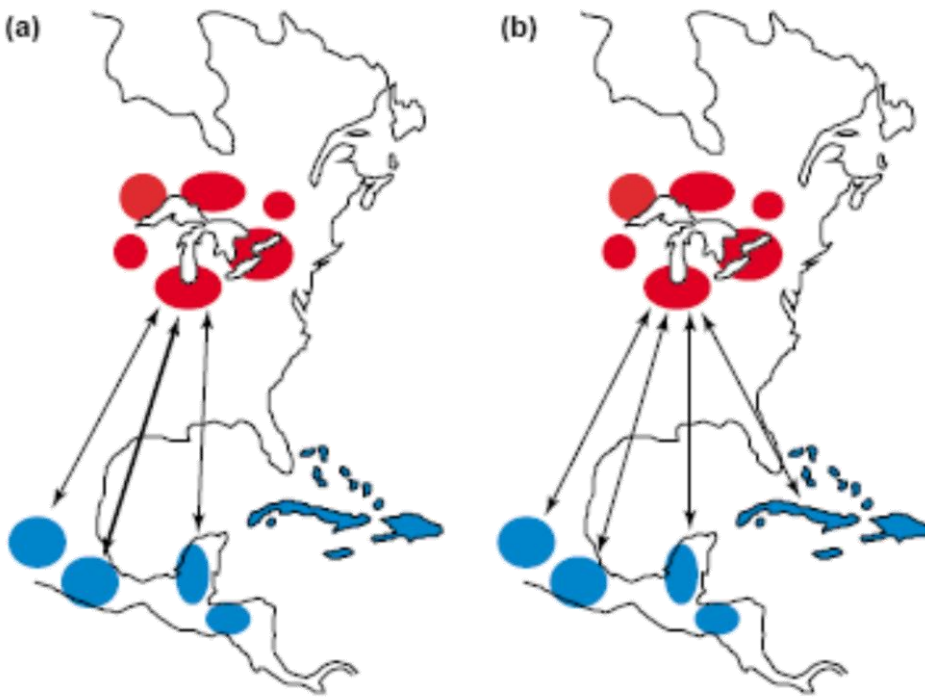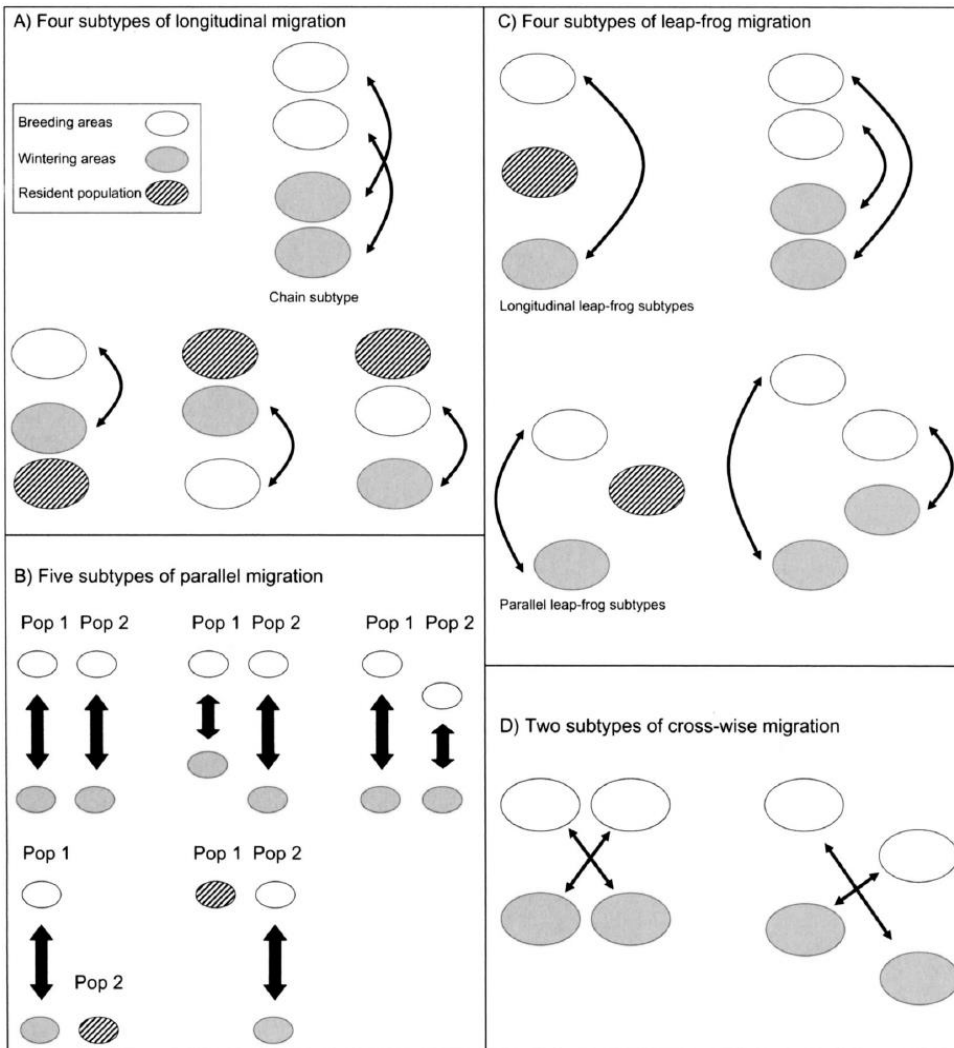
Figure 2: Salomonsen's theoretical types of migration systems leading to strong connectivity: (A) longitudinal migration, (B) parallel migration, (C) leap-frog migration, and (D) cross-wise migration. Legend is in panel A. (from Boulet and Norris 2006, modified from Salomonsen 1955) (to be redrawn before publication).

Terrestrial Mammals, and in particular aridland mammals

Roseline C. Beudels-Jamar de Bolsée[1]

[1] Conservation Biology Unit (O.D. Nature), Royal Belgian Institute of Natural Sciences, 29 rue Vautier, 1000 Bruxelles, Belgium, roseline.beudels@naturalsciences.be, roseline.beudels@skynet.be

Terrestrial mammals migrations are among the most fascinating wildlife spectacle (see CMS symposium on animal migration, Gland, 1997).

- The Serengeti migration, one of the best known of its kind, is the world's largest remaining large mammal migration, with nearly 2 million animals making an annual perambulation across an ecosystem that is nearly 30,000km^2.
- The Mongolian gazelles form mega-herds, reaching up to 250,000 individuals, constantly in the move over their range of rolling arid steppes and grassy plains in search of food, except during the rutting and birthing seasons.
- Now rare, large terrestrial mammal migrations are thought to have once been much a more widespread feature of the world, particularly in dryland systems.
- Fencing and human encroachment have resulted in a dramatic reduction in these wildlife spectacles.
- However, as the Serengeti shows, those migrations that still remain are able to appeal to wildlife tourists from across the world, demonstrating their appeal to our human emotions.
- These spectacular migrations are hugely important in the productive functioning of dryland ecosystems.

In Africa, there is a current preoccupation with barrier fencing around reserves as a response to escalating human wildlife conflict, and there has been recently resurgence in calls for more of such fences.

As a response, a recent article (Durant et al, 2015) calls for developing fencing policies for dryland ecosystems. The paper provides a timely reminder that there is still much we don't know about the impacts of fencing on wildlife, people, and ecosystems. It provides a framework and research agenda to address these gaps, and develop a better understanding of the impacts of large-scale fencing. The paper identifies six research areas that are key to informing evaluations of fencing initiatives: economics; edge permeability; reserve design; connectivity; ecosystem services; and communities.

While all ecosystems are potentially threatened by negative impacts from fencing, drylands are particularly vulnerable, due to the need of both wildlife and people to be able to move across vast landscapes in order to respond to unpredictable rainfall patterns. The research agenda in the article provides an evidence-base to enable better management and policy decisions on fencing in such dryland systems.

CMS has become increasingly aware of an emerging threat from large-scale fencing driven by infrastructure development and border protection. Such fencing initiatives are already having substantial impacts in Asia, and CMS has recently paid particular attention to the negative effects of border fences (between Russia, Mongolia, China) and the Trans-Mongolia railroad, which is fenced on both sides. These extensive border and railroad fences constitute major obstacles to the movements of ungulates such as the Mongolian Gazelle, Goitered Gazelle and Khulan (Mongolian wild ass). In particular, they interrupt the historic east-west migration routes of the Mongolian Gazelle, one of the few remaining large mammal migration spectacles in the world. The erection of such fences, for purposes that are often completely unrelated to wildlife management, constitute serious barriers to migratory movements.

In contrast, fences can also be an important tool for the conservation of species of concern. They have been used to protect core areas against overgrazing, such as the extremely arid and vulnerable areas in Tunisia, Morocco and Senegal, that are key to the survival of many species of threatened ungulates.

There is serious concern about the impact of human-wildlife conflict on both wildlife and on vulnerable livelihoods of marginalised people, and there is real need to better understand the impacts of fencing, or alternative methods, if used to mitigate such conflicts. Moreover, with increasing encroachment of people into the migratory pathways of terrestrial mammals, fences could be used to protect corridors and allow wildlife to move through landscapes that have been subject to extreme anthropogenic modification. Such fences could even be used to help rewild and re-establish past migratory pathways. Understanding the negative, as well as the positive, impacts of such fencing on non-target wildlife and ecosystem services will be critical to the overall success of such schemes.

The Scientific Council of CMS proposes to form a Working Group on "Fencing problems and policies in dryland ecosystems". As well as interested scientific councillors, the Scientific Council of CMS will invite representatives of the scientific bodies of UNCCD and World Heritage Conventions and scientists active in the field to join the Working Group. The Working Group will use the framework proposed in Durant et al., 2015 to construct a catalogue of problems and solutions and agree on a set of recommendations, which could then be adopted by the Conference of the Parties of CMS (and maybe UNCCD as well).

If this proposed research agenda and framework is addressed, through the support of CMS and others, the resulting evidence base will enable better evaluation of fencing interventions and facilitate wise decision-making. This is particularly important for the world's last remaining terrestrial migrations, many of which face serious threats.

There is an urgent need to move this agenda forward if we are to secure the protection of those migratory pathways that still remain. It would be a tragedy if such awe-inspiring natural phenomena of large terrestrial mammal migrations were to be consigned to the history books.

Bat Connectivity

Rodrigo A. Medellin[1] & Erin F. Baerwald[2]

[1] Instituto de Ecologia, UNAM, Circuito Exterior s/n junto al Jardin Botanico Exterior, 04510 Ciudad Universitaria, D. F., Mexico, medellin@iecologia.unam.mx

[2] Department of Biology, Laboratory Building, LB244, University of Regina, 3737 Wascana Parkway, Regina, Saskatchewan, S4S0A2, Canada, girlborealis@gmail.com

As the only mammals capable of true flight, bats are important players in migratory connectivity. They not only require connectivity for large seasonal movements, but they can also help to create and maintain it. Bats are the second largest group of mammals with well over 1,300 species around the world. Because of the great abundance and diversity of bats, they strongly influence the landscape they use, via pollination (Dobat and Peikert-Holle1985, Fleming and Muchhala 2008), seed dispersal (Medellin and Gaona 1999, Lobova et al. 2009), or insect population control (Kalka et al. 2008, Williams-Guillen et al. 2008, Federico et al. 2008, Wiederholt et al. 2017). Many species of bats live in caves, forming the greatest concentrations of warm-blooded vertebrates in the world. These concentrations provide a tremendous number of ecosystem services that spread over many thousands of square kilometers (Medellin et al. 2017). Even bats that do not live in these large colonies, but rather roost solitarily in trees, may come together during seasonal migrations and effect the landscape along their migration corridors (Baerwald and Barclay 2009).

Several dozen species of bat migrate long distances, connecting many ecosystems and countries (Altringham, 2011; Fleming and Eby 2003). Bats are the fastest self-powered flying animal on earth. That is, birds of prey, including peregrine falcons, can fly at up to 200 km/h, but only aided by gravity (i.e., by falling), but the Mexican free-tailed bat can fly at up to 160 km/h unaided by wind or gravity (McCracken et al. 2016). This fast and efficient flight allows bats to move great distances both nightly and seasonally, hundreds of kilometers a night and over a thousand kilometers annually (Breed et al. 2010, Fleming and Eby 2003, McGuire et al. 2012, McCracken et al. 2016, Medellin, pers. obs). The straw-colored fruit bat (*Eidolon helvum*) can move thousands of kilometers across sub-Saharan Africa, from Ghana and Nigeria to Zambia and across the rift valley countries south to southern Africa (Ossa et al. 2012). The common noctule bat (*Nyctalus noctula*) can move up to 1,700 km across Europe and Eurasia (Roer 1995, Strelkov 1997, 2000). The Mexican free-tailed bat (*Tadarida brasiliensis*) moves from southern and central Mexico to the central United States and northern Mexico (Russell et al. 2005). The hoary bat (*Lasiurus cinereus*), a species with a very broad distribution from Argentina to Canada, can also migrate at least 1,500 km annually, from northern Mexico to Canada for example (Cryan 2003). The hoary bat, together with three other species of migratory tree-roosting bats (*Lasiurus borealis, L. blossevillii,* and *L. ega*), is the focus of proposal UNEP/CMS/COP12/Doc.25.1.2 to enlist them in Appendix II of CMS.

Connectivity in bats thus becomes a reality because of the migratory movements. Given the ecosystem services provided by bats, maintaining connectivity is essential (Wiederholt et al. 2015, 2017). The reciprocal subsidies obtained by the countries that share a particular population is an essential pillar to secure cooperation to protect the phenomenon of connectivity and the traveling ecosystem services provided (Semmens et al. 2011, Wiederholt et al. 2017). Unfortunately, very little is still known about migration and connectivity on bats. The urgency of focusing conservation efforts to preserve connectivity in migratory bat populations is apparent in recent studies on the impact of wind energy of the North American population of hoary bats: hundreds of thousands hoary bats are being killed by wind turbines across the United states and Canada every year, mostly during autumn migration (Arnett and Baerwald 2013). If unchecked, this fatality rate is predicted to lead to the disappearance of the hoary bat (and possibly other migratory tree-roosting species) within the next 50 years (Frick et al. 2017). Many more bats around the world may be facing a similar fate.Thus, ensuring connectivity is an important step in conserving many wide-ranging species of bat and the important ecosystem services they provide.

References:

Arnett, E.B. and Baerwald, E.F., 2013. Impacts of wind energy development on bats: implications for conservation. In Bat evolution, ecology, and conservation (pp. 435-456). Springer New York.

Baerwald, E.F., Barclay, R.M.R., 2009. Geographic variation in activity and fatality of migratory bats at wind energy facilities. J. Mammal. 90:1341–1349. http://dx.doi.org/10.1644/09-MAMM-S-104R.1.

Breed, A. C., Field, H. E., Smith, C. S., Edmonston, J. and Meers, J. 2010. Bats without borders: long-distance movements and implications for disease risk management. EcoHealth 7: 204–212

Cryan, P.M. 2003. Seasonal distribution of migratory tree bats (Lasiurus and Lasionycteris) in North America. Journal of Mammalogy. 84: 579-593.

Dobat, K., and Peikert-Holle, T. 1985. Bluten und fledermause. Frankfurt am Main: Verlag Waldemar Kramer.

Fleming, T. H., and P. Eby. 2003. The ecology of bat migration. In T. Kunz and M. B. Fenton (eds.), Bat Ecology. University of Chicago Press, Chicago.

Fleming, T.H., and Muchhala, N. 2008. Nectar-feeding bird and bat niches in two worlds: pantropical comparisons of vertebrate pollination systems. Journal of Biogeography 35: 764–780.

Frick, W. F., E.F. Baerwald, J.F. Pollock, R.M.R. Barclay, J.A. Szymanski, T.J.Weller, A.L. Russell, S.C. Loeb, R.A. Medellin, L.P. McGuire. 2017. Fatalities at wind turbines may threaten population viability of a migratory bat. Biological Conservation 209: 172–177

Lobova, T., Geiselman, C. K., and Mori, S. A. 2009. Seed Dispersal by Bats in the Neotropics. New York: Memoirs of the New York Botanical Garden, NYBG Press.

McCracken, G.F., Kamran, S., Kunz, T., Dechmann, D., Swartz, S., and Wikelski, M. 2016. Airplane tracking documents the fastest flight speeds recorded for bats. Royal Society Open Science 3: 160398. doi:10.1098/rsos.160398

McGuire, L.P., C.G. Guglielmo, S.A. Mackenzie, and P.D. Taylor. 2012. Migratory stopover in the long-distance migrant silver-haired bat, Lasionycteris noctivagans. Journal of Animal Ecology. 81: 377 – 385.

Medellín, R. A. and O. Gaona. 1999. Seed dispersal by bats and birds in forest and disturbed habitats in Chiapas, Mexico. Biotropica, 31:432-441.

Medellin, R. A., R. Wiederholt, L. Lopez-Hoffman. 2017. Conservation relevance of bat caves for biodiversity and ecosystem services. Biological Conservation 211:45-50. http://doi.org/10.1016/j.biocon.2017.01.012

Roer, H. 1995. 60 years of bat-banding in Europe – results and tasks for future research. Myotis 32–33: 251–261.

Semmens, D.J., Diffendorfer, J.E., Lopez-Hoffman, L., and Shapiro, C.D. 2011 Accounting for the ecosystem services of migratory species: quantifying migration support and spatial subsidies. Ecological Economics 12:2236–2242

Strelkov, P.P. 1997. Breeding area and its position in the range of migratory bat species (Chiroptera, Vespertilionidae) in east Europe and adjacent territories. Comunication I, II. Zoologicheskii Journal, 76: 1073-1082, 1381-1390.

Strelkov, P.P. 2000. Seasonal distribution of migratory bat species (Chiroptera, Vespertilionidae) in eastern Europe and adjacent territories: nursing areas. Myotis, 37: 7-25.

Wiederholt, R, L López-Hoffman, C Svancara, G McCracken, W Thogmartin, J Diffendorfer, K Bagstad, P Cryan, A Russell, D Semmens & RA Medellin. 2015. Optimizing conservation strategies for Mexican free-tailed bats: a population viability and ecosystem services approach. Biodiversity and Conservation. DOI 10.1007/s10531-014-0790-7

Wiederholt, R., K. J. Bagstad, G. F. McCracken, J. E. Diffendorfer, J. B. Loomis, D. J. Semmens, A. L. Russell, C. Sansone, K. LaSharra, P. Cryan, C. Reynoso, R. A. Medellín, and L. López-Hoffman. 2017. Improving spatio-temporal benefit transfers for pest control by generalist predators in cotton in the southwestern US. International Journal of Biodiversity Science, Ecosystem Services, and Management, 13: 27–39

Aquatic Mammals and Connectivity

Giuseppe Notarbartolo di Sciara[1]

[1] Tethys Research Institute, Via Benedetto Marcello 43, 20124 Milano, Italy, disciara@tethys.org

Many aquatic mammal species are migratory. Some of them, such as humpback whales, undertake the longest mammalian migration on Earth. Others have less extreme migratory habits, but are continuously on the move nevertheless. For example, fin whales in a population which is resident in the Mediterranean Sea do not appear to follow fixed, cyclically repeated migratory corridors, but move periodically across the region in search of particular feeding hotspots which become productive in predictable times of the year. Local coastal populations of smaller cetaceans such as bottlenose dolphins, perhaps amongst the least migratory of marine mammals, are nevertheless known to move up and down the coastal zone they inhabit, sometimes by several hundreds of km. Even freshwater aquatic mammals can move extensively along the rivers they live in, in response to seasons and to the movements and availability of their prey.

When it comes to protecting the habitats of aquatic mammals, for example through the establishment of protected areas, their highly mobile nature is obviously a challenge. For instance, these animals' breeding grounds are often easy to identify – such as on a beach where elephant seals haul out to mate and give birth to their pups, or in the confined shallows in the lee of the main Hawaiian Islands where young humpback whales are born – but if they are not protected when they leave their breeding grounds, e.g., during the elephant seals' feeding season in the open ocean, or in the Alaskan humpback whale feeding grounds, the positive effects of protecting these animals in their breeding grounds can be easily thwarted. Furthermore, something must also be done to ensure that the animals are not threatened along the corridors these animals travel along.

These considerations emphasize the importance of addressing connectivity issues in the conservation of aquatic mammals, something that cannot be easily done, for instance, through the establishment of protected areas, short of recurring to the option of considering for protection, in some cases, of huge portions of the oceans. This is clearly a challenge, particularly when such portions occur in the high seas.

And yet, aquatic mammal species must face a variety of threats undermining their connectivity, all of them deriving from pressure factors originated by human activities. Here are a few examples:

- intense vessel traffic across major maritime ship lanes intersect whale movements across their critical habitats, such as in the cases of blue whales migrating in the Eastern Tropical Pacific off the coasts of Central America, and Mediterranean fin whales moving from their winter feeding grounds in the Strait of Sicily to the summer feeding grounds in the Ligurian Sea. In some regions whales are presumed to suffer from significant mortality caused by vessel strikes.
- Fishing with large-scale pelagic driftnets, the infamous "walls of death", used to be very popular in the Mediterranean Sea during the last decades of the XX century. These nets were obstructing the movements of sperm whales across the region, and were also a serious source of mortality for these whales which got frequently entangled into them, causing the Mediterranean population to be considered Endangered in the IUCN Red List. Today pelagic driftnets are no longer allowed in the Mediterranean, however they are still operated illegally; the ecological damage they cause has consequently become very difficult to assess.
- Dams built along the courses of major rivers are obstructing the natural movements of river dolphins in many parts of the world. Dam construction has been affecting connectivity, amongst others, of Amazon river dolphins in South America, Ganges and Indus river dolphins in Southern Asia, and Irrawaddy dolphins in Southeast Asia.
- Habitat degradation in the coastal zone of many parts of the word, induced, amongst others, by coastal construction, mangrove deforestation, as well as urban, industrial and agricultural runoff, has

created areas no longer suitable for the life of coastal aquatic mammals such as bottlenose and humpback dolphins, manatees and dugongs, facilitating population fragmentation and inhibiting movements.

- Man-produced noise, such as that caused by pile driving in coastal constructions and by airgun operation in seismic oil & gas exploration, is known to have created barriers to access to their critical habitat to several species of aquatic mammals, with effects in some cases lasting weeks after the cessation of the noise production. Sound generated by military sonar has even been proven to be a cause of mortality of aquatic mammals, such as beaked whales.

Addressing threats to aquatic mammals which negatively affect their connectivity has proven in most cases to pose considerable challenges, however there have been successes. Large-scale pelagic driftnets have been declared illegal because of their lack of selectivity, and consequent negative effects on marine fauna. Ship traffic separation schemes were declared by the International Maritime Organisation (e.g., in Spain and in the USA) to decrease the impact of shipping on threatened aquatic mammals. Negotiations on a treaty to protect biodiversity in areas beyond national jurisdiction (i.e., the high seas) are ongoing under the purview of the United Nations. Finally, Important Marine Mammal Areas (IMMAs) are being currently identified in many of the world's marine regions to provide a tool to decision-makers and managers in instances of marine spatial planning which may interfere with the connectivity and well-being of aquatic mammals.

The road to achieve a coexistence between human activities and aquatic mammal conservation, including ensuring their connectivity, is still formidably uphill, but at least its direction is known.

Balaenoptera physalus, Fin Whale, Photo Margherita Zanardelli

How Flexible are Bird Migrations?

David W. Winkler [1]

[1] Department of Ecology & Evolutionary Biology, Laboratory of Ornithology, Cornell University, Ithaca, NY 14853 USA

Biologists are accustomed to thinking about migratory patterns as being the result of long and slow evolutionary adjustments over many thousands of generations. Viewed from this perspective, human-caused changes in the productivity and distribution of potential migratory stop-over areas creates real concerns about whether the migratory birds that rely on networks of stopover sites will be able to persist when stopover sites disappear (e.g., Baker et al. 2004, Winkler et al. 2014). Yet despite the fact that many migratory routes are likely slowly adjusted traits, there are many lineages of birds that include a great diversity of patterns of migration among closely related species (e.g., Chesser 2000, Helbig 2003, Jahn et al. 2010, Piersma 2011). So-called "partial migration" describes populations of birds, some individuals of which migrate away and others that remain in the same breeding grounds all year, and in some species individual birds migrate some years and remain resident in others (Ogonowski and Conway 2009).

Examples:

Speed of change in migratory patterns

This sort of diversity of migration among closely related birds raises the possibility that migration may be more rapidly changing than generally assumed. House Finches *Haemorhous mexicanus* became regular mid-distance migrants within 20 years of being introduced to eastern North America (Able and Belthoff 1998), and part of the population of Eurasian Blackcaps *Sylvia atricapilla* nesting in Germany adopted a new migratory orientation and timing over less than 30 years to migrate to wintering areas in the UK in response to the winter-long availability of food provided by humans (Berthold et al. 1992).

The Barn Swallow *Hirundo rustica,* one of the most broadly distributed passerines on Earth, has a variety of movement patterns (Dor et al. 2012), and within a given local population there is also a considerable degree of individual variability and flexibility in migratory behavior (Winkler 2007). Before 1980, this species was limited in its breeding distribution to the Northern Hemisphere, but in that year, wintering individuals from eastern North America were found breeding in a colony of six nests near the southern edge of the species' wintering range in Mar Chiquita, Buenos Aires province, central Argentina (Martinez 1983). Before that colonization of South America, the Western Hemisphere population bred no further south than central Mexico, over 7000 km to the north.

Range spread and new migratory patterns

Since the original South American nesting, the breeding population of Barn Swallows in Argentina has spread over 500 km from its starting point to cover most of the large province of Buenos Aires, and it is still expanding into adjoining provinces. A recent study (Winkler et al. 2017) used tiny solar geolocator tags to show that this newly formed population has adopted a migratory strategy like other songbirds nesting in southern South America: rather than migrate back to North America, as did these birds immediate ancestors, the newly established South American swallows migrate only as far north as the north coast of South America in the austral winter.

Connectivity Issue

These birds complicate the interpretation of connectivity threats to migratory birds. On the one hand, they demonstrate that birds can dramatically change their migratory habits in a very short time, forging

connections between nations far across international boundaries. On the other, they suggest the possibility that some birds may be better able than others to cope with anthropogenic changes in habitat conditions to maintain viable populations of migratory birds.

Future Actions

Conservationists cannot assume that migratory birds will either decline or thrive with changes in the habitats on their migratory paths. We need to study much more which species are capable of road change in migrations and which are more constrained, and we can then turn this knowledge into countered conservation action targeted for different species with different migratory flexibilities. These future actions require improved knowledge and regular monitoring of migratory patterns and connectivity across the widest possible range of species and populations of migratory animals whose conservation is the global mission of CMS.

Relevant Literature

Able, K.P. and Belthoff, J.R. (1998). Rapid 'evolution' of migratory behaviour in the introduced house finch of eastern North America. Proceedings of the Royal Society of London B: Biological Sciences 265(1410), 2063-2071.

Baker, A. J., Gonzalez, P. M., Piersma, T., Niles, L. J., do Nascimento, I. D. L. S., Atkinson, P. W., Clark, N.A., Minton, C.D.T., Peck, M.K. & Aarts, G. (2004). Rapid population decline in Red Knots: Fitness consequences of decreased refuelling rates and late arrival in Delaware Bay. Proceedings of the Royal Society B: Biological Sciences, 271(1541), 875.

Berthold, P., Helbig, A.J., Mohr, G., and Querner, U. (1992). Rapid microevolution of migratory behaviour in a wild bird species. Nature 360(6405), 668-670.

Chesser, R.T. (2000). Evolution in the High Andes: The Phylogenetics of Muscisaxicola Ground-Tyrants. Molecular Phylogenetics and Evolution 15(3), 369–380.

Dor, R., Safran, R.J., Vortman, Y., Lotem, A., McGowan, A., Evans, M.R. and Lovette, I.J. (2012). Population genetics and morphological comparisons of migratory European (Hirundo rustica rustica) and sedentary East-Mediterranean (Hirundo rustica transitiva) Barn Swallows. Journal of Heredity 103(1) 55-63.

Helbig, A.J. (2003). Evolution of bird migration: A phylogenetic and biogeographic perspective. In Avian Migration, P. Berthold, E. Gwinner, and E. Sonnenschein, eds. (Springer-Verlag Berlin Heidelberg), pp. 3-20.

Jahn, A.E., Levey, D.J., Hostetler, J.A., and Mamani, A.M.. (2010). Determinants of partial bird migration in the Amazon Basin. Journal of Animal Ecology 79(5), 983-992.

Martinez, M.M. (1983). Nidificación de Hirundo rustica erythrogaster (Boddaert) en la Argentina. (Aves, Hirundinidae). Neotropica 29(81), 83-86.

Ogonowski, M.S., and Conway, C.J. (2009). Migratory decisions in birds: Extent of genetic versus environmental control. Oecologia 161(1), 199–207.

Piersma, T. (2011). Flyway evolution is too fast to be explained by the modern synthesis: Proposals for an 'extended' evolutionary research agenda. Journal of Ornithology 152(Suppl. 1), S151–S159.

Winkler, D.W. (2007). Roosts and migrations of swallows (Hirundinidae). El Hornero 21(2), 85-97.

Winkler, D.W., Jørgensen, C., Both, C., Houston, A.I., McNamara, J.M., Levey, D.J., Partecke, J., Fudickar, A., Kacelnik, A., Roshier, D., and Piersma, T. (2014). Cues, strategies, and outcomes: How migrating vertebrates track environmental change. Movement Ecology 2(10).

Too large to be crossed? Functional connectivity and expanding ecological barriers for African-Eurasian landbird migrants

Fernando Spina[1]

[1] ISPRA, Bird Migration Research Area, Via Cà Fornacetta 9, 40064 Ozzano dell'Emilia (BO), Italy, fernando.spina@isprambiente.it

Migratory landbird flyways often involve the crossing of large and potentially inhospitable ecological barriers such as deserts and extended stretches of open seas. The presence and potential expansion of these barriers contribute to shaping physiological strategies of migratory songbirds, both at the species and population level (Rubolini *et al*. 2002). Crossing these barriers require many hours of non-stop endurance flights, which are the energetically and metabolically most demanding phases of their annual cycle (Jenni *et al*. 2000, Schwilch *et al*. 2002). Birds can only overcome these challenging barriers along their migratory routes provided they have available suitable stopover habitats at the different stages of their migratory flyway. Given the huge amount of energy required to cross such barriers, habitat availability and suitability both before and after prolonged flights are key for the migrants to stage and physically recover along the barrier crossing.

A vast array of species represented by huge numbers of western Palaearctic landbird migrants wintering in sub-Saharan Africa cross the Mediterranean and Sahara during their autumn southward movements and spring northwards flights towards the breeding quarters (Spina *et al*. 1993; Spina & Volponi 2008a, b). For these birds, the availability and distribution of suitable sub-Saharan habitats where they spend the winter and prepare for migration, together with the availability of staging sites along the flyway and especially on arrival from the prolonged desert and Mediterranean crossing, is crucial for their survival (Jenni *et al*. 2006; Cecere *et al*. 2011).

All these habitats and sites are connected within species- and population-specific flyways by birds which regularly and predictably move across them and make use of their ecological conditions and quality.

Unfortunately, crucial habitats that allow these arduous travels of migratory birds as well as their spatial, ecological and functional connectivity is at risk due to direct and indirect anthropogenic threats. This represents a serious situation because crossing ecological barriers non-stop, requires a sufficient threshold fuel level that can only be obtained prior to crossing. The maximum possible amount of energy reserves birds can store and carry is limited by size and by flight aerodynamics, since birds would be unable to fly above a given maximum overall body mass. Similarly, post crossing birds need to replenish their reserves to continue their journeys.

The overall length of the barrier birds wintering in African equatorial forests have to cross without being able to refuel is progressively and rapidly extending. Increasing unsustainable cutting of vegetation for human use along the southern edge of the desert causes the fast southwards expansion of the Sahara, together with climate change causing also severe drought events. At the same time, the northern limits of the tropical forests retreat as well due to intense cutting by unsustainable human population growth.

The connectivity at the base of these migratory systems which have evolved during millennia is therefore under immediate and serious threat. Birds are confronted with a progressively wider barrier; yet, the timing of natural selection makes them unable to follow this expansion by adapting their fattening and flight patterns and strategies in order to accommodate for an increasing need of energy to reach their European breeding grounds.

We must act now in order to ensure conserving the connectivity linking wintering and breeding areas of these landbird migrants through a network of staging and fattening sites. Countries which are connected by these birds along their flyways must join and coordinate forces in order for the barriers not to become just too wide for them to cross.

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References:

- CECERE J.G., Jenni-Eiermann S., SPINA F., BOITANI L. 2011 - Nectar: an energy drink used by European songbirds during spring migration. *J. Ornithol*. 152: 923-931.

- JENNI L., JENNI-EIERMANN S., SPINA F., SCHWABL H., 2000 - Regulation of protein breakdown and adrenocortical response to stress in birds during migratory flight. *Am. J. Physiol. Regulatory Integrative Comp. Physiol*., 278, R1182–R1189.

- JENNI L., MUELLER S., SPINA F., KVIST A., LINDSTROEM Å., 2006 - Effect of endurance flight on haematocrit in migrating birds. *Journal of Ornithology*, 147: 531-542

- RUBOLINI D., GARDIAZABAL PASTOR A., PILASTRO A., SPINA F., 2002 - Ecological barriers shaping fuel stores in barn swallows *Hirundo rustica* following the central and western Mediterranean flyways. *Journal of Avian Biology* 33: 15-22.

- SCHWILCH R., GRATTAROLA A., SPINA F., JENNI L., 2002 - Protein loss during long-distance migratory flight in passerine birds: adaptation and constraint. *The Journal of Experimental Biology* 205, 687–695.

- SPINA F., VOLPONI S., 2008a – Atlante della Migrazione degli Uccelli in Italia. Vol. 1: non-Passeriformi. ISPRA – MATTM, Roma, pp. 800.

- SPINA F., VOLPONI S., 2008b – Atlante della Migrazione degli Uccelli in Italia. Vol. 2: Passeriformi. ISPRA – MATTM, Roma, pp. 629.

- SPINA F., MASSI A., MONTEMAGGIORI A., BACCETTI N., 1993 - Spring migration across central Mediterranean: General results from the "Progetto Piccole Isole". *Vogelwarte*, 37: 1-94.

Seabirds

Barry Baker[1]

[1] Institute of Marine & Antarctic Studies, University of Tasmania, 114 Watsons Rd Kettering, Tasmania 7155, Australia, Barry.Baker@latitude42.com.au

Albatrosses and petrels (Families Diomedeidae and Procellariidae), are seabirds that are long-lived, have high adult survival rates, delayed sexual maturity and low fecundity; all lay single-egg clutches, and nine species (all of which are albatrosses) breed biennially if successful in raising a chick. Given these extreme life-history attributes, changes in adult mortality have a much greater impact on population trajectories than variation in other demographic parameters, including breeding success, proportion of deferring breeders, juvenile survival and recruitment. All species have wide at-sea distribution during the breeding and nonbreeding seasons and these extensive foraging ranges overlap with multiple fisheries in national and international waters, putting them at risk of incidental mortality, the greatest threat they face in the marine environment. Management of such species needs to occur in many countries if the many threats they face are to be reduced across their range.

Albatrosses and large petrels are exceptionally wide-ranging, frequently travelling 100s to 1000s of km on a single foraging trip that can extend to a straight-line distance of 2000 km or more from their breeding colony. This reflects trip durations during incubation and chick-rearing that can be of two to three weeks, although it is more common for the adult to return and feed its chick after a few days, especially when the chick is still young and attended by one of the parents. As the degree of central-place foraging constraint varies with breeding phase, so too does the extent of at-sea distributions; this is sometimes associated with a change in habitat use from oceanic, distant shelf or shelf-slope regions in the pre-laying and incubation periods, to neritic waters much closer to the colony in brood-guard, and then a return to more distant waters for the remainder of chick-rearing. During chick-rearing, parents may adopt a dual foraging strategy, involving the alternation of long and short trips as they balance the demands of chick provisioning with self-maintenance.

Almost all of the 22 albatross species have been tracked at some stage while breeding, and many during the nonbreeding season, whereas there are relatively few tracks from juveniles and immatures during the initial years when birds cannot be accessed at breeding sites. For albatrosses and the larger petrels migration connectivity appears to be weaker than for other well-studied groups of birds, in that migration across ocean basins to breeding and sabbatical sites is usually rapid. For this reason maintaining a focus on the threats at migration end points is more important at present. During the nonbreeding period, many species make a directed, long-distance migration to a productive upwelling, shelf or frontal system, sometimes in a different ocean basin, and return to the colony can involve a circumnavigation of the Antarctic continent. There are, however, numerous exceptions and contrasting strategies. Thus, Atlantic yellow-nosed albatrosses from Tristan da Cunha and Gough Island, and black-browed albatrosses from South Georgia migrate a few thousand km east across the south Atlantic Ocean to the Benguela Upwelling system, where they overlap with nonbreeding white-chinned petrels from colonies in the Indian Ocean, and some white-capped and shy albatrosses that have travelled much longer distances west from the Auckland Islands and Tasmania, respectively. In contrast, white-chinned petrels, also from South Georgia, migrate only to the Patagonian Shelf or the Humboldt Upwelling; in the former, they overlap with wintering black-browed albatrosses from the Falkland Islands and northern royal albatrosses from New Zealand, and in the latter with several species of albatrosses and large petrels from New Zealand, including Salvin's, Buller's, Chatham and Antipodean albatrosses, black and Westland petrels. Even within the same population, there is often extensive variation among individuals in movements and distribution.

Albatrosses and the large petrels (*Procellaria* species) that have been studied display diverse habitat preferences, reflecting the broad range of oceanographic conditions in waters around their scattered colonies, and the more distant regions used at other times of year. They can be specialists or generalists, reflected in the proportion of time spent utilising continental and island shelf breaks and shelf-slope or oceanic waters at different times of year. Several species exhibit pronounced sexual segregation, with

females tending to feed at lower latitudes or further from colonies than males, attributed to competition between sexes or habitat specialisation. There can also be partial or complete spatial segregation between juveniles and adults. Even in areas of spatial overlap, species usually differ in at-sea activity patterns (e.g. frequency of landings, flight and resting bout durations), reflecting the distribution of preferred prey or degree of nocturnality, among others. There are also large differences in diving capability; albatrosses and probably giant petrels (*Macronectes* species), are much poorer divers than *Procellaria* petrels and shearwater species. Intra- and inter-specific variation in distribution, habitat preferences, dive depth and other aspects of behaviour have major implications for the degree of overlap and hence risk of bycatch in different fisheries (see below).

For albatrosses and the *Macronectes* and *Procellaria* petrels there is a strong connection between the species that occur at migration end points with many other seabirds and other taxa, including marine turtles and commercially harvested fish species utilising the same marine resources ('threat connectivity').

Knowledge of the at-sea distribution of juveniles/immatures is a priority if we are to improve understanding on connectivity for albatrosses and the larger petrel species, and future tracking studies and use of developing technologies should facilitate this. For adults, which have been better studied, the demonstrated use of productive upwelling, shelf or frontal systems during the nonbreeding period, often in different ocean basins from where a species may breed, and where they may spend considerable time, indicates the importance of addressing the major conservation issue of fisheries bycatch in these areas, as the highest priority.

Managing goose populations – defined by our knowledge of connectivity

Sergey Dereliev[1] & Jesper Madsen[2]

[1] African-Eurasian Migratory Waterbird Agreement (AEWA), AEWA Secretariat, UN Campus, Platz der Vereinten Nationen 1, 53113 Bonn, Germany, sergey.dereliev@unep-aewa.org

[2] Aarhus University, Department of Bioscience – Kalø Grenåvej 14, DK-8410 Rønde, Denmark

The changes that humans inflict on the natural environment usually have negative impacts on many species, leading to their decline, or even extinction. Some species, however, can benefit from such changes and, as a result, increase their numbers significantly and often exponentially. For example, the populations of several species of geese in Europe have been boosted by the agriculture intensification in the last decades.

Up until the 1970s, most of the goose populations in Europe were depleted, small and even endangered. Then things changed. Also facilitated by increased protection, some species reached numbers that nowadays are two orders of magnitude larger than the first reliable monitoring data. In the 1950s one of the populations of the Barnacle Goose (*Branta leucopsis*), breeding in the Russian Arctic, was estimated at 20,000 individuals; nowadays this same population has reached 1.2 million individuals and continues to grow. This population is no longer breeding only in the Arctic, but has already occupied many other areas in western and northern Europe and is spreading.

Similar increases have been recorded in the case of the Greylag Goose (*Anser anser*), the Greater White-fronted Goose (*Anser albifrons*), the Tundra Bean Goose (*Anser fabalis rossicus*) and the Pink-footed Goose (*Anser brachyrhynchus*) with populations nowadays numbering between around half and more than a million birds.

This continuous population growth leads to overabundance and impacts on the environment, such as competing and suppressing other species, deteriorating tundra and temperate grassland habitats, and polluting waterbodies by deposing large quantities of nutrients, etc. Other impacts are conflicting with human socio-economic interests by causing damage to agriculture crops, elevating risk to civil aviation, encroaching into urban environment, etc.

The majority of the European goose populations are increasing and abundant, but a few, which are still being heavily hunted, are depleted and continue to decline. They also require management, but in a way that will ensure their recovery and regulate hunting activity, so as to maintain their favourable status in the long term.

Careful planning and specific measures are required for the management and conservation of each individual goose population. Therefore, some fundamental knowledge and understanding of spatial and temporal traits is necessary in order to undertake the most appropriate and informed management at a flyway scale:

- **Population boundaries**. The dynamics and trends in each population are different and it is essential to understand where spatially, a line between the birds of the same species lies and whether they are isolated from each other or there is some degree of exchange between them.
- **Distributio**n. Birds tend to occupy and concentrate in certain areas and sites within the range of each population. It is important to know where their breeding and moulting grounds are, which sites they use during migration and during overwintering, as well as the numbers in each of these sites throughout the season and across years.
- **Timing**. Birds spend different amounts of time in different parts of their range. Knowledge of timing of migration events, the role of sites, e.g. their importance for spring fattening, and duration of presence at certain sites is essential for effective management strategies.

- **Movements**. Birds are always on the go. They migrate long distances from their breeding to their wintering grounds with stopovers in other key sites, but also undertake shorter movements, including on a daily basis.
- **Migratory vs. resident behaviour**. It is especially valid for some of the large populations with large ranges that birds may exhibit different behaviours. While one part of the population may regularly and cyclically migrate from one to another part of the range, another may be sedentary and remain in the same limited area for the entire year. It has also been observed that in some populations, birds may change their behaviour from migratory to resident and vice versa.

The following examples demonstrate the importance of the knowledge and understanding of connectivity for effective and appropriate goose management and conservation:

- The Taiga Bean Goose (*Anser fabalis fabalis*) has a depleted and declining population, estimated at less than 60,000 birds, which however is still on the list of huntable species in many countries. It has a large discontinuous breeding range from Fennoscandia to central Siberia with wintering areas across the British Isles, northern Europe and Central Asia. Based on the knowledge of the movements of the birds from the different parts of the range and the linkages that they outline between breeding, stopover and wintering sites, it was possible to define four separate Management Units (MU) within the population (Figure 1). Each of them has well-defined boundaries, although they may overlap at either end of the flyway, and have different sizes and trends. Therefore, the management plan for the Taiga Bean Goose sets different population targets and management objectives for each MU.
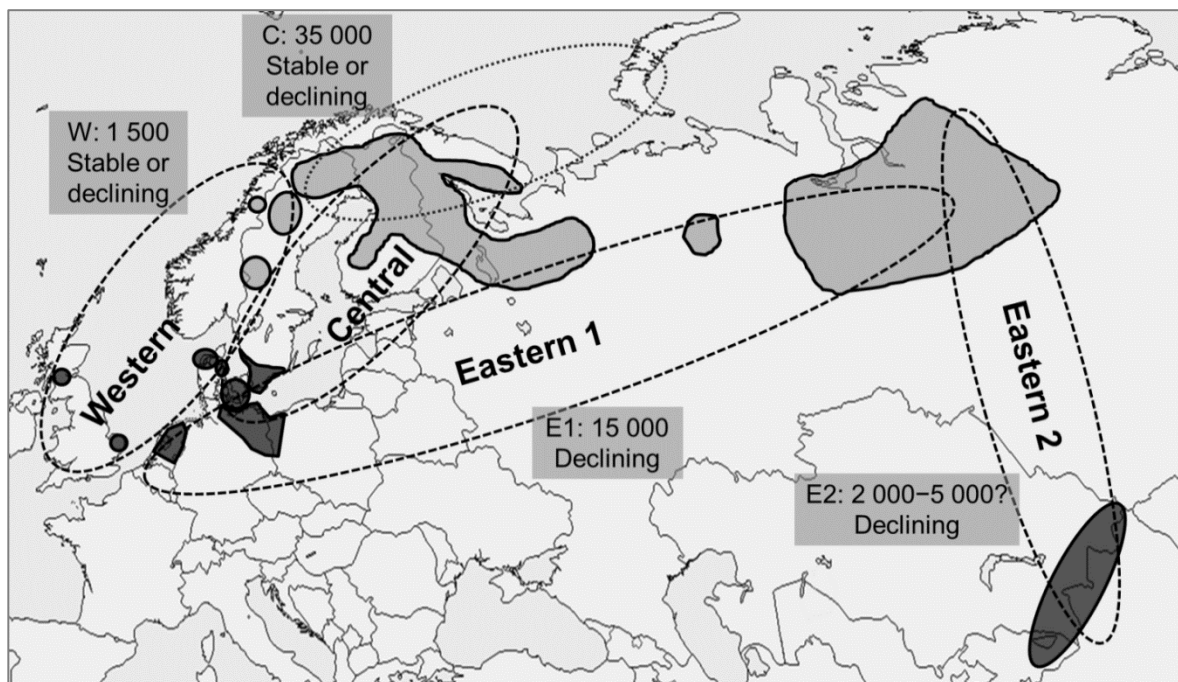
Figure 1. Delineation of Taiga Bean Goose Management Units for the purpose of the International Single Species Action Plan for the sub-species (Marjakangas et al. 2015). The numbers refer to estimated current population sizes accompanied by indicative trends, and the broken lines link breeding areas (light grey) with specific winter quarters (dark grey). The dotted area indicates linkages between breeding areas in northern Fennoscandia and known moulting areas in Novaya Zemlya and the Kola Peninsula.

- In order to recover the Taiga Bean Goose population to a favourable status, some countries introduced a temporary hunting ban. However, the Taiga Bean Goose is very similar in appearance

to the other sub-species – the Tundra Bean Goose – and they may occur together in winter. In order to implement the ban effectively, in some countries, it was identified where and when Taiga Bean Geese occur and where and when they are the dominant sub-species; in those sites and periods the Bean Goose hunting has been suspended altogether.

- The Pink-footed Goose (*Anser brachyrhynchus*) occurs in two flyway populations: one population breeding in Iceland and East Greenland and wintering in Great Britain and another population breeding in Svalbard and wintering in Denmark, the Netherlands and Belgium, with autumn and spring stopover sites in Norway (Figure 2). Molecular and marking/resighting studies have shown that there is little demographic connectivity between the two populations. Both populations have increased, the former to reach so far a level of ca. 400,000 birds, the latter a level of around 80,000 birds. The Iceland & East Greenland-breeding geese feed on crop remains in autumn and winter and sprouting grass in spring, however, causing little conflict with agricultural interests despite their high numbers. The Svalbard-breeding population, however, causes serious conflict with farming interests, particularly in Norway, because the geese are concentrated in a particular, high productive region coinciding with the time of grass growth in spring. This is one of the reasons why this population was selected as the first European test case for adaptive management.
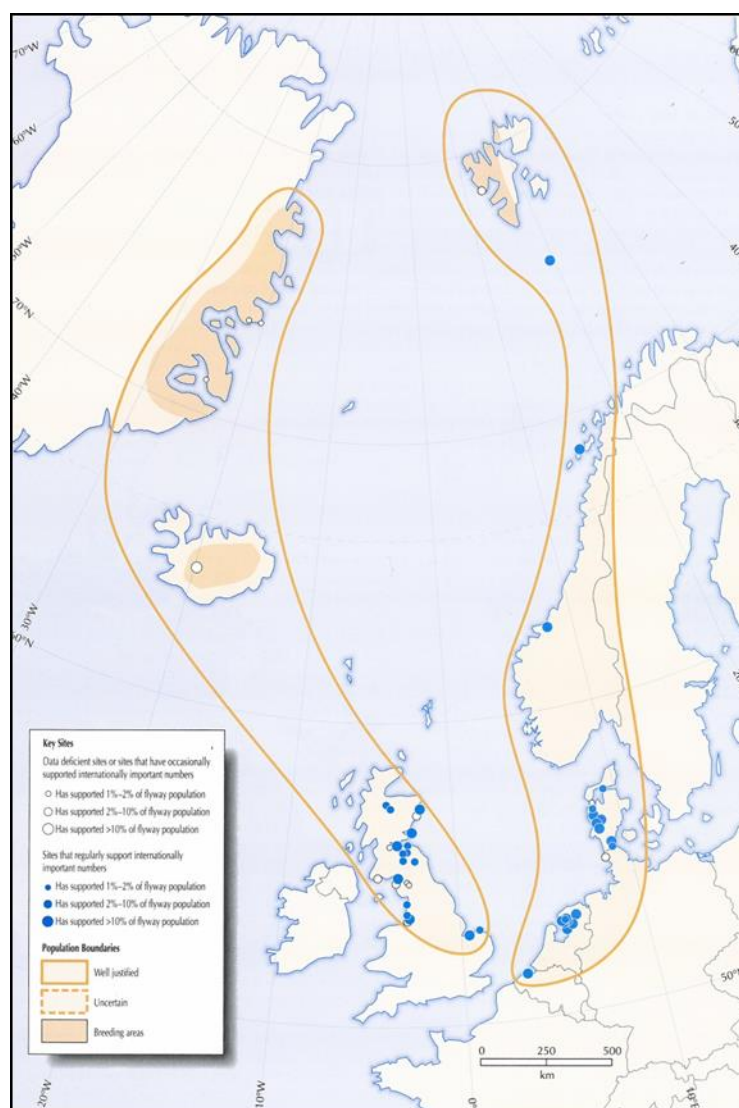

Figure 2. Delineation of the two discrete populations of the Pink-footed Goose (Scott & Rose 1996).

References:

Marjakangas, A., Alhainen, M., Fox, A.D., Heinicke, T., Madsen, J., Nilsson, L. & Rozenfeld, S. (Compilers) 2015. International Single Species Action Plan for the Conservation of the Taiga Bean Goose (*Anser fabalis fabalis*). AEWA Technical Series No. 56. Bonn, Germany.

Scott, D.A. & Rose, P.M. 1996. Atlas of Anatidae Populations in Africa and Western Eurasia. Wetlands International Publication No. 41. Wetlands International, Wageningen, The Netherlands.

Yellow Sea And East Asian – Australasian Flyway Wetlands

Taej Mundkur[1]

[1] Wetlands International, Horapark 9, 6717 LZ Ede, The Netherlands, Taej.Mundkur@wetlands.org

The intertidal and coastal freshwater wetlands in the Yellow Sea and Bohai Sea region bordering eastern China and the western coast of the Korean Peninsula are amongst the most important stopover areas for migratory waterbirds in the world. They are used intensively by millions of waterbirds for feeding and resting during northward and southward migration along the East Asian - Australasian Flyway. Waterbirds breeding in Russia and Alaska (USA), Mongolia and northern China migrate along the coastlines of the Yellow Sea - Bohai Sea to spend the northern winter in the Yangtze River floodplains and southern China, including threatened EAAF endemic species of cranes, geese and ducks, while many others continue their journeys to south to Southeast (and South) Asia, Australia and New Zealand where they spend the non-breeding period. Species like the Great Knot *Calidris tenuirostris* even migrate through the Yellow Sea and across to coastal West Asia. However, these intertidal flats are under great pressure and over the last decades, with over two-thirds of these having been lost through conversion to land for agriculture and coastal developments, at annual loss of 4 per cent between 1990 and 2013.

The Vulnerable Saunders's Gull (Saundersilarus saundersi), largely a Yellow Sea "endemic" species

Many shorebirds and other species are reliant almost exclusively on coastal wetlands during their migration and the Yellow Sea is the last stopover site before they get to their arctic breeding grounds in May/June. For the Bar-tailed Godwit *Limosa lapponica* that migrate from non-breeding grounds in New Zealand and Australia to their breeding grounds in arctic Russia and Alaska, a distance of about 11,000 km, they are doing so with only one stop – along the Yellow Sea! So without this crucial refuelling and rest area being maintained as a healthy and productive habitat, this Bar-tailed Godwit population is expected to crash within a decade.

Our knowledge about bird movements, their dependence on these coastal sites and monitoring wetland change has progressed greatly over the last years. Monitoring of waterbirds on migration and in the non-breeding periods such as through the International Waterbird Census and other citizen-science programmes are providing valuable data on the distribution and abundance of waterbirds and their changes. Besides monitoring loss of habitat, knowledge on some of the main threats to birds through pervasive degradation of the Yellow Sea ecosystem, including discharge of heavy metals and pesticides, massive and regular algal blooms, and the spread of the alien invasive species saltmarsh grass *Spartina alterniflora.* As well, information is being generated on the scale of illegal killing of birds and growing risk and threats from death of birds through collision and electrocution from a rapidly increasing number of poorly located wind farms, powerlines and other man-made structures.

As a result, it is possible to demonstrate for species and populations that depend largely or only the Yellow Sea are now declining most rapidly, with 24 being listed on the IUCN Red List of Threatened Species within the last decade, particularly for some of the long-distant migrating shorebirds, such as EAAF endemic Far Eastern Curlew *Numenius madagascariensis* and the Spoon-billed Sandpiper *Eurynorhynchus pygmeus.*

Besides changes and loss of the Yellow Sea wetlands, pollution, landscape level habitat and land-use changes, degradation and loss of inland and coastal wetlands in parts of North, East and Southeast Asia continue to occur. These changes along the chain of wetlands and associated habitats that waterbirds and other species are reliant on to breed, rest and feed during their annual migrations are having a cumulative negative impact on a wide range of species.

The EAAF Partnership (EAAFP), a collaboration among 36 countries, non-governmental organizations and multilateral arrangements provides a cooperation framework for conservation of migratory waterbirds and wetlands. The EAAFP has formally designated 136

Shell fish harvesting and growing numbers of wind farms on the coast and intertidal areas - two threats to migratory waterbirds in the Yellow Sea

Flyway Network Sites, many of which also listed as Ramsar and World Heritage Sites. However, much more needs to be urgently done to reverse the loss of wetlands and restore them in the Yellow Sea region and elsewhere.

References:

Barter, M. (2002). 'Shorebirds of the Yellow Sea: Importance, Threats and Conservation Status.' Wetlands International Global Series 9, International Wader Studies 12. (Wetlands International – Oceania: Canberra, ACT.)

Chen Kelin, Bai Jiade, Jiang Ming, Chen Qi, Li Yanhui, Lv Yong, Doug Watkins, John Howes, Taej Mundkur, Yang Xiuzhi, Xie Jun, Zhang Xiaohong, (2016) Yellow Sea – Bohai region coordinated waterbird survey 2016. Summary report. Wetlands International - China, Beijing.

Ma,Z. J., Melville,D. S., Liu, J. G., Chen, Y., Yang, H. Y., Ren,W.W., Zhang,Z. W., Piersma, T., and Li, B. (2014). Rethinking China's new great wall. *Science* 346, 912–914. doi:10.1126/science.1257258

Murray, N. J., and Fuller, R. A. (2015). Protecting stopover habitat for migratory shorebirds in East Asia. *Journal of Ornithology* **156**(Suppl 1), 217–225. doi:10.1007/s10336-015-1225-2

Murray, N. J., Clemens, R. S., Rhinn, S. R., Possingham, H. P., and Fuller, R. A. (2014). Tracking the rapid loss of tidal wetlands in the Yellow Sea. *Frontiers in Ecology and the Environment* **12**, 267–272. doi:10.1890/130260

Piersma, T., Lok, T., Chen, Y., Hassell, C., Yang, H. Y., Boyle, A., Slaymaker, M., Chan, Y. C., Melville, D. S., Zhang, Z. W., and Ma, Z. J. (2016). Simultaneous declines in summer survival of three shorebird species signals a flyway at risk. *Journal of Applied Ecology.* doi:10.1111/1365-2664.12582

Studds, C.E., Kendall, BE, Murray, NJ, Wilson, HB, Rogers, DI, Clemens, RS, Gosbell, K., Hassell, CJ., Jessop, R., Melville, DS., Milton, DA, Minton, CDT, Possingham, HP, Riegen, AC, Straw, P., Woehler, EJ & Fuller, RA. 2017. Rapid population decline in migratory shorebirds relying on Yellow Sea tidal mudflats as stopover sites. Nature Communications 8:14895 | doi: 10.1038/ncomms14895

Marine turtles

Colin Limpus[1]

[1] Queensland Department of Environment and Heritage Protection, Block C1, 41 Boggo Rd., Dutton Park Qld 4102 ESP, PO Box 2454 City, Qld, 4001, Australia, Col.Limpus@ehp.qld.gov.au

Marine turtle life histories are among the most complex, largely because of multiple migration patterns that occur within different stages in their life history.

- Hatchling marine turtles disperse from the nesting beaches and are carried in a predictable manner by ocean current during their pelagic post-hatchling life history phase. During this pelagic phase these immature turtles forage on macroplankton in surface waters across many years.
- During this pelagic phase the post-hatchlings disperse across vast areas of ocean, with loggerhead and leatherback turtles travelling across entire ocean basins.
- For all except the leather back turtle, juvenile turtles eventually leave this pelagic phase and move into coastal waters within a few thousand kilometres of their natal beaches and dramatically change their ecology to feed on benthic prey species. Leatherback turtle remain as pelagic plankton foraging species throughout their entire life.
- Turtles in this benthic foraging life history phase do not aggregate in herds or schools. Turtles hatched at the one beach will occupy individual foraging sites scattered over thousands of kilometres of coastal habitat.
- Each turtle occupies its own individual species specific foraging habitat for many years as it grows to maturity. For the population as a whole, the species occupies a vast area of coastal habitat within a few thousand kilometres of their respective breeding areas.
- On reaching maturity when decades old, the adult turtle will migrate to breed within the region where it hatched. The female travels first to a individually specific courtship area for mating before selecting a nesting beach for laying her eggs – not necessarily at the exact beach where hatched but within a few hundred kilometre.
- At the completion of the breeding season, the adult turtles return to their respective individual foraging areas.
- Through the remaining decades of their adult lives, adult turtles will repeat this breeding migration between their respective foraging and breeding sites, usually skipping years between breeding seasons but displaying strong fidelity to their respective foraging and breeding areas.

The connectivity through a diverse network of habitat is critical for the survival of marine turtle species: plankton rich surface waters of the oceans, diverse benthic habitats in shallow coastal waters catering for their species specific diets, and suitable tropical and subtropical beaches for incubation of their eggs. All this has to function in the absence of any parental care or learning from siblings.

As with migratory terrestrial species, marine turtles migrate across national boundaries and are exposed to different management regimes in different countries. However, unlike in the terrestrial scene, marine turtles also travel through "international waters" not owned by any one country, introducing further complexity into their management.

Not readily visible to the broader global community and usually poorly quantified, marine turtles in oceanic waters are significantly impacted by capture and associated mortality in fisheries using long lines and gill nets and by ingestion of or entanglement in marine debris including lost and discarded fishing gear.

- Unless International collaboration and engagement with Regional Fisheries Management Organisations at a global level is connected to reducing bycatch mortality within these fisheries, viable leatherback and loggerhead turtle populations are at risk especially in the Pacific and Indian Oceans.
- Marine turtle population functionality is connected to the global society's short-sighted excessive use disposable synthetic materials. Immediate and significant reductions in existing levels of marine debris, especially plastics and lost and discarded fishing gear, are needed if major declines in all marine turtle populations are to be avoided. Additionally, since these are ongoing threats, prevention of continued entry of marine debris in to our oceans needs to be addressed.

In coastal waters there is a more diverse array of threats to marine turtle populations that are connected to human use of coastal resources:

- In the absence of effective mitigation measures, bycatch mortality with coastal trawling, bottom set longline and gill net fisheries through their interaction with the older age classes of turtles expands on the impact of oceanic fisheries bycatch, further threatening marine turtle population survival.
- Sediment and pollution outflow from expanded agricultural, pastoral, urban and industrial activities throughout catchments is degrading coastal marine habitat such as coral reef and seagrass meadows which are critical for maintenance of green, hawksbill and loggerhead turtle populations.
- Excessive take of turtles and/or eggs to feed increasing human populations in coastal communities, especially in less developed regions, is not sustainable for several regional leatherback, green, and hawksbill stocks.

Management of fisheries bycatch within coastal waters, management of pollution of coastal waters from river outflow to coastal marine habitats and management of excess harvest of turtles and their eggs are dependent on conservation actions from within the individual countries.

Failure to maintain connection between breeding turtles and suitable nesting and incubation habitat is seriously impacting marine turtles globally.

- Alienation of nesting beaches through encroachment of urban and industrial development in coastal area is reducing incubation susses of eggs and diminishing hatchling production.
- As a consequence of past introductions beyond their natural distribution, feral predators such as pigs and foxes in Australia threaten the survival of multiple species on marine turtles.
- Sky glow alteration of light horizons over turtle nesting beaches causes reduction in the size of nesting populations and elevated mortality of hatchlings on shore and in the adjacent waters.

With climate change driven by the past and present excesses of industrialised societies adding new threats impacting global marine turtle population through global warming, sea level rise and increased extreme weather events, cooperative concerted actions are required to reduce turtle mortality and enhance breeding success across all marine turtle life history phases, on beaches and out into oceanic waters and back to coastal waters by all levels of society, from the local communities, Local government, State Government, National governments and international agencies.

CMS and its daughter agreements can play a significant role in facilitating collaborative global actions to recover our threatened marine turtle populations.

The European Eel (*Anguilla anguilla*)

Matthew Gollock[1], David Freestone[2] & Faith Bulger[2]

[1] Conservation Programmes ZSL, Chair - The IUCN Anguillid Eel Specialist Group, Regent's Park, London, NW1 4RY, mattgollock@gmail.com

[2] Sargasso Sea Commission, davidacfreestone@gmail.com, Faith.Bulger@iucn.org

The European eel (*Anguilla anguilla*) has a life history best described as 'facultatively catadromous'. True catadromy could be described as feeding and growing in freshwater, and breeding in the marine environment, however, the European eel's growth phase is often described as 'continental' as they are found in fresh, brackish and coastal waters. As such 'freshwater' is not believed to be essential to the continuation of the species – hence facultative catadromy. Breeding and spawning of the European eel occurs in the marine environment and this element is believed to be essential for the completion of the life cycle. While there is some understanding of the eel's continental life history, relatively little is known about its marine phase. There are still no exact data about specific spawning sites, however, from, and building upon, work carried out by Johannes Schmidt in the early part of the 20th Century (Schmidt, 1922) it has been deduced that spawning takes place in an elliptic zone, about 2,000 km wide in the Sargasso Sea, in the West Central Atlantic (approximately centred around 26°N 60°W). It should be noted that the American eel (*Anguilla rostrata*) is believed to spawn in a sympatric area of the Sargasso Sea (McCleave et al., 1987). Surveys of *A. anguilla* leptocephali indicate that spawning peaks in early March and continues to July (McCleave, 1993) and that they are <10mm upon hatching (McCleave et al., 1987). Spent adults are assumed to die after spawning.

The leptocephali migrate towards their continental habitat and are believed to feed on 'marine snow' – particulate organic matter – during this period (Otake et al., 1993). By the time they reach the continental slope they are as large as 100 mm and have metamorphosed to become elongate, transparent glass eels. The majority of continental landings occur in late-autumn to early-spring in Iberian and Bay of Biscay waters - they are delayed in more northerly sites until temperatures rise in the spring. Sexually undifferentiated glass eels are washed into rivers, estuaries and coastal waters tidally before developing into pigmented elvers (Tesch, 1977) - this is vague term but usually implies an eel above 10-15cm in length. Eels grow and mature over a wide temporal range from anywhere between five and 50 years - dependent on environmental conditions, food availability, the sex of the individual and access to and from suitable growth habitat. During this growth period they may migrate within and between freshwater and saline habitats; feed on a broad range of prey including fish, crustaceans, bivalves, shrimp and polychaete worms; and equally, are able to fast for extended periods (reviewed in van Ginneken and Maes, 2005).

Sex determination is principally driven by environmental factors, with high densities often producing more males (Davey and Jellyman, 2005). Males grow faster than females, however, females achieve a greater age and size than males when sexually mature - fat stores are used to fuel the migration to the Sargasso, and in the case of females, produce eggs (Svedäng and Wickström, 1997). Yellow eels that are ready for the seaward migration undergo morphological and physiological changes to become silver eels (Tesch, 1977). The age at which silver eels mature and undertake their spawning migration is hugely variable and dependent on the latitude and temperature of the environment in which they have grown, physical barriers that block migration routes, growth rate and sex. From the data available, lower bound estimates for average period of the continental growth phase are approximately 3-8 years for males and 4-5 years for females, and upper bound estimates are approximately 12-15 years for males and 18-20 for females (Acou et al., 2003; Froese and Pauly, 2005; Durif et al., 2009). However, data is lacking from some parts of its range and there is no known size threshold or age before which initiation of silvering occurs - what triggers this process is still not known (Svedang et al., 1996). Once eels have begun silvering, initiation of the 'downstream' migration of anguillids is believed to be triggered by lunar stage and atmospheric conditions (Todd, 1981). The silver eels then begin the migration to the Sargasso which may take at least 6 months depending on the location of the

river that they are migrating from (Kettle et al., 2011; Righton et al., 2016). Eels are not believed to feed during the oceanic migration and their alimentary tract degenerates (Pankhurst and Sorensen, 1984), and it is only during this migration that full sexual maturity is believed to occur, but our understanding of this process is poor. In recent years, researchers have been successful in attaching satellite tags to large female silver eels and this work has given us a new insight into the spawning migration of the European eel (Aarestrup et al., 2009; Emilhat et al., 2016). Adult eels have been found to swim towards the Canary and Azores currents exhibiting a diel vertical migration (Castonguay and McCleave, 1987; Aarestrup et al., 2009; Emilhat et al., 2016). It has been proposed that eels that spawn in the Sargasso Sea (i.e. American and European eels), locate their spawning ground using the convergence of currents in the region (Kleckner and McCleave 1988; Miller and McCleave, 1994) – sometimes referred to as the North Atlantic Subtropical Convergence Zone. Eels have also been found to have a magnetic sense (Durif et al., 2013) which may play a role in the migration. Once mature eels reach the Sargasso Sea, spawning occurs and the life cycle continues with fertilized eggs hatching to produce leptocephali.

Arguably the best studied population metric is recruitment – both of glass eels and juvenile yellow eels/elvers - and the joint European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) and International Council for the Exploration of the Sea (ICES) eel working group (WGEEL) has been analyzing recruitment data from continental Europe for many years. Since the early 1980s, a steady and almost continent-wide decline of ~90% has been observed in the recruitment of glass eels (see fig.) – in some catchments this has been as high as 99% (Gollock et al., 2011). In 2009 the WGEEL recruitment index dropped to its lowest historical level, less than 1% for the North Sea and 5% elsewhere in the distribution area (ICES, 2013a). Strong language has been used in light of these findings e.g. recruitment was 'outside its safe biological limits' and as such efforts should be made to 'reduce all anthropogenic impacts to as close to zero as possible' (ICES, 2006). The most recent data however, indicates that the recruitment index has increased to 2.7% of the 1960–1979 reference level in the 'North Sea' series, and to 10.7% in the 'Elsewhere' series, but both remain far from 'healthy' (ICES, 2016). This could possibly be in response to the closure of silver eel fisheries across Europe in 2009, although this increase is within the natural variation of historical records (ICES, 2012). Whilst data from catch returns indicate this increase in recruitment, the impact of the overall decline will continue to influence adult stock for at least one generation length (ICES, 2012). For the North African range of the population there is considerably less information. A regional Red List assessment in North Africa suggests that *A. anguilla* is 'Endangered' due to a decline in recruitment of 50% in the last 10 years with annual catches declining by between 10 and 25% since the 1980s, and by more in Tunisia alone (Azeroual, 2010).

In 2014, the European eel (*Anguilla anguilla*) was listed on Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS). The proposal for the listing was submitted by Monaco with support from the Sargasso Sea Commission which collated existing knowledge on the species and outlined how addition to Appendix II would benefit the species.

To investigate the ways in which such cooperation may improve the conservation status of this extraordinary migratory species, the Secretariats of the Sargasso Sea Commission and of the Convention on Migratory Species convened a Range States Meeting in Galway Bay, Ireland in October 2016. This workshop include representatives from a number of the range states in which European eels are found, as well as experts from North America. This Range State Meeting reviewed the threats to both the European and American eel and discusses measures that could be taken at an international level to protect them during their migration, including the development of an instrument – i.e. a treaty or MOU – under the CMS – which might seek to afford all the protections that international law allows to the area where they spawn - the Sargasso Sea.
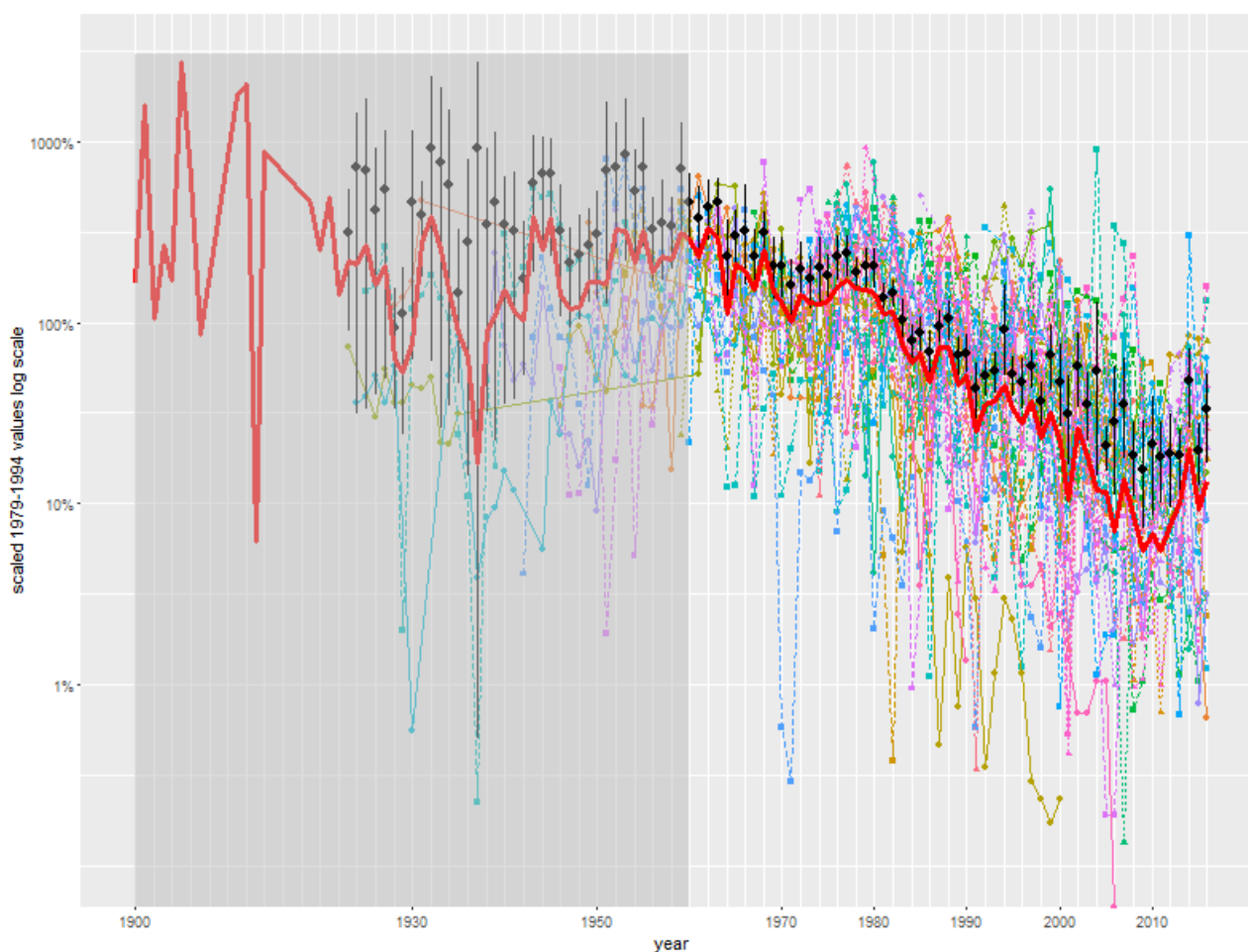
Time-series of glass eel and yellow eel recruitment in European rivers with time-series having data for the 1979–1994 period (45 sites). Each time-series has been scaled to its 1979–1994 average. Note the logarithmic scale on the y-axis. The mean values and their bootstrap confidence interval (95%) are represented as black dots and bars. Geometric means are presented in red.

References:

Aarestrup, K., Akland, F., Hansen, M.M., Righton, D., Gargan, P., Castonguay, M., Bernatchez, L., Howey, P., Sparholt, H., Pedersen, M.I., and McKinley, R.S. (2009) Oceanic spawning migration of the European eel (Anguilla anguilla). Science 325: 1660.

Acou, A., Lefebvre, F., Contournet, P., Poizat, G., Panfili, J. and Crivelli, A.J. 2003. Silvering of female eels (Anguilla anguilla) in two sub-populations of the Rhône Delta. Bulletin Francais de la Peche et de la Pisciculture 368: 55-68.

Amilhat, E., Aarestrup, K., Faliex, E., Simon, G., Westerberg, H and Righton, D. (2016) First evidence of European eels exiting the Mediterranean Sea during their spawning migration. Scientific Reports 6, Article number: 21817 (2016).

Azeroual, A. (2010) Anguilla anguilla In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. (http://www.iucnredlist.org/details/60344/20)

Castonguay, M. and McCleave, J. D. (1987) Vertical distributions, did and ontogenic vertical migrations and net avoidance of leptocephati of Anguilla and other common species in the Sargasso Sea. Journal of Plankton Research 9: 195-214.

Davey, A.J.H., and Jellyman, D.J. (2005) Sex determination in freshwater eels and management options for manipulation of sex. Reviews in Fish Biology and Fisheries 15: 37-52.

Durif, C. M. F., van Ginneken, V., Dufour, S., Moeller, T. and Elie, P. (2009) Seasonal evolution and individual differences in silvering eels from different locations. In: G. Van den Thillart, S. Dufour, and J.C. Rankin, (eds.), Spawning migration of the European eel: Reproduction index, a useful tool for conservation management pp. 13-38: Springer Netherlands.

Durif, C.M.F., Browman, H.I., Skiftesvik, A.B., Vallestad, L.A., Stockhausen, H.H. and Phillips J.B. (2013) Magnetic compass orientation in the European eel. PLoS ONE 8(3): e59212.

Froese, R. and Pauly, D. (eds.) (2005) FishBase version (11/2005) World Wide Web electronic publication.

Gollock, M., Curnick, D. and Debney, A. (2011) Recent recruitment trends of juvenile eels in tributaries of the River Thames. Hydrobiologia 672:33–37.

ICES (2006) Report of the 2006 session of the Joint EIFAC/ICES Working Group on Eels.

ICES (2012) Report of the 2012 session of the Joint EIFAC/ICES Working Group on Eels.

ICES (2013) Report of the 2013 session of the Joint EIFAC/ICES Working Group on Eels.

ICES (2016) Report of the Working Group on Eels (WGEEL), 15–22 September 2016, Cordoba, Spain. ICES CM 2016/AACOM:19. 106 pp.

Kettle, A.J., Vallestad, L.A. and Wibig, J. (2011) Where once the eel and the elephant were together: decline of the European eel because of changing hydrology in southwest Europe and northwest Africa? Fish and Fisheries 12: 380–411.

Kleckner, R.C. and McCleave, J.D. (1988) The northern limit of spawning by Atlantic eels (Anguilla spp.) in the Sargasso Sea in relation to thermal fronts and surface water masses. Journal Marine Research 46: 647–667.

McCleave, J. D., Kleckner, R. C. and Castonguay M. (1987) Reproductive sympatry of American and European eels and implications for migration and taxonomy. American Fisheries Society Symposium 1: 286–297.<

McCleave, J.D. (1993) Physical and behavioral controls on the oceanic distribution and migration of leptocephali. Journal of Fish Biology 43: 243-273.

Miller, M.J. and McCleave J.D. (1994) Species assemblages of leptocephali in the subtropical convergence zone of the Sargasso Sea. Journal of Marine Research 52: 743–7772.

Otake, T., Nogami, K. and Maruyama K. (1993) Dissolved and particulate organic matter as possible food sources for eel leptocephali. Marine Ecology Progress Series 92: 27–34.

Pankhurst, N.W. and Sorensen, P.W. (1984) Degeneration of the alimentary tract in sexually maturing European Anguilla anguilla (L.) and American eels Anguilla rostrata (LeSueur). Canadian Journal of Zoology 62: 1143-1149.

Righton DA, Westerberg H, Feunteun E, Okland F, Gargan P, Amilhat E, et al. (2016) Empirical observations of the spawning migration of European eels: The long and dangerous road to the Sargasso Sea. Sci Adv. 2016;2: e1501694.

Schmidt, J. (1922) The breeding places of the eel. Philosophical Transactions of the Royal Society of London Series B 211: 179-208.

Svedang, H., Neuman, E. and Wickstroem H. (1996) Maturation patterns in female European eel: age and size at the silver eel stage. Journal of Fish Biology 48:342-351.

Svedang, H. and Wickstroem, H. (1997) Low fat contents in female silver eels: indications of insufficient energetic stores for migration and gonadal development. Journal of Fish Biology 50: 475-486.

Tesch, F.W. (1977) The Eel—Biology and Management of anguillid eels. Chapman annd Hall: London.

Todd, P.R. (1981) Timing and periodicity of migrating New Zealand freshwater eels (Anguilla spp.). New Zealand Journal of Marine and Freshwater Research 15: 225–235.

van Ginneken, V.J. T. and Maes, G.E. (2005) The European eel (Anguilla anguilla, Linnaeus), its Lifecycle, Evolution and Reproduction: A Literature Review. Reviews in Fish Biology and Fisheries 15: 367-398.

Migratory Sharks

Daniel C. Dunn[1] & Guillermo Ortuno Crespo[1]

[1] Marine Geospatial Ecology Lab, Nicholas School of the Environment, Duke University, USA, daniel.dunn@duke.edu

The taxonomic class *Chondrichthyes* is comprised by 1,041 species belonging to the *Elasmobranchii* and *Holocephali* subclasses; of these species, only 37.4% of them are considered 'safe' under conservation standards (Dulvy *et al.*, 2014). Understanding the life histories and spatiotemporal distributions of *Chondrichthyes* is crucial for their adequate management and conservation, especially for those species which have large and dynamic ranges. A 2014 report by the secretariat of the Convention of Migratory Species (CMS) and United Nations Environment Programme (UNEP) assessed the migratory and threat status of all Chondrichthyan fishes (Fowler 2014). The report identified 95 migratory and 56 possibly migratory species, of which 63% are classified as *threatened* or *near threatened* under IUCN standards and a further 27% are *data deficient*. Dulvy *et al.*, (2008) noted that ~75% of the 21 migratory oceanic shark species which inhabit the high seas are *threatened* or *near threatened*. Fisheries impacts remain as the main threat to shark populations and have been linked to the decline of several large pelagic sharks (Baum *et al.*, 2003).

While our knowledge on the ranges and connectivity patterns of migratory *Chondrichthyan* species is improving, the wealth of data available is still significantly constrained geographically and taxonomically. A review of shark satellite tagging studies revealed that between 1984 and 2010 only 17 shark species from 7 different families had been tagged with satellite devices (Hammerschlag *et al.*, 2011), meaning that the migratory and dispersal patterns of most migratory shark species remain largely unknown. For those species which are well studied, very diverse movement have been reported. *Rhincodon typus* display incredible migratory journeys between the three largest ocean basins (Sequeira *et al.*, 2013), *Carcharodon carcharias* do not migrate between basins, but do display highly targeted transoceanic migrations (Bonfil *et al.*, 2005), smaller migratory sharks like *Sphyrna lewini* show no transoceanic connectivity, but do display high levels of genetic connectivity between coastal nurseries along the coasts of continents (Duncan *et al.*, 2006).

The importance of collecting this ecological information becomes clear in studies like that by Queiroz *et al.*,(2016) which showcases the distribution and intensity of spatiotemporal overlap between pelagic fishing fleets and migratory sharks in the Atlantic basin. Several species of migratory shark display marked sex-biased and size-based spatial segregation; this has implications at the population as different groups may be experiencing different levels of exposure to fisheries impacts (Pardini *et al.*, 2001; Mucientes *et al.*, 2009). Ford (1921) asserts that the exploitation of sex-specific schools of *Squalus acanthias* may have contributed to the collapse of the population in the English Channel.

Migratory sharks inhabit and connect different ecosystems throughout their spatial range and life cycles; from offshore pelagic systems to coastal kelp ecosystems, as is the case of *Prionace glauca* (Vögler *et al.*, 2012). Understanding and preserving these ecological connections is important for the wellbeing of migratory species. For instance, *Sphyrna lewini* show strong connectivity between coastal states in the Eastern Tropical Pacific, where they carry out different life history stages. Movement of the species has been tracked from foraging grounds in Galapagos Marine Reserve to coastal Costa Rican waters where they finish gestation and complete parturition (Nance *et al.*, 2011; Ketchum *et al.*, 2014). Removing suitable nursery habitat in Costa Rica may have ecological implications for the wider Pacific population. The distribution of these species can cross multiple maritime jurisdictional boundaries (Southall *et al.*, 2006; Harrison 2012);

thus, requiring international cooperation for their adequate management. Regional Fisheries Management Organizations have developed stock assessments and catch/bycatch quota systems for only a few migratory shark species, further efforts will be needed to preserve the demographic and spatial structure of these species.

Over the last three decades, genetic studies on elasmobranch species have improved our understanding on the genetic relatedness and connectivity of migratory shark species across ocean regions (Dudgeon et al., 2012). These studies have demonstrated that population structure of sharks at the regional-scale varies across taxa; while *Cetorhinus maximus* show no genetic structure *among ocean basins,* Charcharodon carcharias show strong genetic structuring at the ocean-basin level (Pardini *et al.*, 2001). Understanding the spatial component of these population connections is crucial to their conservation as network analysis studies on shark movement have demonstrated that disrupting sites of ecological importance to the population can negatively impact their overall connectivity (Jacoby *et al.*, 2012).

References:

Pardini, A.T., Jones, C.S., Noble, L.R., Kreiser, B., Malcolm, H., Bruce, B.D., Stevens, J.D., Cliff, G., Scholl, M.C., Francis, M. and Duffy, C.A., 2001. Sex-biased dispersal of great white sharks.*Nature*,*412*(6843), pp.139-140.

Jacoby, D.M., Brooks, E.J., Croft, D.P. and Sims, D.W., 2012. Developing a deeper understanding of animal movements and spatial dynamics through novel application of network analyses.*Methods in Ecology and Evolution*,*3*(3), pp.574-583.

Bonfil, R., Meÿer, M., Scholl, M.C., Johnson, R., O'brien, S., Oosthuizen, H., Swanson, S., Kotze, D. and Paterson, M., 2005. Transoceanic migration, spatial dynamics, and population linkages of white sharks.*Science*,*310*(5745), pp.100-103.

Dulvy, N.K., Baum, J.K., Clarke, S., Compagno, L.J., Cortés, E., Domingo, A., Fordham, S., Fowler, S., Francis, M.P., Gibson, C. and Martínez, J., 2008. You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays.*Aquatic Conservation: Marine and Freshwater Ecosystems*,*18*(5), pp.459-482.

Dulvy, N.K., Fowler, S.L., Musick, J.A., Cavanagh, R.D., Kyne, P.M., Harrison, L.R., Carlson, J.K., Davidson, L.N., Fordham, S.V., Francis, M.P. and Pollock, C.M., 2014. Extinction risk and conservation of the world's sharks and rays.*Elife*,*3*, p.e00590.

Duncan, K.M., Martin, A.P., Bowen, B.W. and De Couet, H.G., 2006. Global phylogeography of the scalloped hammerhead shark (Sphyrna lewini).*Molecular ecology*,*15*(8), pp.2239-2251.

Ford, E., 1921. A contribution to our knowledge of the life-histories of the dogfishes landed at Plymouth.*Journal of the Marine Biological Association of the United Kingdom (New Series)*,*12*(03), pp.468-505.

Fowler, S., 2014. The Conservation Status of Migratory Sharks.*UNEP/CMS Secretariat, Bonn, Germany*.

Hammerschlag, N., Gallagher, A.J. and Lazarre, D.M., 2011. A review of shark satellite tagging studies.*Journal of Experimental Marine Biology and Ecology*,*398*(1), pp.1-8.

Harrison, A.L., 2012. A synthesis of marine predator migrations, distribution, species overlap, and use of Pacific Ocean Exclusive Economic Zones.

Ketchum, J.T., Hearn, A., Klimley, A.P., Peñaherrera, C., Espinoza, E., Bessudo, S., Soler, G. and Arauz, R., 2014. Inter-island movements of scalloped hammerhead sharks (Sphyrna lewini) and seasonal connectivity in a marine protected area of the eastern tropical Pacific.*Marine Biology*,*161*(4), pp.939-951.

Mucientes, G.R., Queiroz, N., Sousa, L.L., Tarroso, P. and Sims, D.W., 2009. Sexual segregation of pelagic sharks and the potential threat from fisheries.*Biology Letters*, pp.rsbl-2008.

Nance, H.A., Klimley, P., Galván-Magaña, F., Martínez-Ortíz, J. and Marko, P.B., 2011. Demographic processes underlying subtle patterns of population structure in the scalloped hammerhead shark, Sphyrna lewini.*Plos One*,*6*(7), p.e21459.

Pardini, A.T., Jones, C.S., Noble, L.R., Kreiser, B., Malcolm, H., Bruce, B.D., Stevens, J.D., Cliff, G., Scholl, M.C., Francis, M. and Duffy, C.A., 2001. Sex-biased dispersal of great white sharks.*Nature*,*412*(6843), pp.139-140.

Queiroz, N., Humphries, N.E., Mucientes, G., Hammerschlag, N., Lima, F.P., Scales, K.L., Miller, P.I., Sousa, L.L., Seabra, R. and Sims, D.W., 2016. Ocean-wide tracking of pelagic sharks reveals extent of overlap with longline fishing hotspots.*Proceedings of the National Academy of Sciences*,*113*(6), pp.1582-1587.

Sequeira, A.M.M., Mellin, C., Meekan, M.G., Sims, D.W. and Bradshaw, C.J.A., 2013. Inferred global connectivity of whale shark Rhincodon typus populations.*Journal of fish biology*,*82*(2), pp.367-389.

Southall, E.J., Sims, D.W., Witt, M.J. and Metcalfe, J.D., 2006. Seasonal space-use estimates of basking sharks in relation to protection and political–economic zones in the North-east Atlantic.*Biological conservation*,*132*(1), pp.33-39.

Vögler, R., Beier, E., Ortega-Garcia, S., Santana-Hern_andez, H., and Valdez-Flores, J. J. (2012). Ecological patterns, distribution and population structure of Prionace glauca (Chondrichthyes: Carcharhinidae) in the tropical-subtropical transition zone of the north-eastern Paci_c. Marine Environmental Research, 73(C):37{52.

Insect Migration and Connectivity

Keith A. Hobson[1]

[1] Department of Biology, Western University, Canada, khobson6@uwo.ca

Although less recognized than avian or mammalian migration, several species of insects undergo long-distance migrations in response to seasonal changes in the abundance of key resources. Given the relatively small size of insects, the distances travelled and the ecological barriers encountered, these migrations can be particularly impressive. In many cases, insect migrations are also completed over several generations and the individuals arriving at key breeding, wintering or stopover sites differ from those that previously used these sites. Insects perform vital ecological services through plant pollination and by serving as food sources for higher trophic-level species. They can also be significant pests and vectors of disease and so detailed understanding of their movements and migratory connectivity are crucial to their conservation and management. Two species of insect, the Monarch Butterfly (*Danaus plexippus*) and the Globe Skimmer (*Pantala flavescens*) dragonfly, are iconic migratory species that underline the importance of considering conservation measures that include an understanding of migratory connectivity across political boundaries.
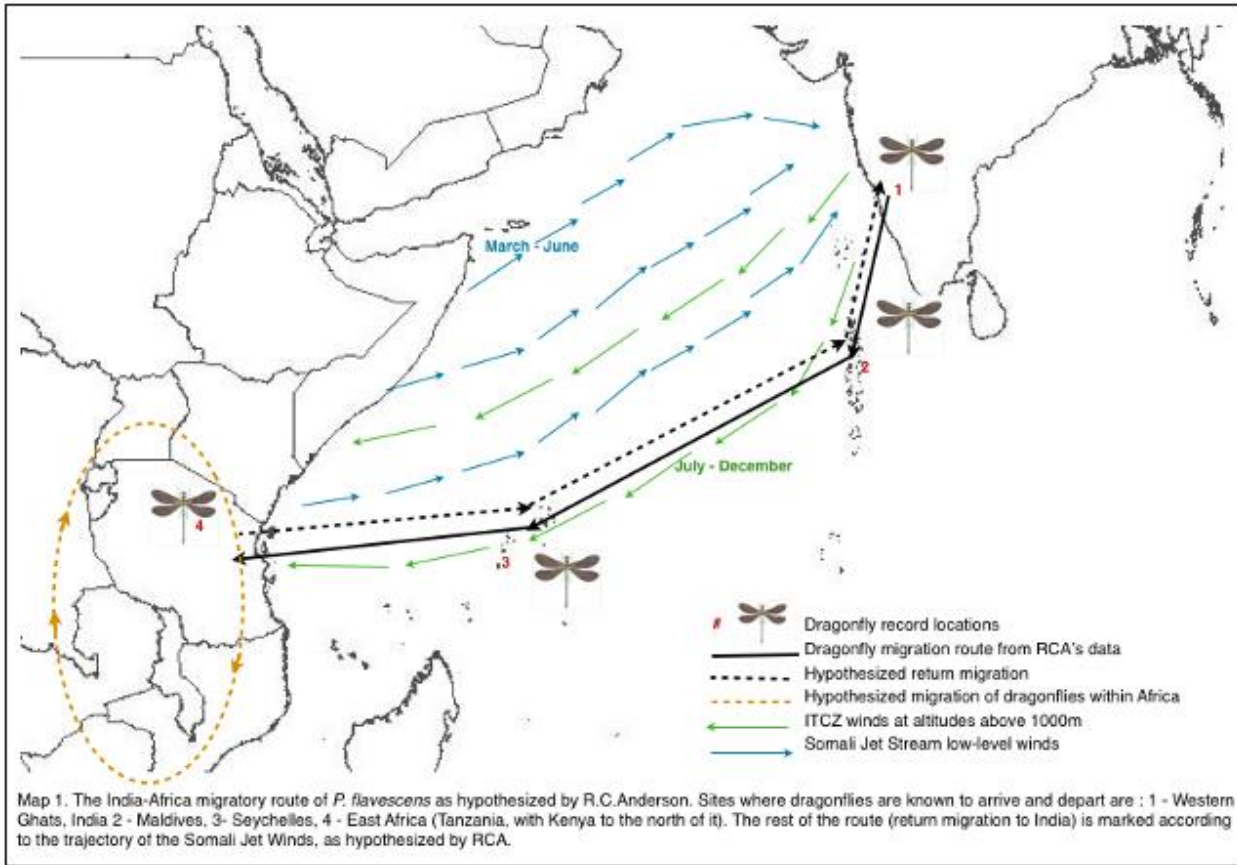
Examples:

The eastern component of North America's Monarch Butterfly population undergo well-documented annual migrations from their breeding grounds in the United States and Canada to a small cluster of wintering sites in the Oyamel fir forests of central Mexico. These butterflies specialize in using host milkweed (*Asclepius* spp.) plants for reproduction that confer some protection from predators through the use of toxic plant cardenolides. Thus, the availability and distribution of host milkweed on the breeding grounds and the availability of safe and suitable overwinter roosts in Mexico many thousands of kilometers away, define key resources that are critical to the survival of this migratory phenomenon. Important also are the availability of nectar resources encountered *en route* between breeding and wintering sites because monarchs need to bring enough fuel in the form of lipids to sustain them during the 4 month overwinter fast where they only use drinking water. The location and nature of these nectar corridors that support migration and sustain overwinter populations are poorly understood.

The Globe Skimmer dragonfly derives its name from its broad distribution and ability to travel over vast distances that include ocean crossings. Unlike many dragonflies, this species is adapted to making use of ephemeral pools created by monsoonal rains due to a particularly short (~ 6 week) aquatic larval stage.

Migrations of these insects are believed to involve migrations between the Indian subcontinent and Africa using high altitude winds. The migration is ultimately completed by successive generations returning to ancestral origins by again making use of winds between Africa and India. This multi-generational migration is

Map 1. The India-Africa migratory route of *P. flavescens* as hypothesized by R.C.Anderson. Sites where dragonflies are known to arrive and depart are : 1 - Western Ghats, India 2 - Maldives, 3- Seychelles, 4 - East Africa (Tanzania, with Kenya to the north of it). The rest of the route (return migration to India) is marked according to the trajectory of the Somali Jet Winds, as hypothesized by RCA.

of the order of 14000 Km!

Connectivity Issue

Populations of monarchs have declined tremendously in recent years but it is not known to what extent factors on the breeding, wintering and stopover sites may be contributing to this decline.

On the breeding grounds, milkweed availability has diminished due to intensive agriculture and the use of genetically modified crops that can sustain herbicide treatment for weed control. Insecticides may also be a factor.

On the wintering grounds, forest loss and thinning has contributed to the loss or degradation of these sites. Weather conditions experienced throughout the annual cycle and how these are changing due to anthropogenic factors undoubtedly will influence survivorship in this species. Recently, the planting of tropical milkweed in the southern United States has resulted in the genesis of non migratory populations there that are coincidentally more susceptible to parasite infection**.** Dragonflies similarly rely on key habitats being linked along their routes and this will involve an understanding especially of which wetlands throughout their life cycle are critical.

Future Actions
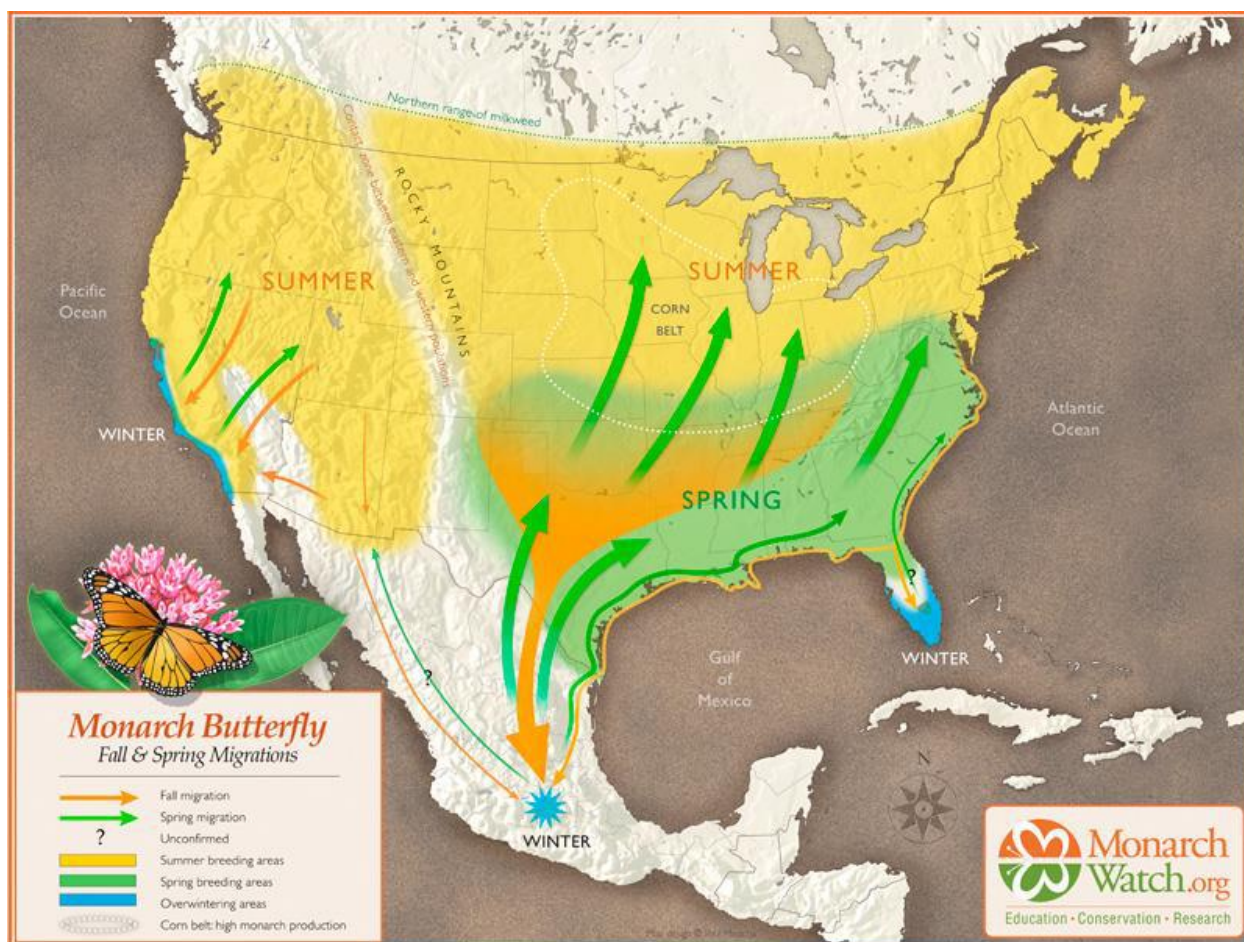
Currently, estimates of breeding and overwintering populations are extremely crude and improvements of these estimates and on an annual basis are much needed. Other demographic information such as reproductive success and survivorship at each stage of the annual cycle would allow much more informed modeling of where monarchs and other migratory insects are most susceptible and where conservation efforts would be most effective.

References:

Altizer, S.M. K.A. Hobson, A.K Davis, J.C de Roode; L.I Wassenaar. 2015. Do healthy monarchs migrate farther? Tracking natal origins of parasitized vs. uninfected monarch butterflies overwintering in Mexico. PLoS ONE 10(1) e0141371. oi:10.1371/journal.pone.0141371

Flockhart, D.T., L.P. Brower, M.I. Ramirez, K.A. Hobson, L.I. Wassenaar, S. Altizer and D. R. Norris. 2017. Regional climate on the breeding grounds predicts variation in the natal origin of monarch butterflies overwintering in Mexico over 38 years. *Global Change Biology*. doi:10.1111/gcb.13589.

Hobson, K.A., R. C. Anderson, D. X. Soto and L. I. Wassenaar. 2012. Isotopic evidence that dragonflies (*Pantala flavescens*) migrating through the Maldives come from the northern Indian subcontinent. PLoS ONE 7(12): e52594. doi:10.1371/journal.pone.0052594

Stefanescu C., D.X. Soto, G. Talavera, R. Vila, and K.A. Hobson. 2016. Tracking origins and autumn movements of the Painted Lady Butterfly (*Vanessa cardui*) across the African Sahara. Biology Letters 12: 20160561.http://dx.doi.org/10.1098/rsbl.2016.0561.

Wassenaar, L., and K.A. Hobson. 1998. Natal origins of migratory Monarch Butterflies at wintering colonies in Mexico: New isotopic evidence. *Proceedings of the National Academy of Sciences* 95:15436-15439.