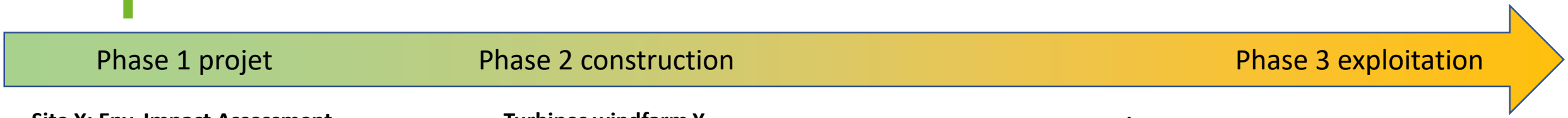
«Reduction of Avian Mortality in Operating Wind Farms»

WP3 R3 : Determine minimum detection distances for birds to avoid collisions

Julie FLUHR, Olivier DURIEZ, Axèle ALEXIS, Aurélien BESNARD

18/11/2021

Integration of research results into the process of windfarm development



Site X: Env. Impact Assessment, G-Bif:
➔ List of species of concern recorded at site X

Turbines windfarm Y
- Turbine braking / stopping time
- Location in landscape

Detection/reaction device

WP3R4 PhD: <u>turbine makers</u>
- perception and behaviour of birds

WP4 Protocole 1: <u>Detection device makers</u>
- Grid of performances of each device

WP3R3 web app EolDist: <u>State auth., EIA & detection-device and turbine makers</u>
- Range of minimal distances of detection for species of concern

WP2R2 web app EolDemo: <u>EIA & State auth.</u>
- Quantification of demographic impacts

WP4 Protocole 2: <u>WF Operators</u>
- Evaluation of performances at site X in windfarm Y

Underlined = main users / beneficiaries

Why studying minimal detection distance?

How much time before collision?

9.5 m.s $^{-1}$

Why studying minimal detection distance?

How much time ~~before collision~~ to shutdown turbine?

9.5 m.s $^{-1}$

$$\text{Speed} = \frac{distance}{time}$$

$$\text{time} = \frac{distance}{speed}$$

Why studying minimal detection distance?

Time to shutdown = $T_{decision}$

$$time = \frac{distance}{speed}$$

Detection + classification
of the target

Analysis collision risk~
trajectory, speed, altitude

DETECTION / REACTION
device

Why studying minimal detection distance?

Time to shutdown = $T_{decision}$ + T_{signal}

$$time = \frac{distance}{speed}$$

Detection + classification
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Analysis collision risk~
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DETECTION / REACTION
device

Sending command
Detection device => SCADA

Processing command
SCADA => turbine

Wind Turbine

Why studying minimal detection distance?

Time to shutdown = $T_{decision}$ + T_{signal} + T_{rotor}

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Slow / Stop rotor ~
turbine model + wind speed

Why studying minimal detection distance?

Time to shutdown = $T_{decision}$ + T_{signal} + T_{rotor}

$$time = \frac{distance}{speed}$$

9.5 m.s $^{-1}$

How much time to shutdown turbine?

At what distance should we detect the bird to have enough time to shutdown turbine?

Why studying minimal detection distance?

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$$time = \frac{distance}{speed}$$

How much time to shutdown turbine?

9.5 m.s $^{-1}$

At what distance should we detect the bird to have enough time to shutdown turbine?

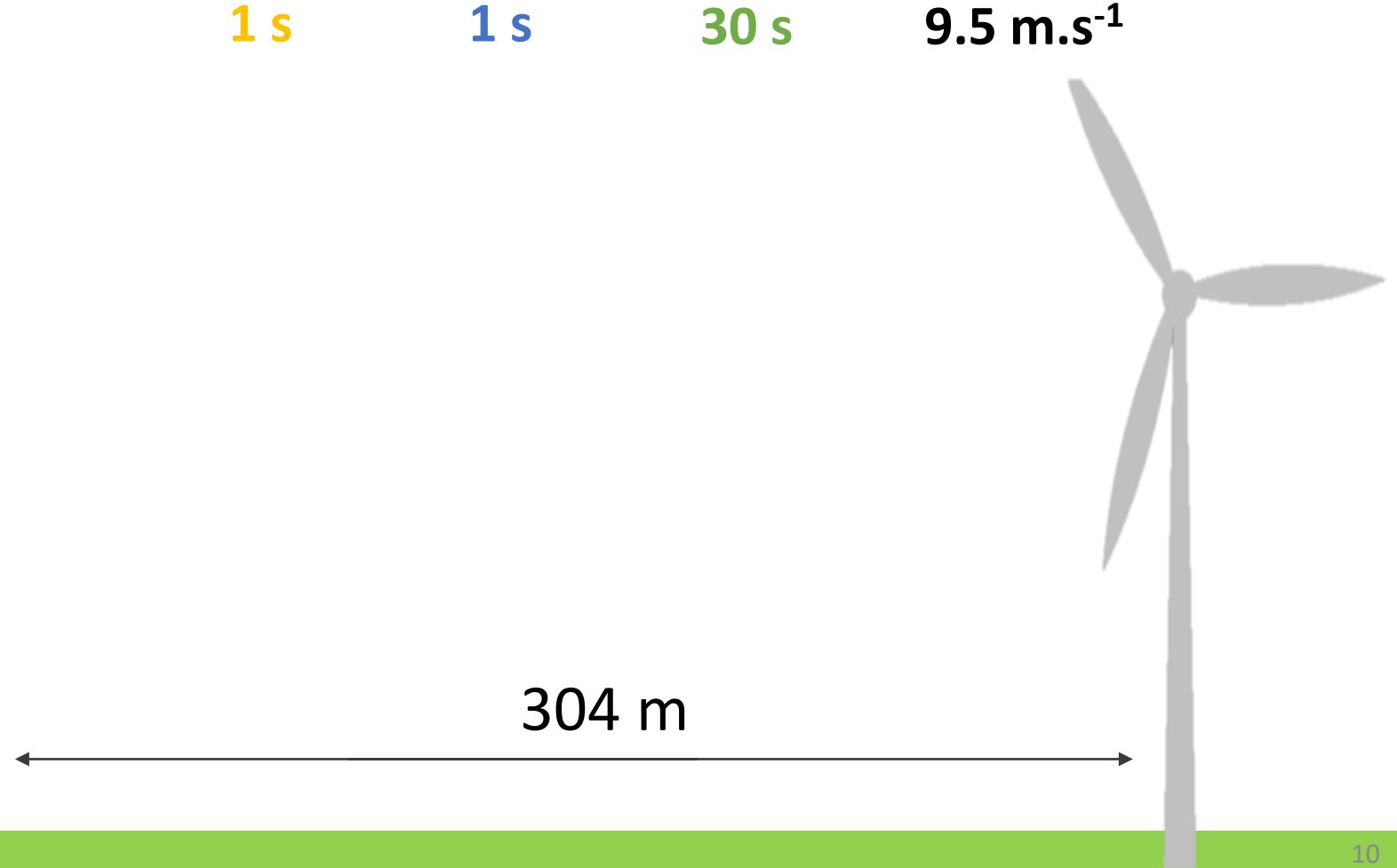
Distance = time * speed

Minimal distance detection = ($T_{decision}$ + T_{signal} + T_{rotor}) * Flight speed

Why studying minimal detection distance?

Minimal distance detection = ($T_{decision}$ + T_{signal} + T_{rotor}) * Flight speed

1 s **1 s** **30 s** **9.5 m.s^{-1}**



Why studying minimal detection distance?

Minimal distance detection = ($T_{decision}$ + T_{signal} + T_{rotor}) * Flight speed

1 s **1 s** **30 s** **12.5 m.s^{-1}**

384 m

Why studying minimal detection distance?

Minimal distance detection = ($T_{decision}$ + T_{signal} + T_{rotor}) * Flight speed

1 s **1 s** **20 s** **12.5 m.s^{-1}**

264 m

Why studying minimal detection distance?

Minimal distance detection = ($T_{decision}$ + T_{signal} + T_{rotor}) * Flight speed

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of the target

Analysis collision risk~
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Slow / Stop rotor ~
turbine model + wind speed

Objective: Web Application EolDist

<u>2 problems:</u>

1. **Need to know duration of shutdown of rotor**
   - Rarely available

2. **Need to build a database of flight speed for many species of concern**
   - Difficult to measure
   - Published values disseminated

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➔ **<u>Creation of a web application :</u> calculate minimal detection distances for a range of bird species of concern**

<u>Users</u>: Environmental Impact Assessment companies, detection-device makers, turbine makers, State authorities

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Wind Turbine

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turbine model + wind speed

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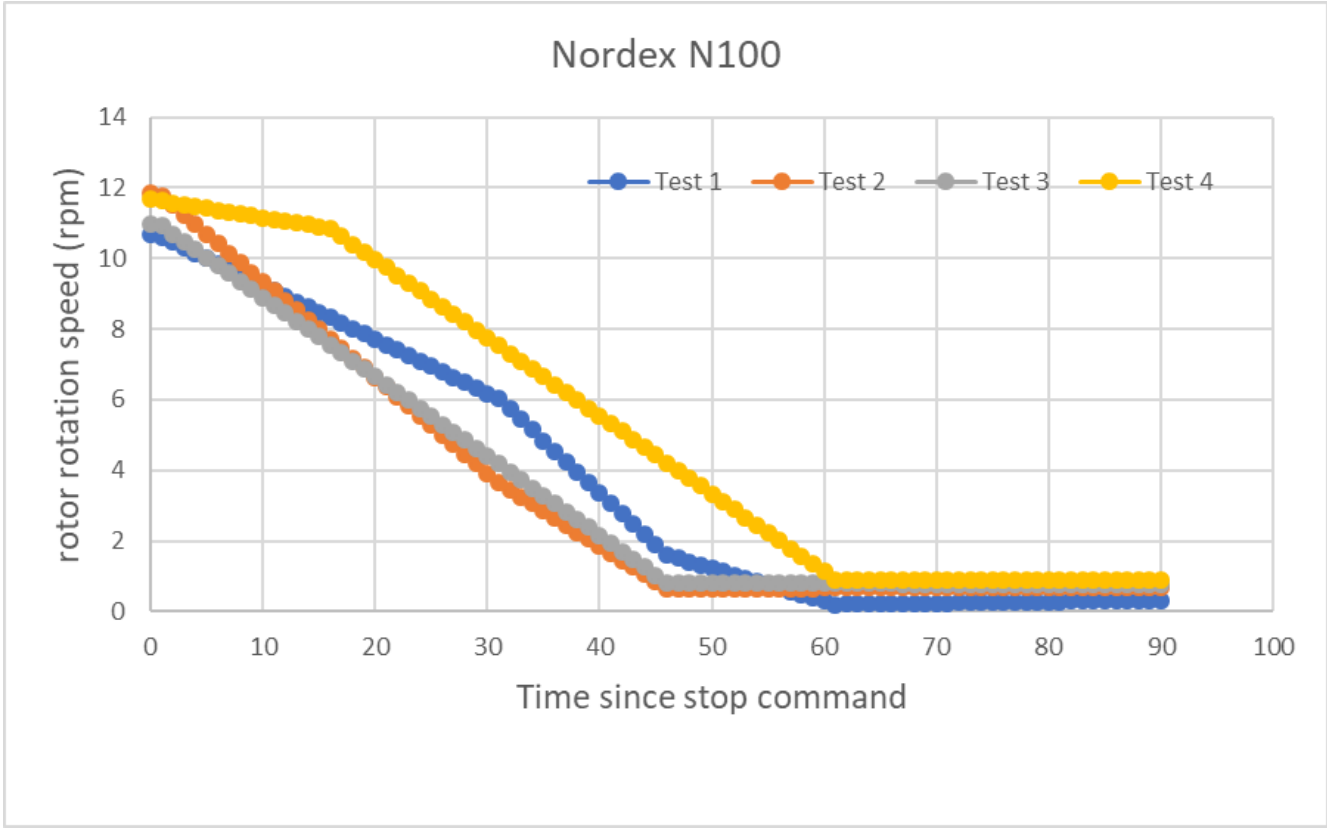
What factors affect shutdown duration of turbine T_{rotor}?

Protocol of tests of T_{rotor}

- Record rotation speed during 90 s after shutdown command
- 7 operators made 137 tests (10 models of turbines)



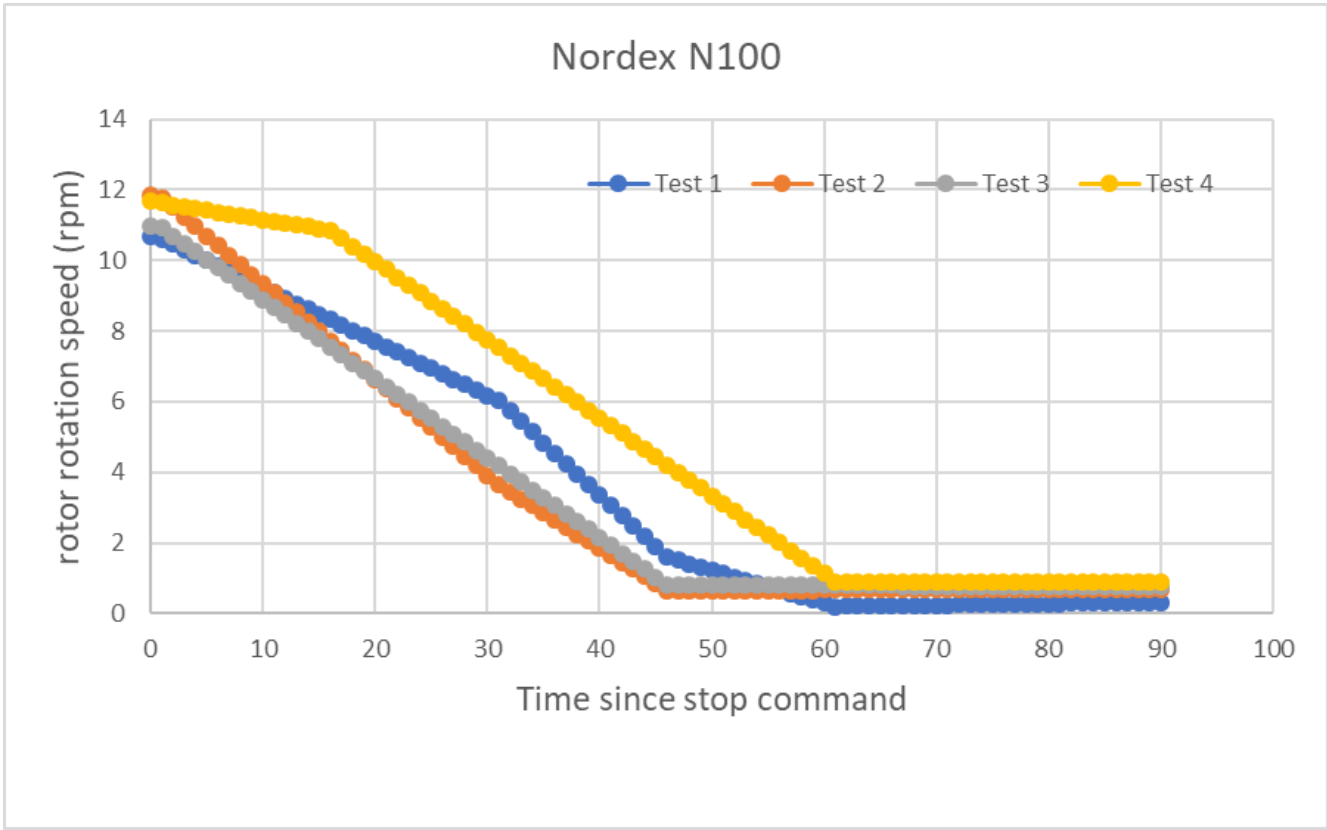
What factors affect shutdown duration of turbine T_{rotor}?

1. Probability to reach a shutdown threshold (3 or 2 rpm)

- 3 rpm: 93% tests reached threshold
- 2 rpm: 84% tests reached threshold

⇒ <u>Effect of 3 parameters:</u>

- Type of machine
- Blade length
- Initial wind speed



What factors affect shutdown duration of turbine T_{rotor}?

2. Duration to reach a shutdown threshold (3 or 2 rpm)

- 3 rpm: Duration T_{rotor} = 32.2 ± 13.5 s (max 55 s)
- 2 rpm: Duration T_{rotor} = 38.8 ± 14.5 s (max 65 s)

➔ Interaction type machine, blade length and initial wind speed

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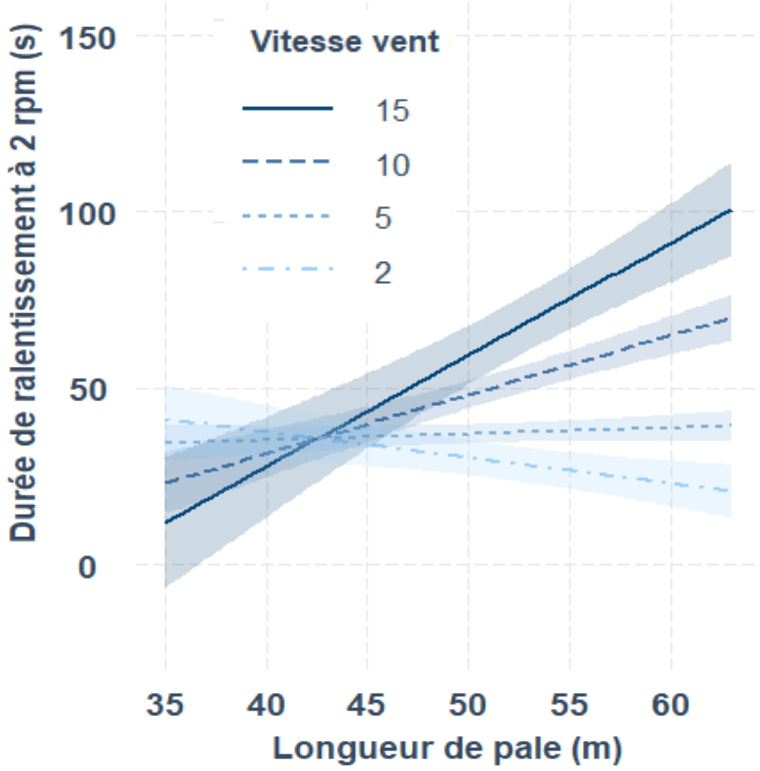

- *High wind speed:* shutdown duration shorter for short blades
- *Low wind speed:* similar shutdown duration for short / long blades

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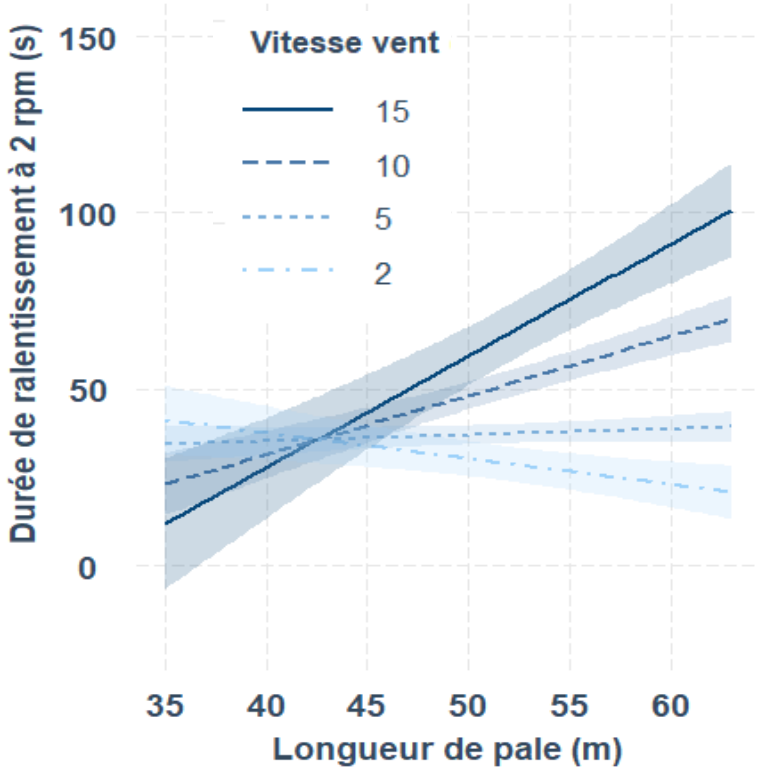
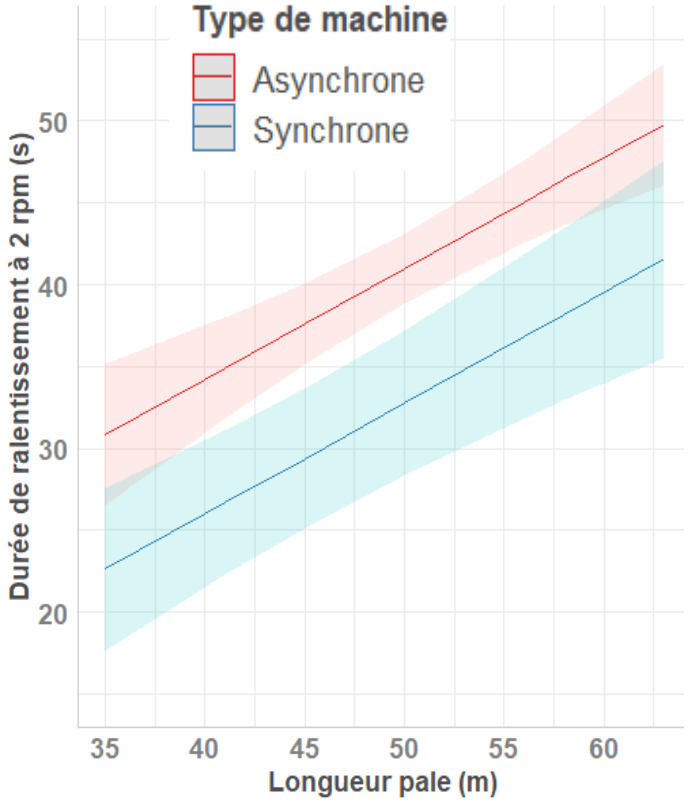


- *High wind speed:* shutdown duration shorter for short blades
- *Low wind speed:* similar shutdown duration for short / long blades
- *Effect of machine type:* shutdown duration always shorter for synchronous machines



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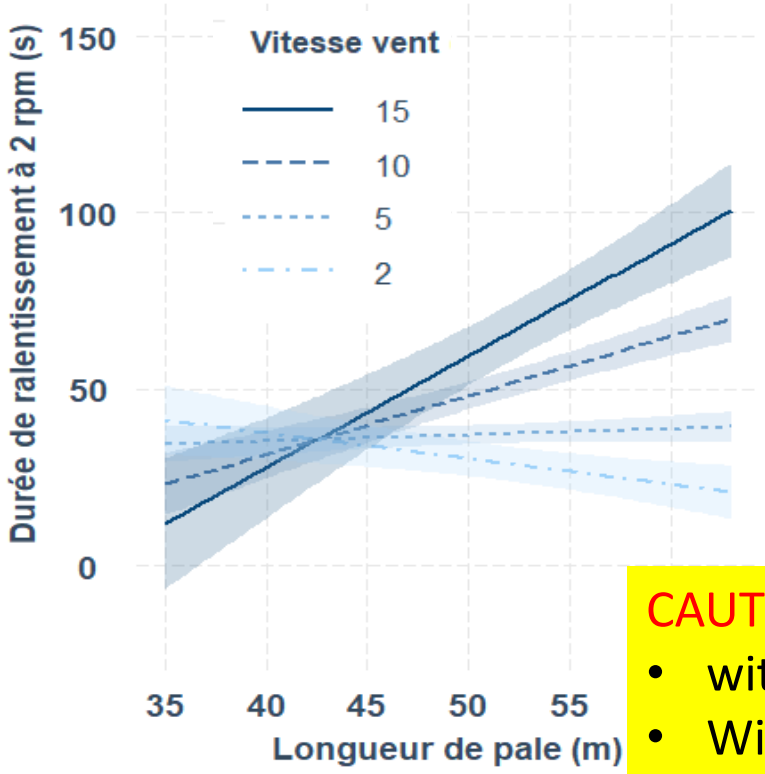

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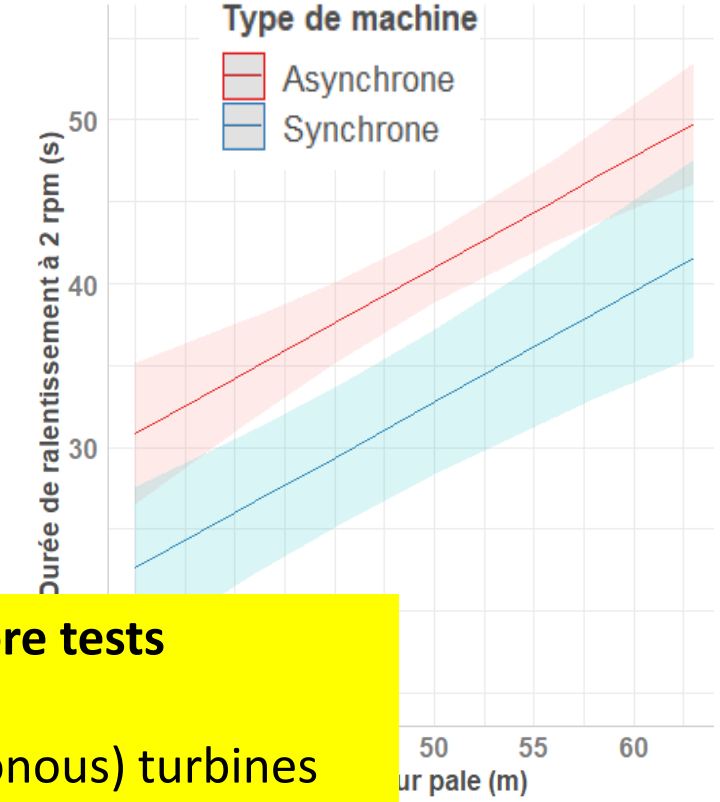
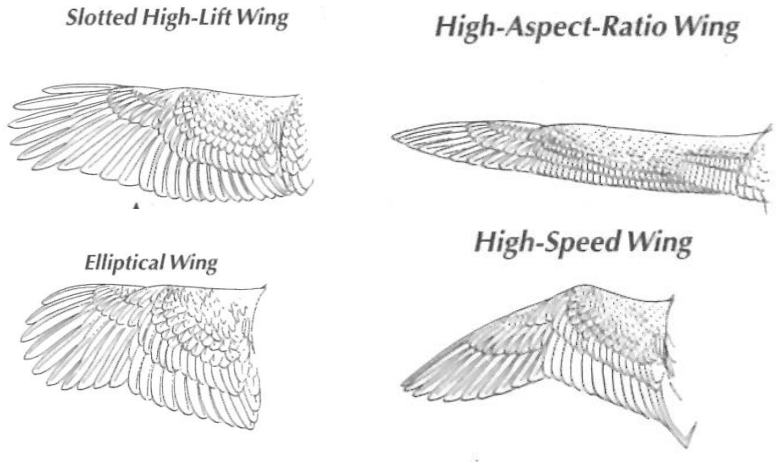


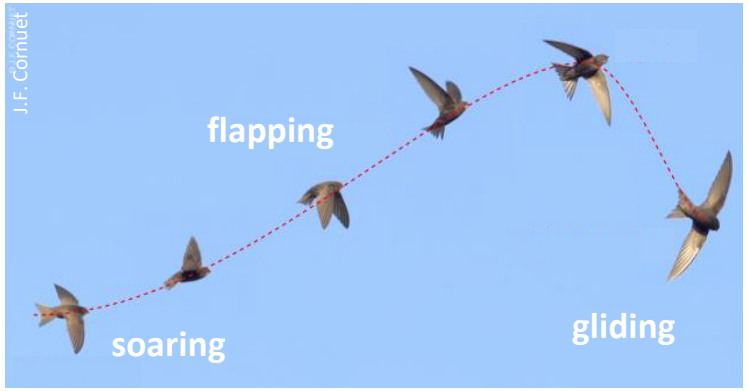
CAUTION: unbalanced sample of tests: **need more tests**

- with wind speed > 10 m.s -1
- With large (synchronous) and small (asynchronous) turbines

What factors affect bird flight speed?

Bird morphology & Flight type





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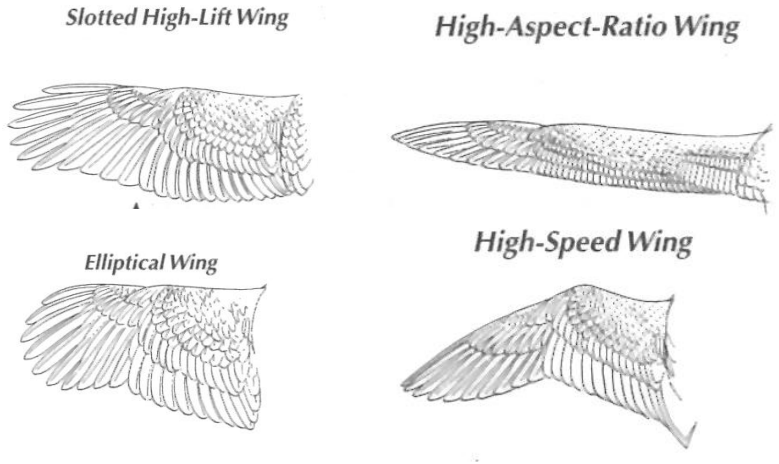
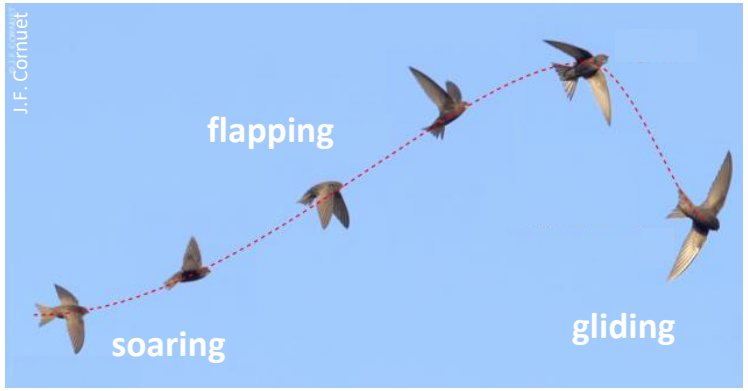
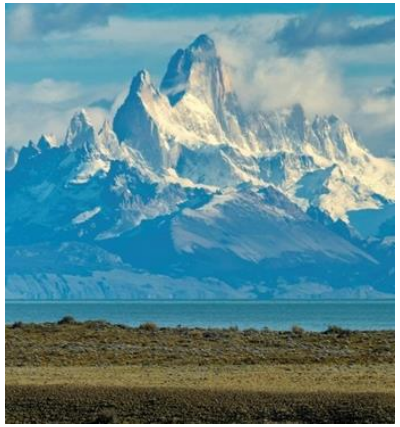




Environmental conditions

Wind speed and direction

Topography



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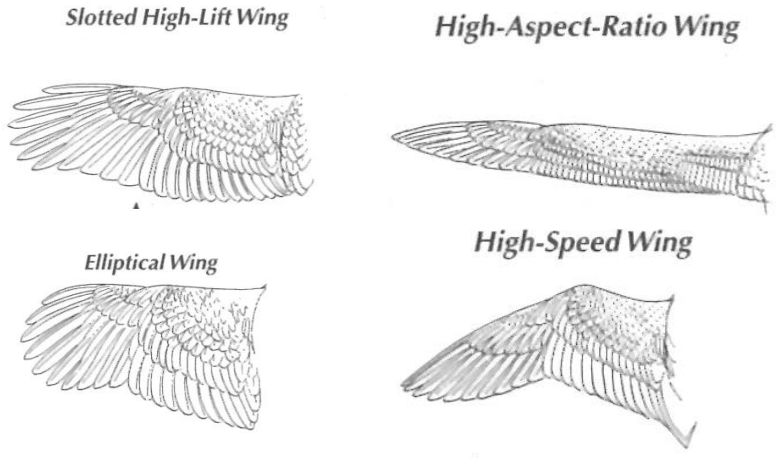

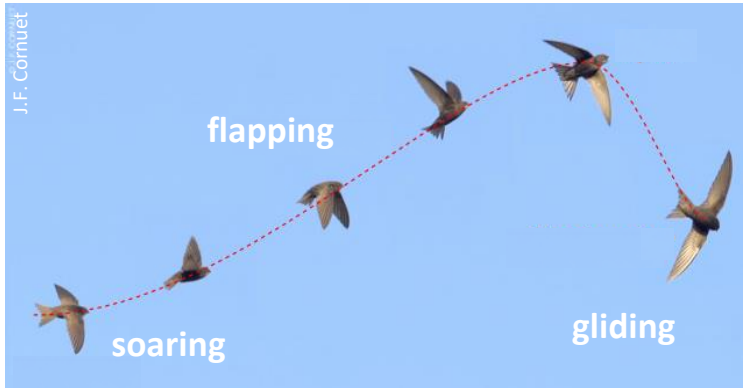

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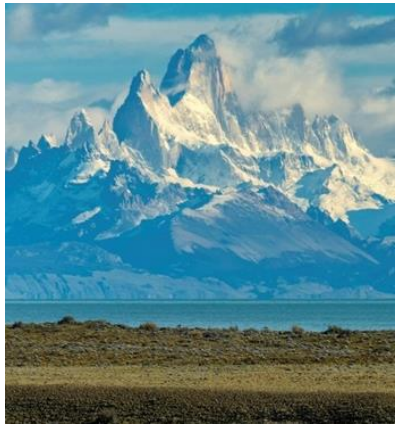

Motivation, context

Migratory flight

What factors affect bird flight speed?

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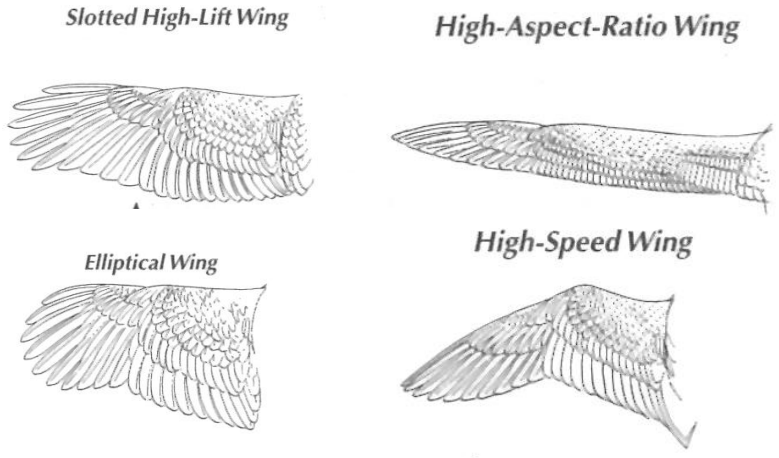

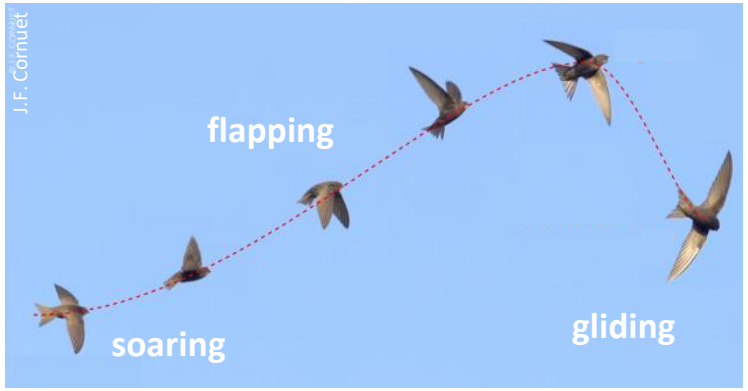

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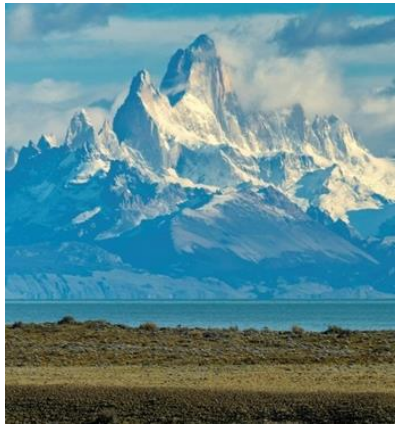

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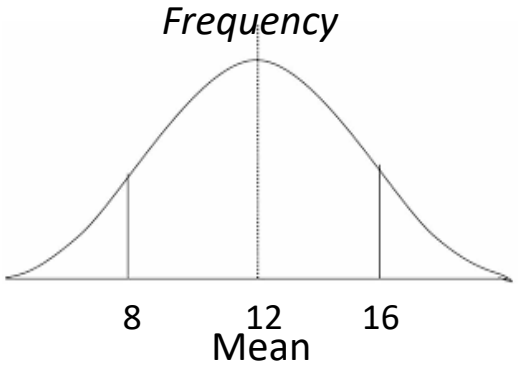
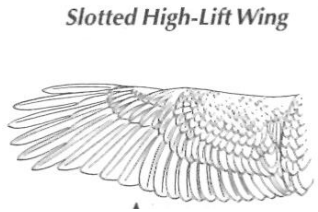


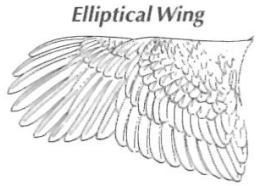
Flight speed (m.s $^{-1}$)

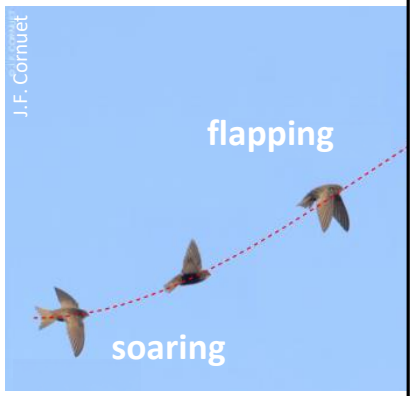
Large variability of flight speed within species

What factors affect bird flight speed?

Bird morphology





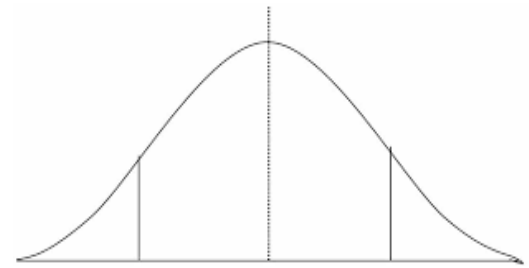


ontext

cal flight

Herring (cc by-nd)

light



Flight speed (m.s $^{-1}$)

Large variability of flight speed within species

More information on technical note
https://mape.cnrs.fr/fr/valorisation-scientifique

What factors affect bird flight speed?

Database of flight speed for 163 bird species

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Database of flight speed for 163 bird species

- Litterature search of published values
  - **139 species** recorded remotely by radar / Ornithodolite (mostly migration)
  - **6 species** recorded by telemetry (GPS / VHF)

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Database of flight speed for 163 bird species

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- <u>Analysis of unpublished data from GPS tracking</u>
  - **24 species** (mostly local context + some migration)

Spatule blanche

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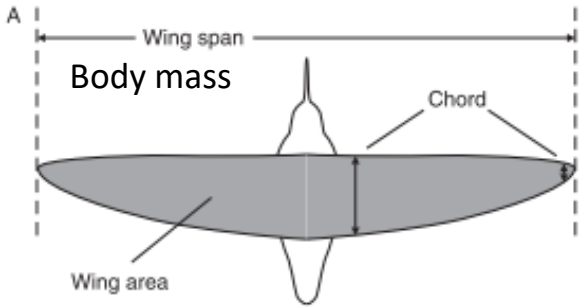
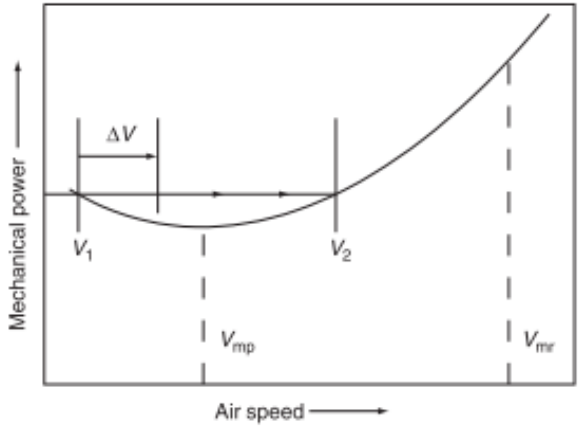
- <u>Analysis of theoretical flight speed</u>
  - **17 species**, simulated with Flight program, Pennycuick 2008





Web application EolDist: principle and work flow

INPUT

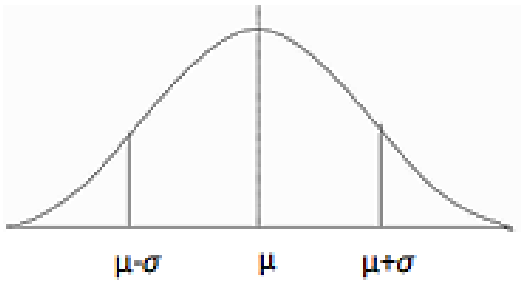
Flight speed

Species

Flight Context
Local / Migratory

Set by user

OUTPUT



- **Range of flight speed for the species**
- **Mean ± standard deviation (m/s)**

Web application EolDist: principle and work flow

INPUT

Flight speed

Species

Flight Context
Local / Migratory

Set by user

T decision — Pre-set at 1 second

T signal — Pre-set at 1 second

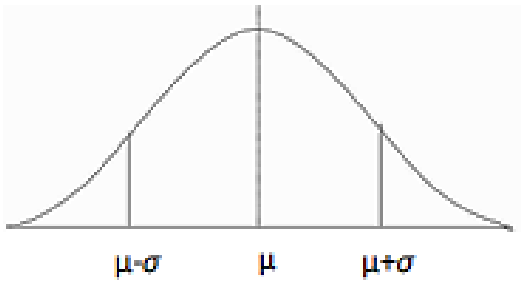
T rotor — Estimated with our results

L rotor — Set by user

- **Type of machine** (Synchrone / Asynchrone)
- **Mean wind speed (m/s)** (5, 10 ou 15)
- **Rotation speed threshold (rpm)** (3, 2, 1)

Set by user

OUTPUT



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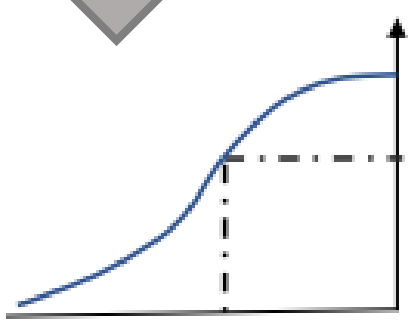


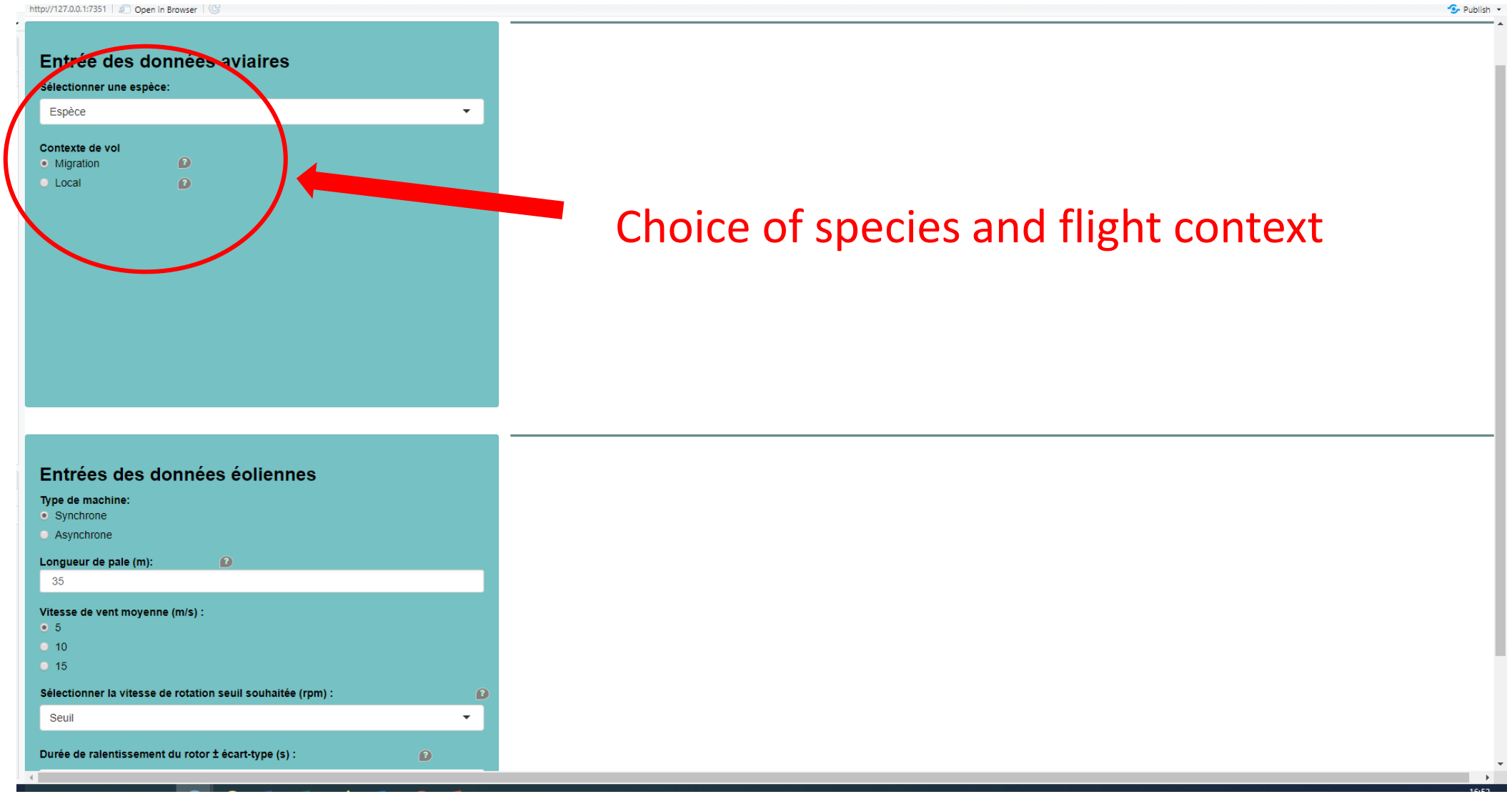
- **Duration to reach shutdown threshold ± standard deviation (s)**
- **Distribution of detection distance for the species**
- **Minimal detection distance (m)**

Demo of web application EolDist

Exemple 1: Griffon vulture *Gyps fulvus*
Large soaring raptor (8 kg)
One of the main victim of collisions in Spain

Exemple 2: Lesser kestrel *Falco naumanni*
Small raptor (200 g), active flier
One of the main victim of collisions in southern France

Demo of web application EolDist



Choice of species and flight context

Demo of web application EolDist

Exemple 1: Griffon vulture *Gyps fulvus*

Exemple 2: Lesser kestrel *Falco naumanni*

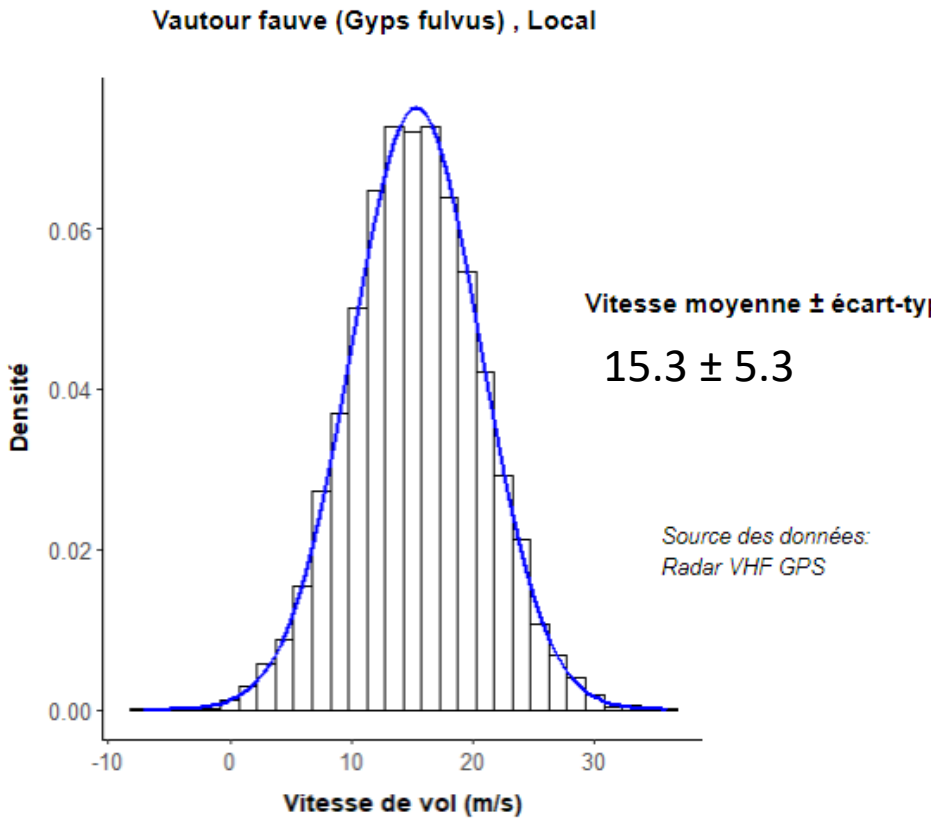
Entrée des données aviaires

Sélectionner une espèce:

Vautour fauve (Gyps fulvus)

Contexte de vol

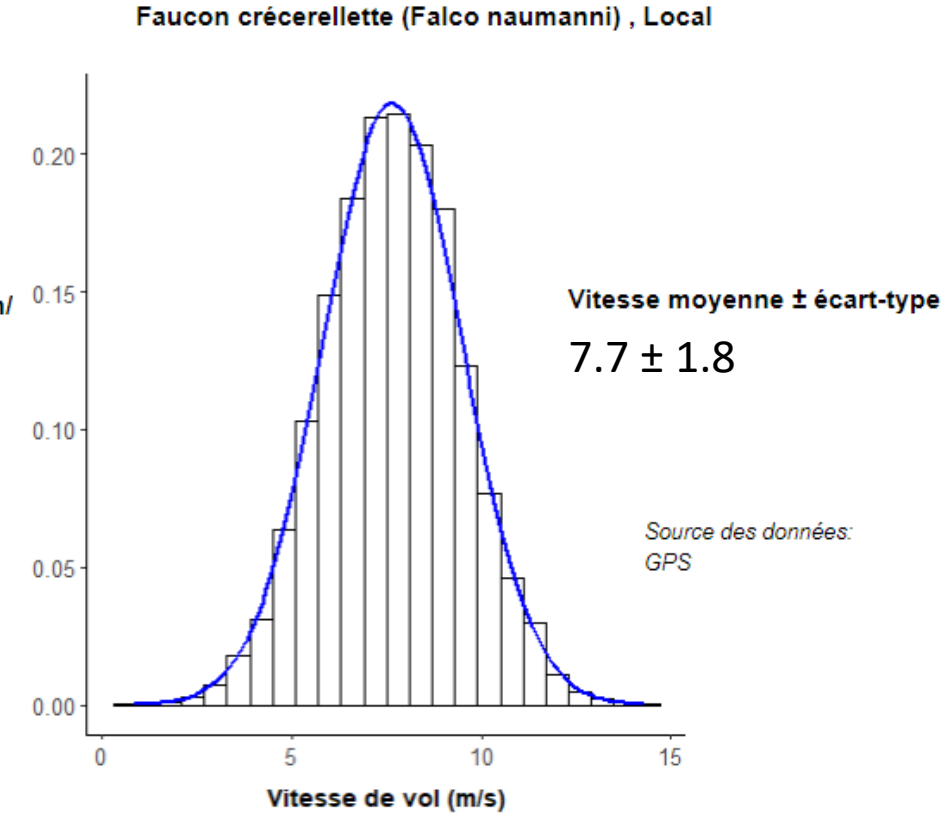
- Migration
- Local



Vitesse moyenne ± écart-type (m/

15.3 ± 5.3

Source des données:
Radar VHF GPS



Vitesse moyenne ± écart-type

7.7 ± 1.8

Source des données:
GPS

Demo of web application EolDist

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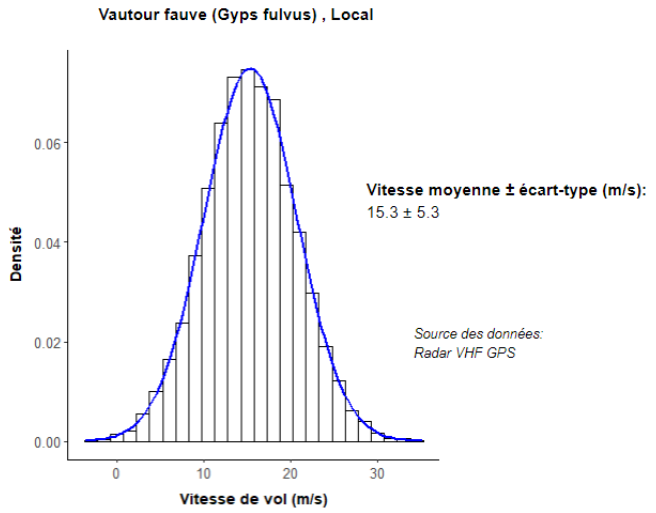


Entrées des données éoliennes

Type de machine:

- Synchrone
- Asynchrone

Longueur de pale (m):

45

Vitesse de vent moyenne (m/s) :

- 5
- 10
- 15

Sélectionner la vitesse de rotation seuil souhaitée (rpm) :

Seuil

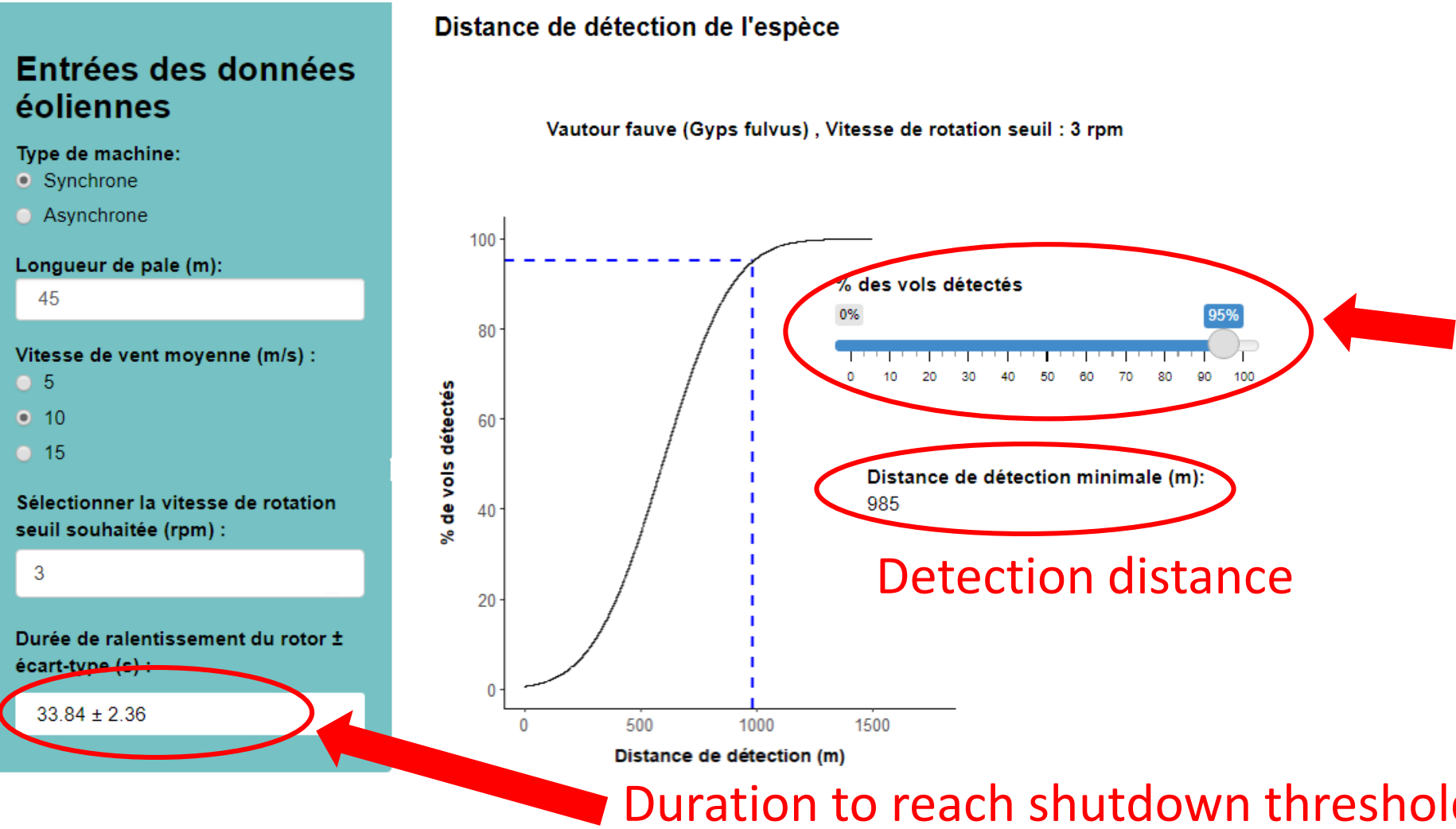
Durée de ralentissement du rotor ± écart-type (s) :

Choice of

- turbine features (synchrone/asynchrone), blade length
- wind speed
- Shutdown threshold

Demo of web application EolDist

Exemple 1: Griffon vulture *Gyps fulvus*



Choice of % of flight detected

Detection distance

Duration to reach shutdown threshold

Demo of web application EolDist

Exemple 1: Griffon vulture *Gyps fulvus*

Machine synchrone
45 m blade length
Threshold shutdown 3 rpm
95% flight detected

Exemple 2: Lesser kestrel *Falco naumanni*

Entrées des données éoliennes

Type de machine:
- (•) Synchrone
- ( ) Asynchrone

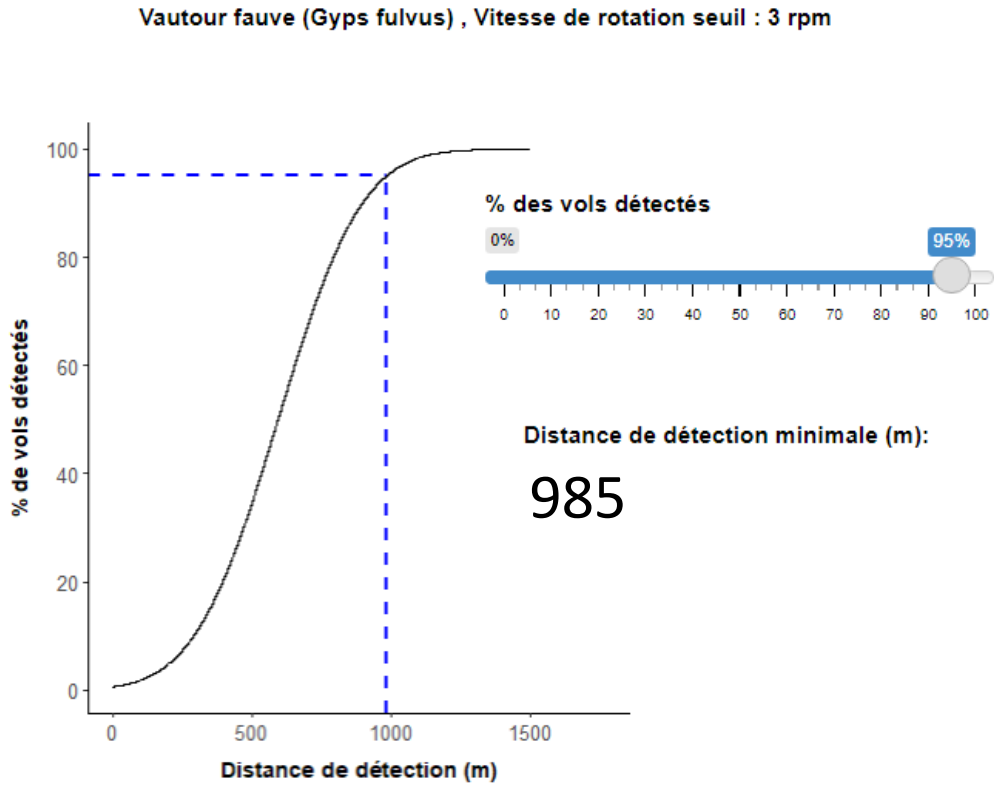
Longueur de pale (m):
45

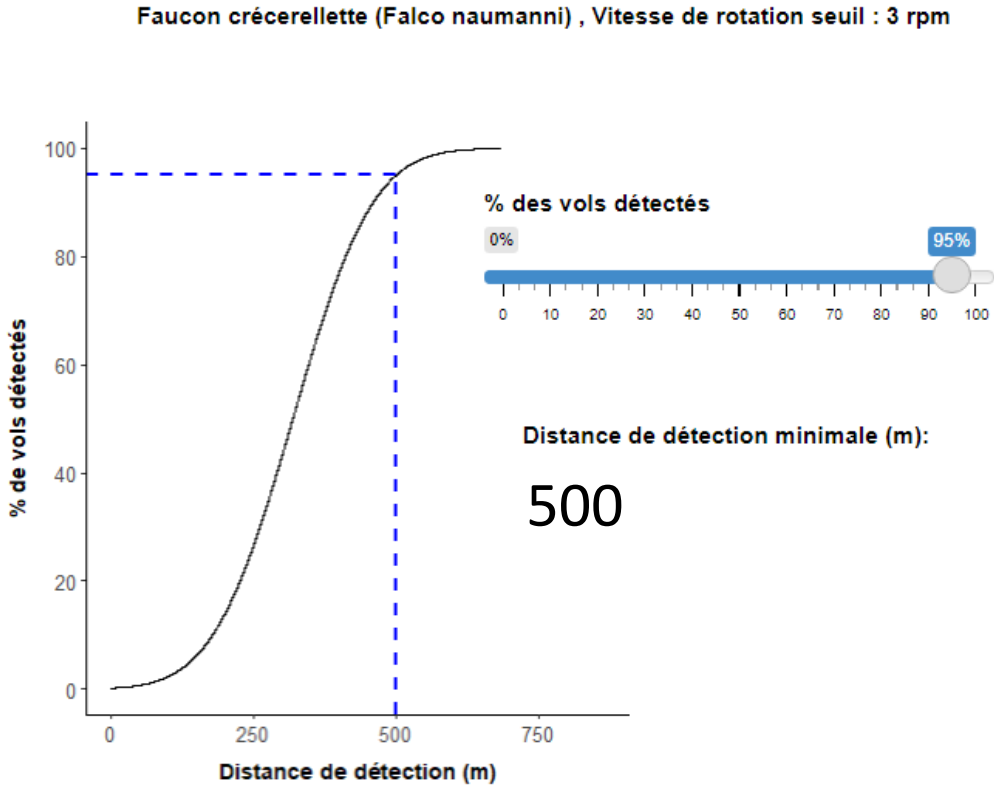
Vitesse de vent moyenne (m/s) :
- ( ) 5
- (•) 10
- ( ) 15

Sélectionner la vitesse de rotation seuil souhaitée (rpm) :
3

Durée de ralentissement du rotor ± écart-type (s) :
33.84 ± 2.36

Distance de détection de l'espèce





Demo of web application EolDist

Exemple 1: Griffon vulture *Gyps fulvus*

Machine synchrone
45 m blade length
Threshold shutdown 2 rpm
95% flight detected

Exemple 2: Lesser kestrel *Falco naumanni*

Entrées des données éoliennes

Type de machine:
- (•) Synchrone
- ( ) Asynchrone

Longueur de pale (m): 45

Vitesse de vent moyenne (m/s) :
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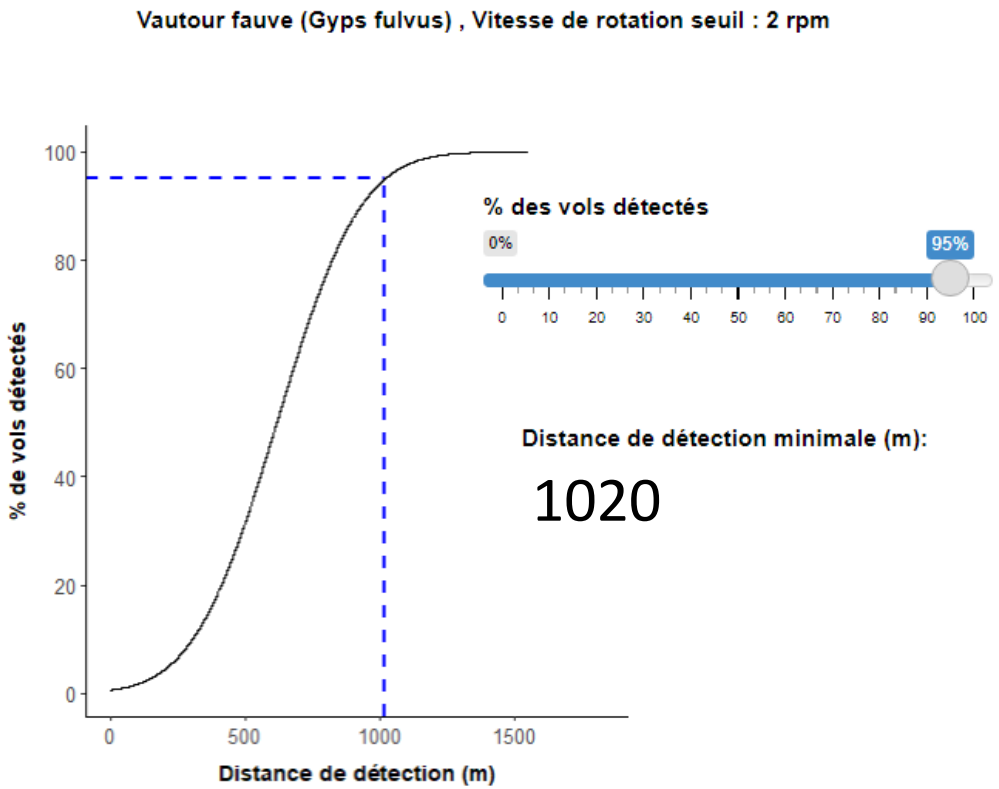
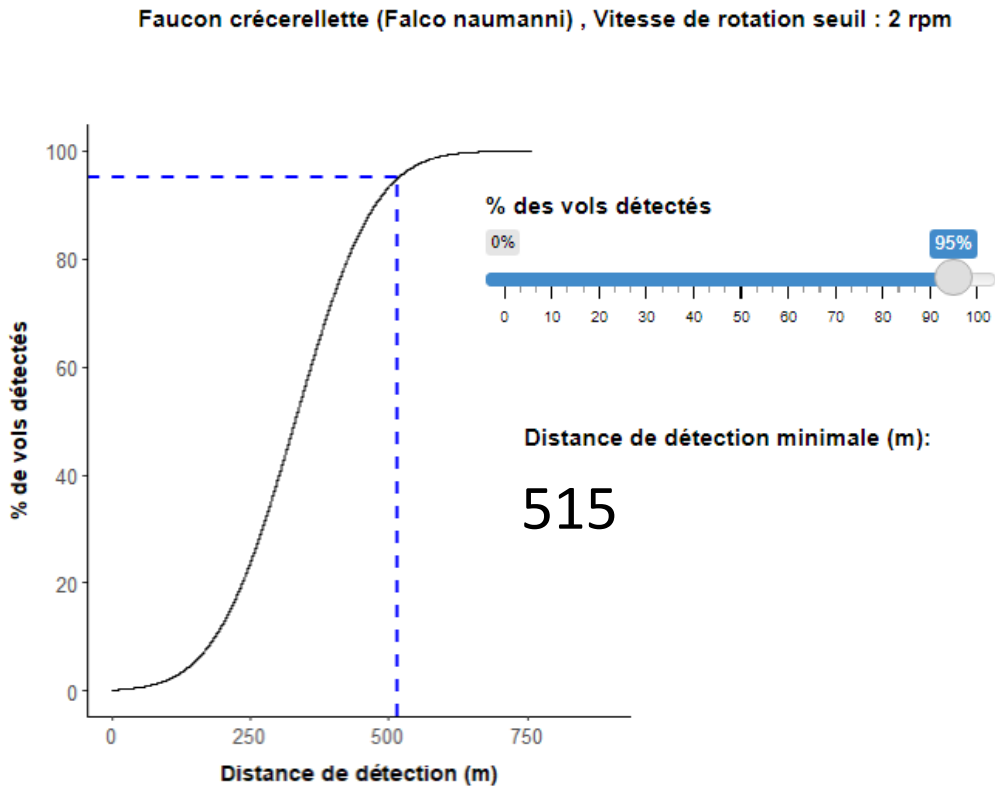
Sélectionner la vitesse de rotation seuil souhaitée (rpm) : 2

Durée de ralentissement du rotor ± écart-type (s) : 35.25 ± 3.58





Demo of web application EolDist

Exemple 1: Griffon vulture *Gyps fulvus*

Machine synchrone
45 m blade length
Threshold shutdown 2 rpm
50% flights detected

Exemple 2: Lesser kestrel *Falco naumanni*

Entrées des données éoliennes

Type de machine:
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Longueur de pale (m): 45

Vitesse de vent moyenne (m/s) :
- ( ) 5
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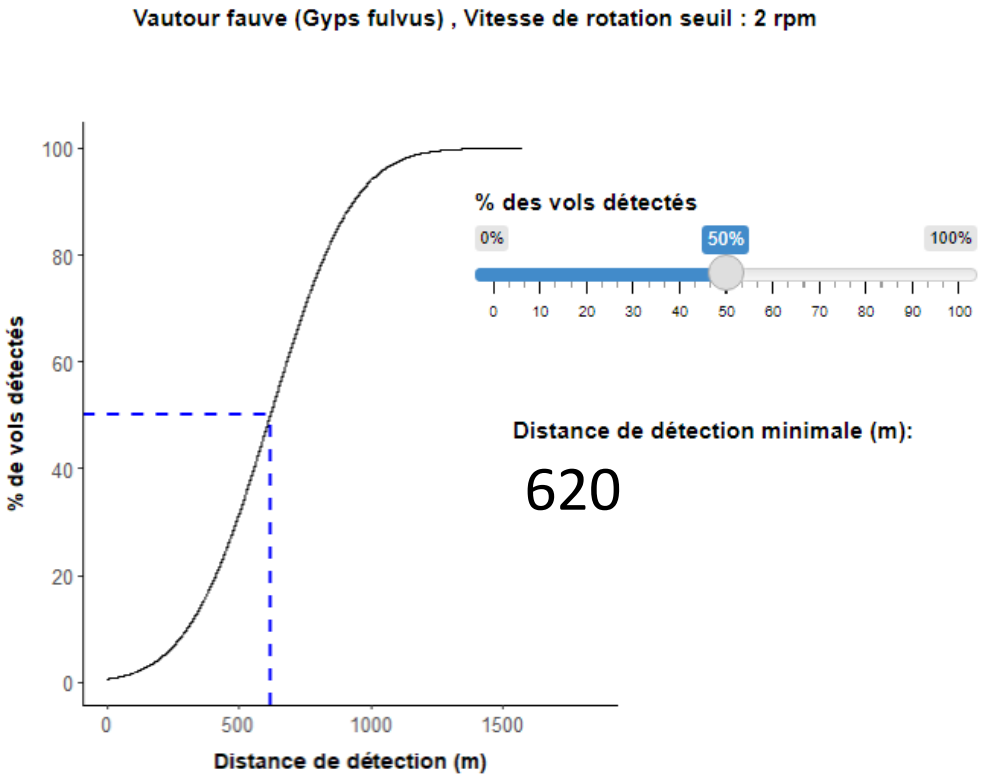
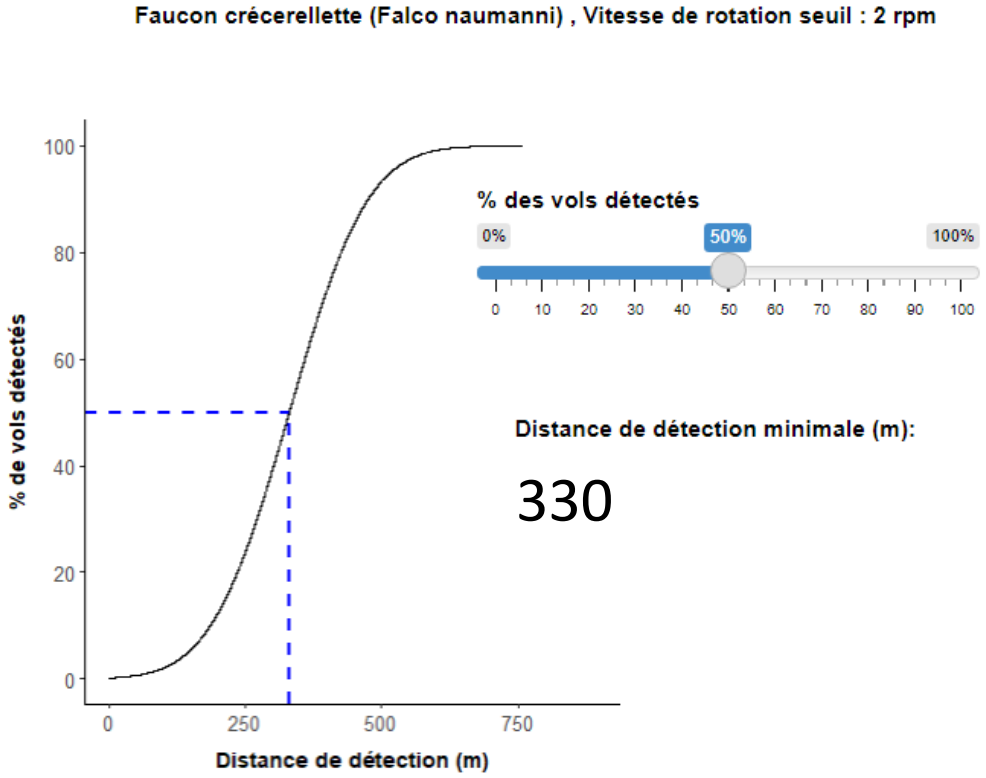
Sélectionner la vitesse de rotation seuil souhaitée (rpm) : 2

Durée de ralentissement du rotor ± écart-type (s) : 35.25 ± 3.58





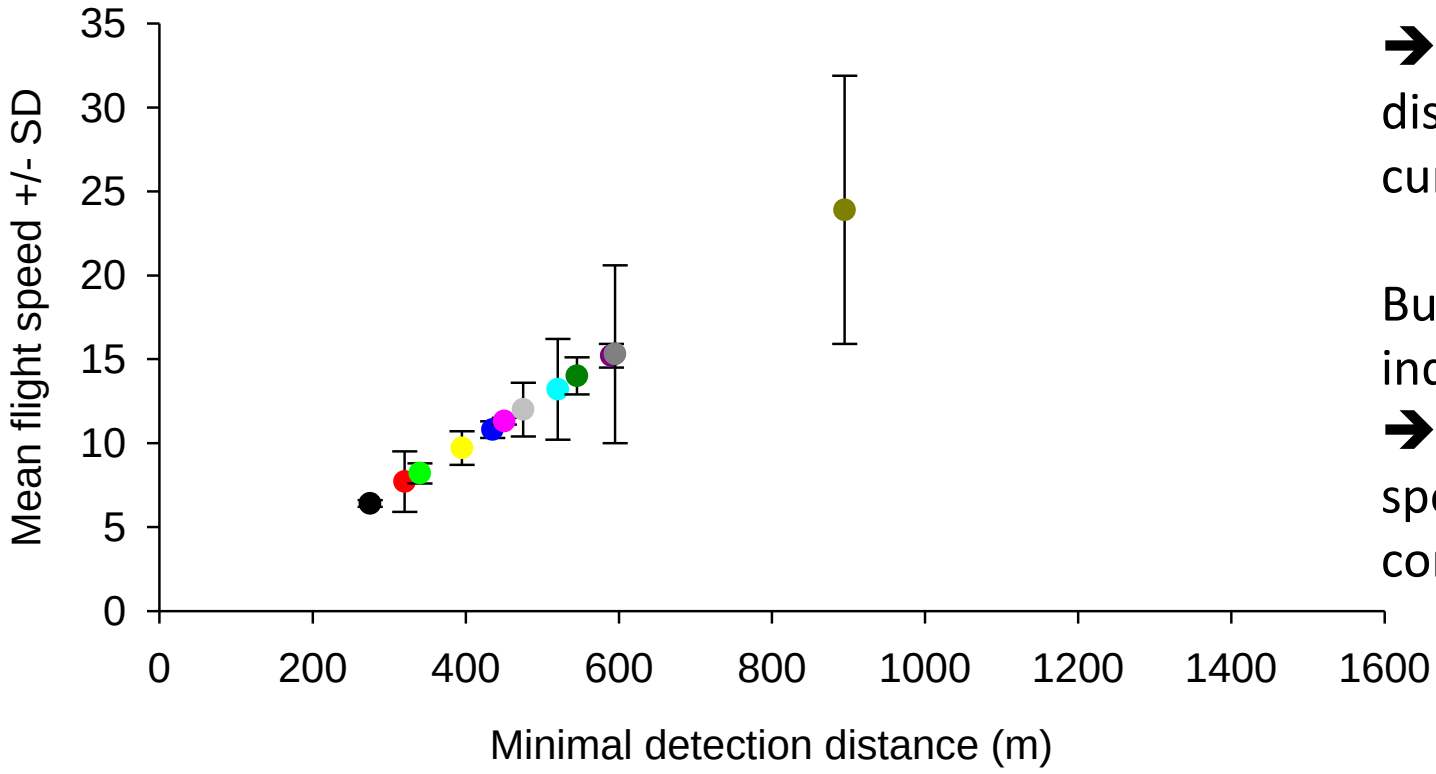
Demo of web application EolDist

Simulations for 12 species of conservation concern (PNA) ➔ importance of the detection threshold

Local flight context

- Circus pygargus
- Falco naumanni
- Milvus milvus
- Platalea leucorodia
- Ciconia nigra
- Grus grus
- Tetrax tetrax
- Neophron percnopterus
- Haliaeetus albicilla
- Cygnus columbianus
- Gyps fulvus
- Falco peregrinus

Machine synchrone, blade 45m, wind 10 m/s,
threshold 3 rpm (51 km/h) detection 50% of flights



Shutdown duration: 33.8 ± 2.4 s

➔ Minimum detection distances globally suitable for current detection devices

But Risk of collision for 50% of individuals

➔ Ethically impossible for species of conservation concern

Demo of web application EolDist

Simulations for 12 species of conservation concern (PNA) ➔ importance of the detection threshold

Local flight context

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- Milvus milvus
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- Neophron percnopterus
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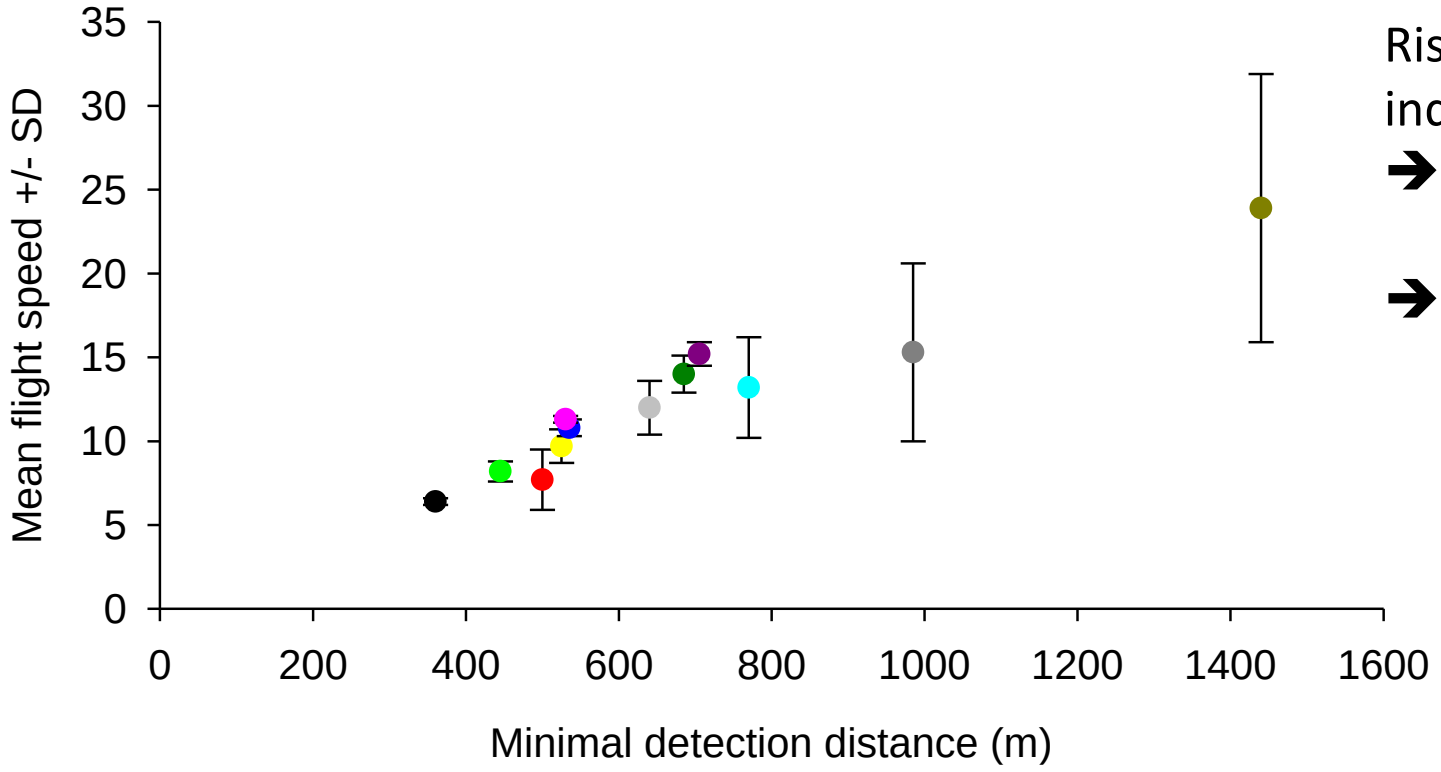
- Cygnus columbianus
- Gyps fulvus
- Falco peregrinus

Machine synchrone, blade 45m, wind 10 m/s,
threshold 3 rpm (51 km/h), detection 95% of flights



Shutdown duration: 33.8 ± 2.4 s

Risk of collision for 5% of individuals

➔ Ethically suitable for rare species

➔ Large increase (+35%) of minimal detection distance, difficult to satisfy with current devices

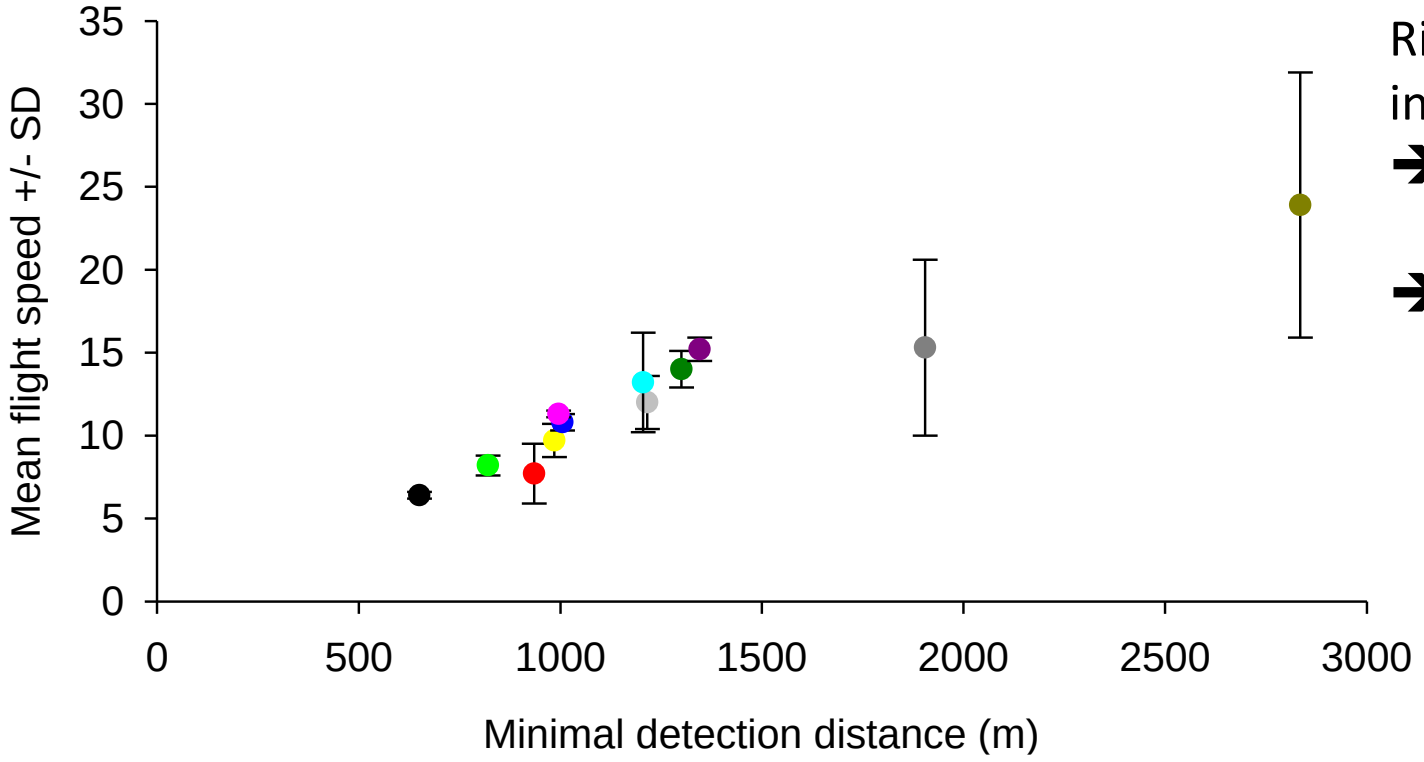
Demo of web application EolDist

Simulations for 12 species of conservation concern (PNA) ➔ importance of the detection threshold

Local flight context

- Circus pygargus
- Falco naumanni
- Milvus milvus
- Platalea leucorodia
- Ciconia nigra
- Grus grus
- Tetrax tetrax
- Neophron percnopterus
- Haliaeetus albicilla
- Cygnus columbianus
- Gyps fulvus
- Falco peregrinus

Machine asynchrone, blade 63m, wind 10 m/s, threshold 2 rpm (50 km/h), detection 95% of flights



Shutdown duration: 69.9 ± 3.3 s

Risk of collision for 5% of individuals

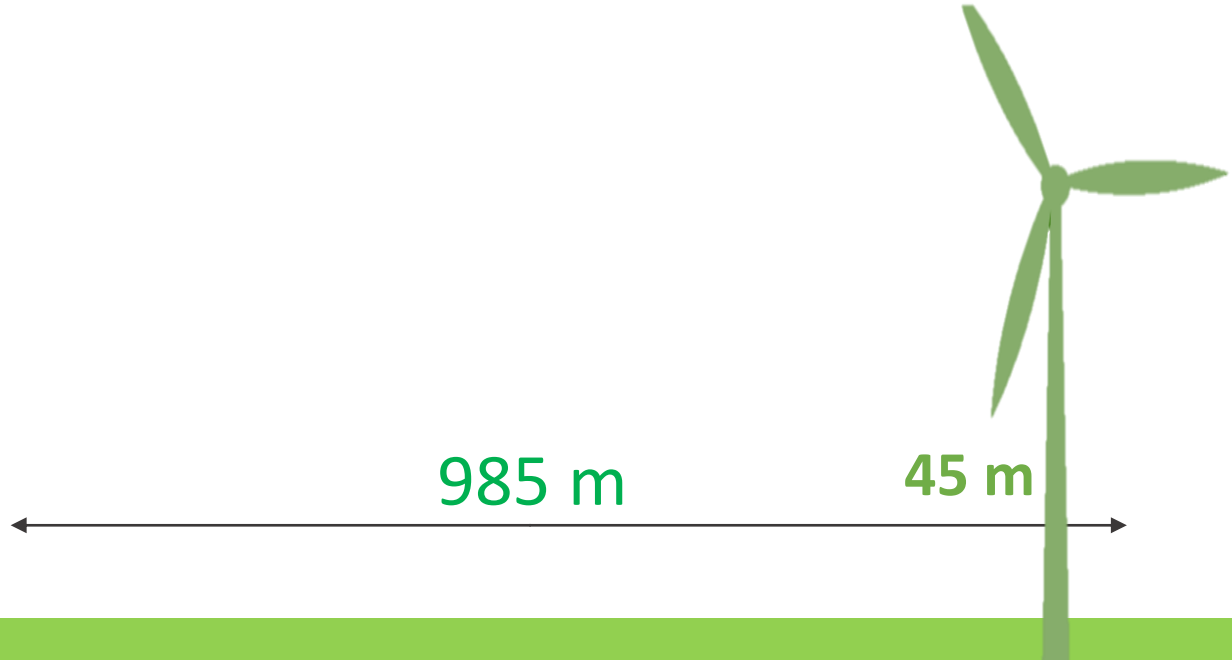
➔ Ethically suitable for rare species

➔ VERY Large increase of minimal detection distance

Solutions of improvements for the current trend of size increase?

Minimal distance detection = ($T_{decision}$ + T_{signal} + **T_{rotor}**) * Flight speed

1 s **1 s** **34 s** **15.3 m.s^{-1}**



Solutions of improvements for the current trend of size increase?

Minimal distance detection = ($T_{decision}$ + T_{signal} + **T_{rotor}**) * Flight speed

1 s | 1 s | 34 s | 69 s | **15.3 m.s^{-1}**

Solutions of improvements for the current trend of size increase?

Minimal distance detection = ($T_{decision}$ + T_{signal} + **T_{rotor}**) * Flight speed

1 s 1 s 34 s **15.3 m.s^{-1}**

69 s

Slow down bird flight speed?

Solutions of improvements for the current trend of size increase?

Minimal distance detection = ($T_{decision}$ + T_{signal} + **T_{rotor}**) * Flight speed

$T_{decision}$	T_{signal}	**T_{rotor}**	Flight speed
1 s	1 s	34 s	**15.3 m.s^{-1}**
		69 s	

Slow down bird flight speed?

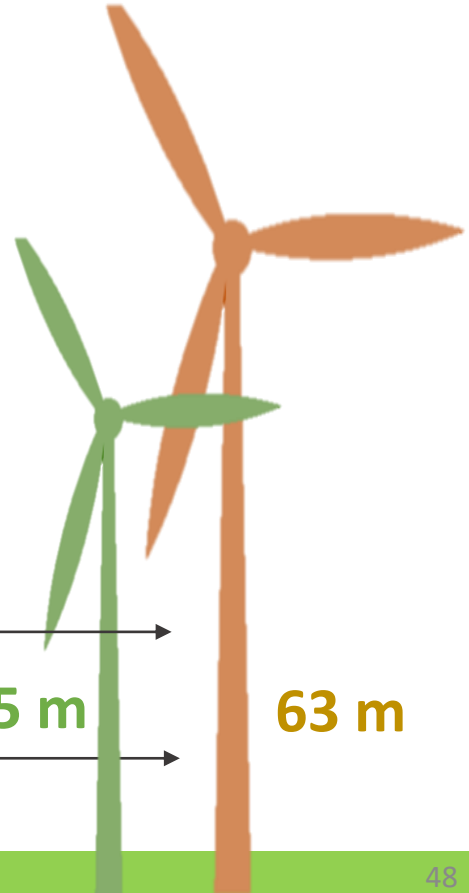
Increasing minimum detection distance for efficient shutdown?

1905 m

985 m

45 m

63 m



Solutions of improvements for the current trend of size increase?

Minimal distance detection = ($T_{decision}$ + T_{signal} + **T_{rotor}**) * Flight speed

1 s 1 s 34 s 69 s **15.3 m.s^{-1}**

Slow down bird flight speed?

Reducing shutdown duration?

Increasing minimum detection distance for efficient shutdown?

1905 m

985 m

45 m

63 m

Conclusion

- Web application EolDist is simple and functionnal
  - Available online before December 2021
  - English version soon available

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- For turbine makers ➔ incentive to reduce shutdown duration

Conclusion

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- For detection device makers ➔ finding the best match between detection technical possibilities and birds flight behaviour
- For turbine makers ➔ incentive to reduce shutdown duration

Perspectives:

- More shutdown tests at high wind speed with more machines ➔ robustness of shutdown durations estimates
- List of species available can be updated for other continents (depending on availability of new data of flight speed)

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