La Rochelle Université
Institut Littoral Urbain Durable Intelligent

HR EXCELLENCE IN RESEARCH

**PhD project**

**Location**

Centre d'Etudes Biologiques de Chizé, UMR7372 du CNRS -La Rochelle Université

**Title**

Migration and habitat use strategies in a sentinel species of Atlantic coastal ecosystems, the white stork

**Supervision**

Co-supervision by Christophe Barbraud and Timothée Bonnet

Four important collaborators will contribute to specific aspects of the project :
Frédéric Angelier Coraline Bichet and Olivier Chastel and CEBC, CNRS-La Rochelle Université, and Paco Bustamante at LIENSs, La Rochelle Université

**Scientific relevance to the university's priorities**

As a potential umbrella species for coastal wetland communities and a sentinel for the ecological status of coastal wetlands, conservation strategies designed for the white stork could benefit co-occurring species and the maintenance of coastal marshes in good overall ecological condition. The white stork therefore appears to be a relevant species for understanding the ecological responses of coastal marshes to global change. The PhD project, by providing new knowledge enabling a better understanding of habitat use, migratory strategies and their potential physiological and phenotypic consequences, and by basing itself on long-term monitoring of this species, fits in perfectly with the 'Trajectories and long-term understanding of coastal areas' theme. The results of the thesis project will enable us to identify and quantify the effects of various anthropogenic (e.g. modification of feeding habitats) and environmental disturbances (e.g. submersions during extreme meteorological and marine events, temperature increases, changes in rainfall, salinization), and to help us scenario the effects of management methods aimed at the sustainability of ecosystem services in coastal areas.

***Project details***

## Scientific context

Coastal ecosystems play a crucial role for biodiversity and human societies as climate regulators, sources of food and well-being (Albert et al. 2020). However, these complex ecosystems, the true interfaces between marine and terrestrial ecosystems, are subject to numerous natural and anthropogenic disturbances. Indeed, coastal areas are subject to multiple risks including climate change, habitat modifications due to urbanization and intensive agriculture, and pollution (He and Silliman 2019). Understanding these systems and their dynamics to be able to anticipate their evolution requires long-term observations between their different components. Nevertheless, the ecological responses of coastal zones to global change are currently neglected and

poorly understood. It is therefore necessary to characterize the evolutionary trajectories of the structure and functioning of coastal communities, to identify and quantify the effects of the various anthropogenic and environmental disturbances, and to scenario the effects of management methods aimed at the sustainability of ecosystem services in coastal areas.

The marshes of Brouage and the Gironde estuary are home to a particularly remarkable biological wealth (Leroux 1988, Barbraud et al. 1999, Sternalski et al. 2013, Musseau et al. 2014 & 2017, Rapinel et al. 2018, Lorrain-Soligon e al. 2021). As a result, these marshes are classified as Natura 2000 sites and host several national and regional nature reserves (https://mapgeodata.fr/maps/environnement/natura.php). Today, these coastal and back-coastal areas are used mainly for cattle breeding, cereal growing, tourism and recreational activities (hunting, fishing, hiking, birdwatching, etc.). This coastal territory, which is both anthropized and a biodiversity hotspot, has to cope with rising ocean levels, submersion during extreme weather and sea events, rising temperatures, changes in rainfall, salinization and changes in farming practices. All these features make these marshes exceptional objects for studying the ecological responses of coastal areas to global change. In addition to their intrinsic biological richness, the marshes of Brouage and the Gironde estuary are breeding, wintering and migratory stopover sites of international importance for numerous bird species (Barbraud et al. 1999, Musseau et al. 2014, Jourdan et al. 2022). These marshes thus contribute to the connectivity of habitats stretching from northern Europe to sub-Saharan Africa. Among these species, the white stork (Ciconia ciconia) is an emblematic species of the Charente coastal marshes, where the highest densities in France are currently found (Gadenne et al. 2014, Bonnet-Lebrun et al. in revision). Due to its high position in the food web, the white stork is a potential umbrella species for littoral wetland communities (Olsson & Rogers 2009, Tobolka et al. 2012, Kronenberg et al. 2017). Thus, conservation strategies designed for this species could benefit co-occurring species and the maintenance of coastal marshes in good ecological condition (Branton & Richardson 2011, Runge et al. 2019, Mortelliti et al. 2022). The white stork therefore appears to be a perfectly relevant species for understanding the ecological responses of coastal marshes to global change.

**Scientific gaps**

While our understanding of the demographic functioning and population dynamics of the Atlantic white stork has progressed in recent decades (Barbraud et al. 1991, 1999, Saether et al. 2006, 2013, Nevoux et al. 2008a, 2008b), knowledge of the use of coastal habitats during the breeding season and the effects of anthropogenic factors on this use remains very incomplete (Gadenne et al. 2014). This represents a first barrier to our understanding of the ecological impacts of current environmental changes on this species and the coastal ecosystems it uses. A second major barrier concerns the characterization and understanding of this population's migration and wintering strategies. Indeed, with the exception of occasional sightings of banded individuals outside the breeding grounds, the migratory characteristics of this population remain unknown to this day.

The main scientific questions are :

First axis : Strategies for migration and wintering, and fitness

- What are the migration and wintering strategies of the Atlantic white stork population?

- What are the links between these strategies and individual fitness?

Second axis : Habitat use and its consequences

- Which Atlantic coastal habitats are used by white storks during breeding?

- Which consequences on eco-physilogical traits?

- What are the consequences of habitat changes linked to human activities and climate change on habitat use?

**Methods**

*Species studied and available knowledge*

The white stork is a large bird (3-3.5 kg, wingspan 195-215 cm) found throughout Europe, where it breeds during the summer. It lays between 3 and 5 eggs, producing 3 to 4 fledglings (Schierer, 1967). It is a long-lived bird, whose life expectancy in the wild can exceed 20 years.

The white stork has a wide range of prey at different trophic levels, which it exploits to feed itself and its offspring (earthworms, aquatic insects, amphibians, small crustaceans, small mammals, Cramp & Simmons, 1977; Barbraud & Barbraud, 1997; Antczak et al., 2002; Barbraud et al., 2002). It is an active predator, foraging on foot in feeding areas. At its historic wintering and migration sites in the Sahelian zone, it consumes mainly insects (grasshoppers and locusts). Storks have also been observed in large numbers at open dumps, feeding on waste and organic matter, sometimes even overwintering in these areas (Martinez Rodriguez, 1995; Tortosa et al., 2002; Archaux et al., 2004). During breeding, white storks are central-place foragers. The quality of the foraging areas and the distance between them and the nest are important parameters influencing the energy intake of the chicks (Johst et al., 2001). On average, foraging distance does not exceed 5 km around the nest (Alonso et al., 1991; Johst et al., 2001; Denac, 2006).

In winter, white storks migrate to Africa via two main migration routes. Western European populations pass through the Strait of Gibraltar to wintering grounds in the Western Sahel. Eastern European populations pass through the Bosphorus Strait to reach wintering grounds in the eastern Sahel or South Africa. Several studies have recently investigated the migratory strategies of the white stork, but most focus on the ontogeny of these strategies (e.g. Rotics et al. 2016, 2017, 2021, Flack et al. 2016, Cheng et al. 2019, Lopez-Calderón et al. 2023). However, the spatial characterization and inter-individual variability of migration strategies and habitat use on breeding grounds remain very incomplete in adults. Furthermore, our understanding of the effects of intrinsic and extrinsic factors, such as sex, breeding status, habitat types or climate variability, on the behaviors and activity patterns of adult white storks remains very patchy (Zurell et al. 2018). In this sense, the white stork monitoring program run by the Centre d'Etudes Biologiques de Chizé (CEBC) since 1978 in the marshes of Brouage and the Gironde estuary, as well as at several coastal sites in Pays de la Loire and Brittany, provides unique demographic and spatial data (https://www.cebc.cnrs.fr/cigognes-blanches/). With more than 6,200 chicks banded and 32 adults equipped with GPS tags to date, this long-term program (capture-mark-recapture data, GPS geolocation data, accelerometry activity data, biometric and phenotypic data) makes it possible to analyze the behavior, habitat use, demography and population dynamics of a migratory species faced with coastal risks. The data already collected by this long-term project will form a solid basis for the thesis project, ensuring its feasibility.

**Axis 1: Migration strategy and phenotypic fitness**

Related scientific questions: What migration strategies exist within the white stork population of the French Atlantic coastal zone? What are the links between these strategies and the phenotypic aptitude of individuals? Are some strategies more optimal than others? The first step will be to characterize migration and wintering strategies (departure and return dates, migration routes,

migration durations, types of migratory stopovers, distances travelled and wintering areas) within the population. In fact, mapping the movements of adult white storks fitted with GPS tags shows very high inter- and intra-individual variability in migration routes between different breeding seasons. This suggests that there may be different migration strategies with adaptive mechanisms (gender effects, cary-over effects…) within this population, which the PhD student will have to characterize. The second stage will involve quantifying the various activities associated with these strategies. Using GPS-equipped individuals fitted with accelerometers, it was recently shown that the time spent by individuals in different activities (flying, walking, resting) could be quantified on a daily scale, and that walking behavior was a very good indicator of foraging effort (Barbraud et al. 2024). In addition, global dynamic body acceleration (GDBA), which can be calculated from accelerometer data, is a relevant metric of individuals' overall activity that can be linked to energy expenditure (Flack et al. 2016). The PhD student therefore also looked for links between foraging effort characterized by the identification of walking behaviors, ADCG and the migratory characteristics of individuals. These results will make it possible to determine whether there are differences in activity and foraging effort between migratory strategies.

Finally, the PhD student will examine whether migratory characteristics, activity budgets and ADGC have consequences on demographic parameters directly linked to the phenotypic fitness of individuals (number of young produced, annual survival probability). This will enable us i) to test the hypothesis of the existence of migratory strategies that perform better than others in terms of phenotypic aptitude and ii) to explore the effect of changes in migratory strategies explained by global change on the demography of the populations monitored. For this first line of research, the PhD student will have access to existing behavioral data from the tracking of 32 individuals equipped with GPS with accelerometers, for which the number of young has been measured since 2018. The PhD student will also participate in the deployment of GPS on new individuals during his first two years. The PhD student will be trained in spatial and statistical analysis by the co-supervisors and the GPS stork tracking project partner (Dr. Raphaël Musseau, researcher at BioSphère Environnement).

**Axis 2: Use of coastal habitats and its consequences**

Related scientific questions: Which habitats are used by white storks in the Atlantic coastal zone during the breeding season? What are the consequences for ecophysiological traits? What are the consequences of habitat changes linked to anthropogenic activities and climate change on habitat use?

The aim of this axis is to determine the use of the different habitats available during the breeding season in Atlantic coastal marshes subject to multiple anthropogenic pressures (intensive agriculture, salinization, submersion, temperature increases, changes in rainfall).

Initially, the PhD student will characterize, on a fine spatial and temporal scale, the use of habitats by storks equipped with GPS and accelerometers by quantifying the relative proportions of different activities (flying, walking, resting) and the ADGC in the various habitats, on individuals already equipped, as well as on those who will be equipped during the first two years of the thesis. The quality and selection of habitats used will be characterized using several metrics (proportion of time spent in each habitat, relative use of each habitat according to availability). As the data are available over several years, the hypothesis of an effect of variability in meteo-climatic conditions (rainfall, temperature) on the differential use of habitats will be tested. Secondly, the doctoral student will test the existence of a correlation between habitats used (quality, selection) and the phenotypic fitness of individuals (number of young produced, body condition of young), using various physiological markers of health status (telomere length, basal

immune capacities, stress hormones) and trophic (stable isotopes of carbon and nitrogen indicating trophic level and type of habitats used, analysis of prey species consumed from rejection pellets) and demographic (juvenile survival and age at recruitment into the population) markers. For this second line of research, the PhD student will be able to use the biometric data collected since 2002 as part of the demographic monitoring of the population. Physiological markers can be measured from blood samples taken during a sampling campaign in 2019, and the PhD student will participate in the acquisition of new samples during a field season in the first year of the thesis. For these physiological markers, the PhD student will benefit from the expertise of several project leaders: F. Angelier for telomeres, C. Bichet for immunity, and O. Chastel for hormones.

**Expected results**

*Axis 1 : Migration strategy and phenotypic fitness*

Spot observations of banded individuals and preliminary data from GPS tracking suggest the existence of three migratory strategies within the Atlantic white stork population. We therefore expect to identify three strategies: a sedentary strategy, a short/medium-distance migration strategy and a long-distance migration strategy. Given the strong potential differences between habitats and distances associated with these strategies, we predict differences in individual activity budgets associated with each strategy. Consequently, we expect to find links between these strategies and the phenotypic fitness of individuals, reproductive phenology (earlier in sedentary than in migratory species), as well as different trade-offs between demographic traits such as reproduction and survival depending on the strategy.

*Axis 2 : Use of coastal habitats and its consequences*

Several predictions can be made. Firstly, given the species' ecology and previous knowledge (Gadenne et al. 2014), some habitats will be more used and preferred for foraging during the breeding period (wet meadows, temporary pools, canals and ditches) than others (cereal crops, urban or forested areas). Secondly, the differential use of habitats will be reflected in differences in isotopic niches and will be modulated by meteo-climatic conditions (rainfall, temperature), and may therefore differ from year to year. Thirdly, variability in the habitats available and used will have an effect on the quality of the young produced and on phenotypic fitness. More specifically, the number of young produced, their quality (body condition, juvenile survival), and their physiological state (telomere length, immune capacity, hormonal stress levels) will be negatively related to the proportion of less favorable habitats used by breeding adults.

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**Partnership**

The thesis project will be implemented with the collaboration of BioSphère Environnement (Raphaël Musseau and Céline Rousselle), as scientific partners of the project. BioSphère Environnement (http ://www.biosphere-environnement.com/) is a research institute organized as an association under the French law of July 1, 1901, with the aim of i) conducting research programs and expert assessments in ecology and conservation biology, ii) training in ecology (sampling strategies, data analysis and processing: modeling...), iii) promoting technical and scientific culture in biology and ecology (conferences, popularization publications, educational workshops developed in collaboration with schools...). Based on the Gironde estuary, the organization works in particular on coastal ecosystems and wetlands, and the impact of changes and disturbances (global changes, etc.) on maintaining the ecological functions of these ecosystems. BioSphère Environnement has been working in partnership with CEBC since 2016 on demographic monitoring of the white stork population in the Gironde estuary, and since 2018 on GPS tracking.

**Impacts**

- **Outreach**

The knowledge generated during the project will be communicated to as many people as possible in a variety of ways, depending on the knowledge to be shared and the associated resources

available. The movements of GPS-equipped birds can be viewed by all via the open science tools described above. The doctoral student, project leaders and partners will take part in various public events in the laboratories associated with the project and at La Rochelle University (Fête de la science, Ménigoute festival, “recherche hors les murs”) and at cultural or thematic events organized by local authorities and land managers (Maison de Broue, Pôle Nature de Vitrezay, Fête de la Nature). This type of communication can also take the form of press articles for the general public or for scientific mediation. Information on the project and associated results will be directly accessible on the personal and institutional websites of the project sponsors and partners. The white stork nests monitored as part of CEBC's research program on this species are located on private property, as well as on some land owned by the Conservatoire des Espaces Naturels. This will enable the knowledge acquired during the thesis project to be disseminated easily and directly to landowners, raising their awareness of the role of this species in coastal ecosystems and the importance of these ecosystems. Finally, as two of the project leaders (P. Bustamante and C. Bichet) are teacher-researchers at La Rochelle University, communicating this work to the student community will also be an important channel of dissemination.

- **Informing public policies**

Some of the results of the thesis (e.g.: importance and quality of habitats used by storks during breeding) will be made available and may be integrated into territorial planning instruments, such as the territorial climate-air-energy plan or the zero net artificialisation objective, with a focus on habitats particularly favorable to umbrella species such as the white stork.

**Phd student’s expected work**

The doctoral student’s work programme is designed to provide him or her with experience and skills in all aspects of scientific research, namely data acquisition (handling and monitoring of wild birds, laboratory analysis), data analysis (statistics, modelling), scientific writing and communication (scientific community and general public). The aim of this programme is to give all the assets and skills to the future doctor to continue his career in research, through postdoctoral contracts, then through the successful completion of competitions, such as CNRS competitions or university competitions. Moreover, in order to be able to apply for a university position, the doctoral student will be encouraged to carry out courses (vacations) within the Department of Biology of La Rochelle University.

**Supervision and support**

This thesis will be co-directed by Christophe Barbraud (DR2 HDR) and Timothée Bonnet (CRCN, HDR in progress), with the scientific support of the other four project leaders at CEBC and LIENSs, Frédéric Angelier, Coraline Bichet, Paco Bustamante and Olivier Chastel. It/her PhD person will be brought. e and encouraged. e to collaborate by other researchers of the team or other teams of CEBC. At CPEC, he/she will also be supported by the common services (biological analysis and analyses and modelling). At CPEC, the doctoral student. The EU will benefit from a stimulating environment with many PhD students, researchers, teacher-researchers, engineers and postdocs, and their national and international partners. The fieldwork will be systematically accompanied by the presence of one of the thesis directors or experienced collaborators. Annual thesis monitoring committees will be organised with external researchers.

In addition to the salary funded by ExcelLR, funding (ExcelLR, CEBC, CPER and Brouage Observat-

ory Project) is acquired to cover measurements of physiological and immunological parameters, GPS beacons, field and office equipment, mission and publication costs. A desk, new laptop and associated peripherals will be available.