Industry Briefing Note

Migration bottlenecks: mapping available movement data to de-risk wind energy development at an early stage

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Summary

Protected areas, Key Biodiversity Areas and other recognised sites for birds are often identified using surveys, count data and other evidence of important breeding, feeding, roosting and staging habitats. However, these site-based assessments generally do not capture how birds move between important sites and across the wider landscape or seascape, leaving the airspace that connects them largely unconsidered and unprotected. This gap is especially important during migration. Although migratory soaring birds travel along broadly demarcated flyways, coastlines, water crossings, straits, ridgelines and mountain passes can funnel large numbers through relatively narrow bottlenecks. These features are often also attractive for wind energy development because of their strong and consistent wind resource, creating potential conflict between migratory movement and development opportunity. Managing this risk is limited by incomplete knowledge of seasonal routes, flight heights, alternative pathways and weather-dependent movements.

Satellite and GPS tracking can help fill this gap. When interpreted alongside migration counts, radar, field surveys and expert knowledge, movement data can reveal alternative routes, bottlenecks, staging areas, sea crossings and differences between seasons or age classes. This evidence is particularly valuable before sites are fixed, when avoiding higher-risk areas remains possible, and survey investment can be directed towards the uncertainties most likely to affect feasibility, permitting and finance.

Key highlights

- **Movement data adds the missing connective layer.** Site designations show where important biodiversity features occur, while tracking can show how migratory birds travel between breeding, staging and wintering areas.

- **Combining migration and wind-resource data can change business and investment decisions.** It shows where strong wind resource may coincide with concentrated bird movement, while also identifying areas where development may present lower migration risk. This supports early avoidance, comparison of development options, proportionate survey design and reduced exposure to costly redesign after land, seabed rights or grid routes have been committed.

- **Tracking is most powerful as one line of evidence.** Sample size, tag bias and temporal resolution mean it should guide, not replace, targeted field surveys and other monitoring.

- **The same evidence serves several users.** Governments can strengthen strategic planning and ESIA requirements; developers can refine siting and survey design; lenders can improve screening and due diligence.

- **Türkiye offers a timely example.** Tracking of soaring bird migration around the Sea of Marmara identified distinct routes and confirmed greater potential migration risk in the western development area.

Why conventional screening misses bird migration routes

Wind energy can affect migratory birds through collision and barrier effects. These risks may be concentrated in a small part of a much wider flyway, particularly where soaring birds avoid long water crossings, follow coastlines or depend on thermal and orographic lift. Yet global flyway maps are usually too coarse for project decisions, while KBAs, protected areas and species occurrence datasets are largely static. A proposed wind development may sit outside a recognised site but still intersect the route used by birds moving between important sites.

This evidence gap matters for both onshore and offshore wind. Offshore areas can intersect low or direct sea crossings that are poorly represented by land-based counts. Onshore projects can create cumulative collision or barrier risks where several developments occupy the same narrow corridor. Mapping movement before project boundaries are finalised provides a landscape-scale basis for applying the mitigation hierarchy.

How tracking data can be used to support safer site selection

Tracking records from research programmes and repositories can be compiled across priority species, filtered by season and life stage, and assessed against candidate wind areas and associated infrastructure. Data are not always available for all species or flyways and if timelines are sufficient, projects could look at supporting additional tagging studies. Raw tracks show route diversity; density summaries indicate repeated use; and altitude data can help identify potential overlap with rotor-swept height, subject to the accuracy and reference system of the tags.

Our interpretation of tracking data examines:

- the relative use of alternative corridors and crossing points;
- seasonal, annual and weather-related variation;
- differences between adults, juveniles and other tracked groups;
- flight altitude and potential exposure to turbines;
- staging, roosting, congregation or aborted-crossing behaviour; and
- gaps requiring migration counts, vantage point surveys, radar, acoustic monitoring or further tagging.

Using tracking data to identify migration monitoring stations on the ground

Movement mapping can guide the design of the most suitable locations for migration counts. GPS tracks indicate where routes converge into bottlenecks and where birds are likely to pass within view of observers; topography, access and potential double-counting can then be assessed to select practical stations. Around the Gulf of İskenderun, exploratory surveys at 13 localities found the small hills north of the gulf to be more consistently suitable for migration count stations than the Belen Pass (Oppel et al., 2014). Consequently, three stations near Sarımazı were recommended for long-term autumn monitoring, and subsequent migration counts recorded over 100,000 migratory soaring birds including ~900 Egyptian Vultures – the vast majority of the regional population.

The configuration was expected to record most Egyptian Vultures using the eastern Mediterranean corridor while allowing movements under different weather conditions to be captured. This illustrates how broad movement evidence can be translated into a defensible count network, then refined through field testing rather than selecting stations from mapped tracks alone.

At national scale, combining migration and wind-resource data can identify where commercially viable areas may overlap with migratory bottlenecks, as well as where development may present comparatively lower apparent risk to migrating birds (Figure 1).

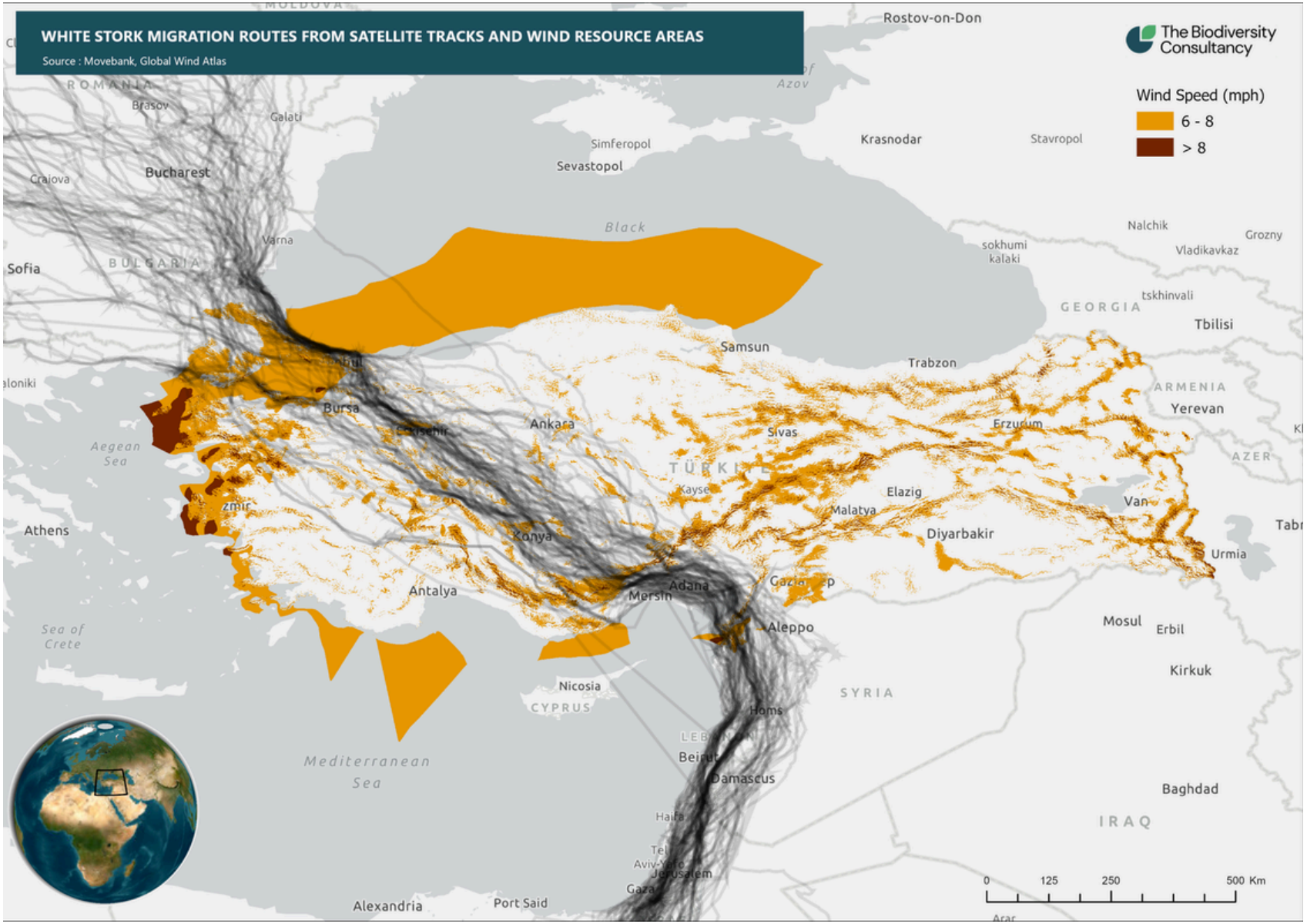

Figure 1. *Strategic national-scale mapping presents the opportunity to combine available movement data with wind speed (in this case ≥6 m/s) to show where stronger wind resource areas (shown in yellow and red) may coincide with migratory bottlenecks. It also indicates areas where migration risk may be comparatively lower, helping prioritise regional or project-scale siting and assessment.*

At country scale, the purpose is not to define project constraints at fine resolution, but to identify where more detailed work is most likely to change decisions. Combining migration evidence with wind-speed data adds a development perspective: it highlights areas where commercially attractive wind resource may overlap with migration bottlenecks due to coastal convergence zones, straits, ridgelines / mountain passes and sea crossings, as well as areas where the same resource may be available with comparatively lower apparent risk to migrating birds. This can support strategic zoning, comparison of development areas and early allocation of proportionate survey effort. Higher-resolution tracks, altimeter data, seasonal and age-class filters, terrain and weather data, expert interpretation and targeted surveys are still needed before drawing project-level conclusions, and areas with few available tracks should not be treated as low risk by default.

Lessons from Türkiye and the Sea of Marmara

A recent review for proposed offshore wind development areas in the Sea of Marmara combined publicly available and provider-supplied tracking data for White Stork, Egyptian Vulture, Lesser Spotted Eagle, Booted Eagle, Black Kite and Black Stork. The analysis drew on Movebank, the Egyptian Vulture New LIFE project, and maps supplied by the Directorate for the Management of Protected Areas, Management Unit of Evros Delta and Dadia National Parks, within Greece's Natural Environment and Climate Change Agency.

The combined evidence confirmed that large soaring birds use broadly similar routes around the Sea of Marmara, but not at equal intensity. White Stork data clearly separated the main Bosphorus route from a smaller route using the Marmara islands as stepping stones (Figure 2). A comparison of tracked routes indicated that this island route is used by globally important numbers of birds with seasonal and species- specific patterns of usage.

Tracking data for Endangered Egyptian Vultures, known to be at risk from wind energy (Carrete et al., 2009), added a different lens to the risk perspective. Juvenile and immature birds tended to follow the routes of White Storks, however, due to their inexperience they congregated at the coastline before crossings, or even abandoned crossing attempts. Inexperienced birds are known to make risky sea crossings – a source of high juvenile mortality (Oppel et al., 2015). Maps shared for the other soaring bird species reinforced the initial hypothesis that the western Sea of Marmara corridor is important and that use differs between routes and species. These findings helped prioritise migration studies and vantage point surveys where they would add most value.

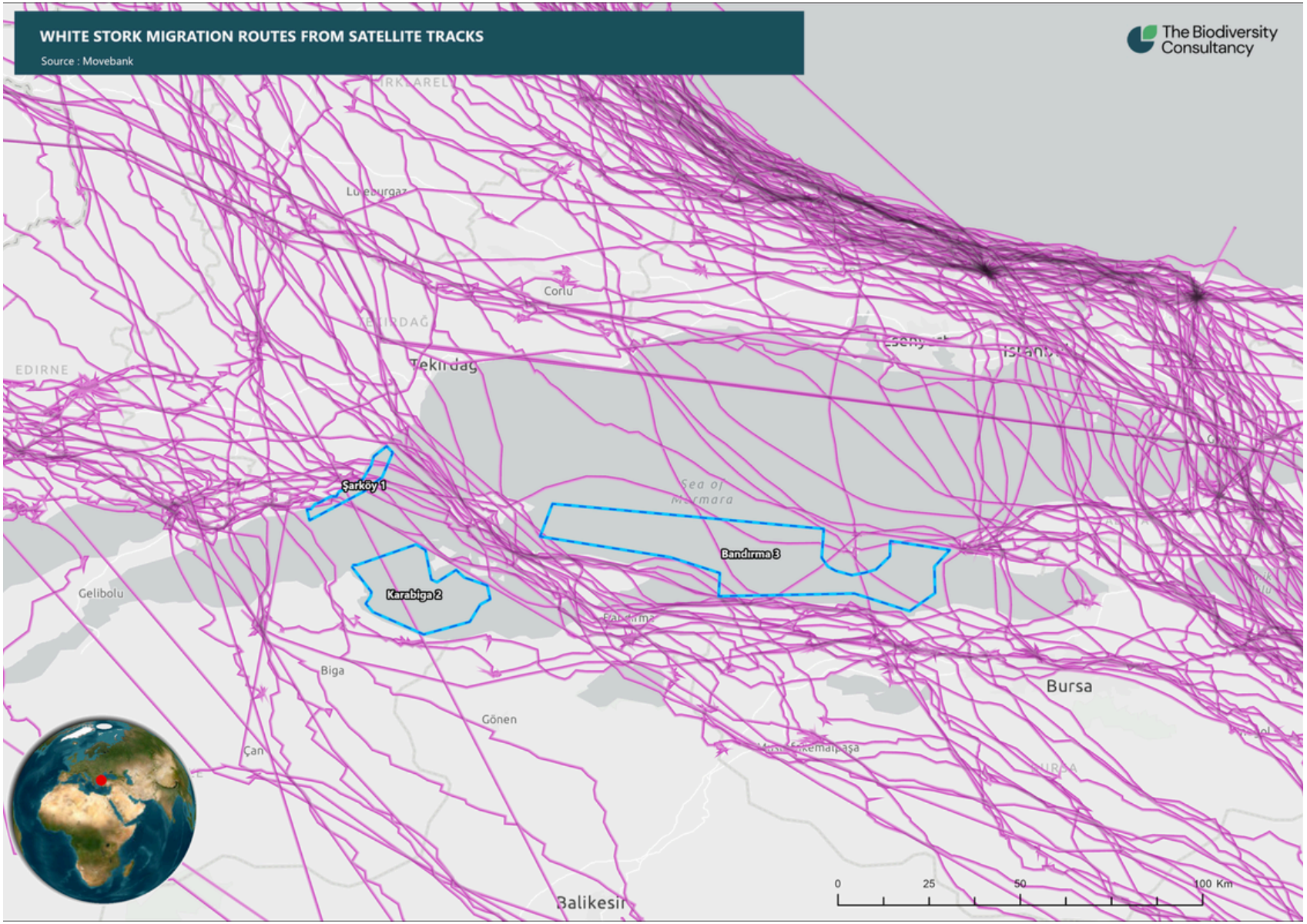

Figure 2. *White Stork satellite tracking data show a major route through the Bosphorus and a secondary crossing through the Sea of Marmara islands. Source: Movebank, 2026.*

Good practice is to document data provenance and permissions, retain raw and processed outputs, test sensitivity to analytical choices, and present results with clear confidence statements. Mapping should be iterative: tracking data form an early hypothesis, expert consultation and field surveys test it, and pre- and post-construction monitoring refine future planning.

Recommendations

1. **Map movement alongside wind resource before allocating sites.** Use available tracking and wind-speed data during national and regional planning to identify potential conflict areas and comparatively lower-risk development opportunities, not only once an ESIA starts.

2. **Assess functional connectivity.** Consider routes between KBAs, protected areas, roosts, staging areas and other important sites, including offshore crossings and associated grid infrastructure.

3. **Use multiple lines of evidence.** Combine tracking with counts, radar, vantage point surveys, acoustic monitoring, literature and local expertise.

4. **Target survey investment and count-station placement.** Use national mapping to identify priority regions, then combine higher-resolution movement data with topography, visibility, access and pilot counts to locate stations that capture concentrated passage without avoidable double-counting.

5. **Plan for cumulative risk.** Share compatible data and use common survey standards so impacts from multiple projects can be assessed at flyway or regional scale.

6. **Keep maps current.** Update analyses as new tags, projects and monitoring results become available, while respecting provider permissions and restrictions on sensitive data.

7. **Encourage data sharing.** Where additional soaring bird migration studies are being conducted, encourage researchers to make data available on platforms such as Trektellen for count data or Movebank / Seabird Tracking Database for tracking data.

Selected sources

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If you need to meet biodiversity disclosure requirements and determine the right monitoring approach

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