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# Time-Frequency Exploration of the Repertoire and Evolution of Humpback Whale Songs in the Caribbean Sea



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## INTRODUCTION

- Humpback Whales (*Megaptera novaengliae*) produce **complex and organized songs** composed of a base unit = the **vocalization** [1]
- These songs evolve during the **breeding season** and over the years [2].

## OBJECTIVES

**Automatically detect and classify** Humpback Whale vocalizations. Analyze repertoire changes as a function of **time** and relative **distance** within and across breeding seasons.

## MATERIALS AND METHODS

- CARI'MAM project** : 18 Stations in the Caribbean (from Bonaire to Bermuda)
- Recording Duration : 1 min, ShutdownTime : 5 min
- Recording Period : ~ 30 days.

## ANNOTATION

A total of **1,894 vocalizations** of **28 different types** were manually annotated in **time and frequency**. We added the human voice and other possible confusions in the background.

## DETECTION/CLASSIFICATION

YOLOv5 [3] is a computer vision model, designed for **object detection**. Considering that a vocalization has a characteristic frequency contour shape recognizable on a **spectrogram**, we fine-tuned a model on our annotations to learn how to **detect and classify Humpback Whale vocalization**.

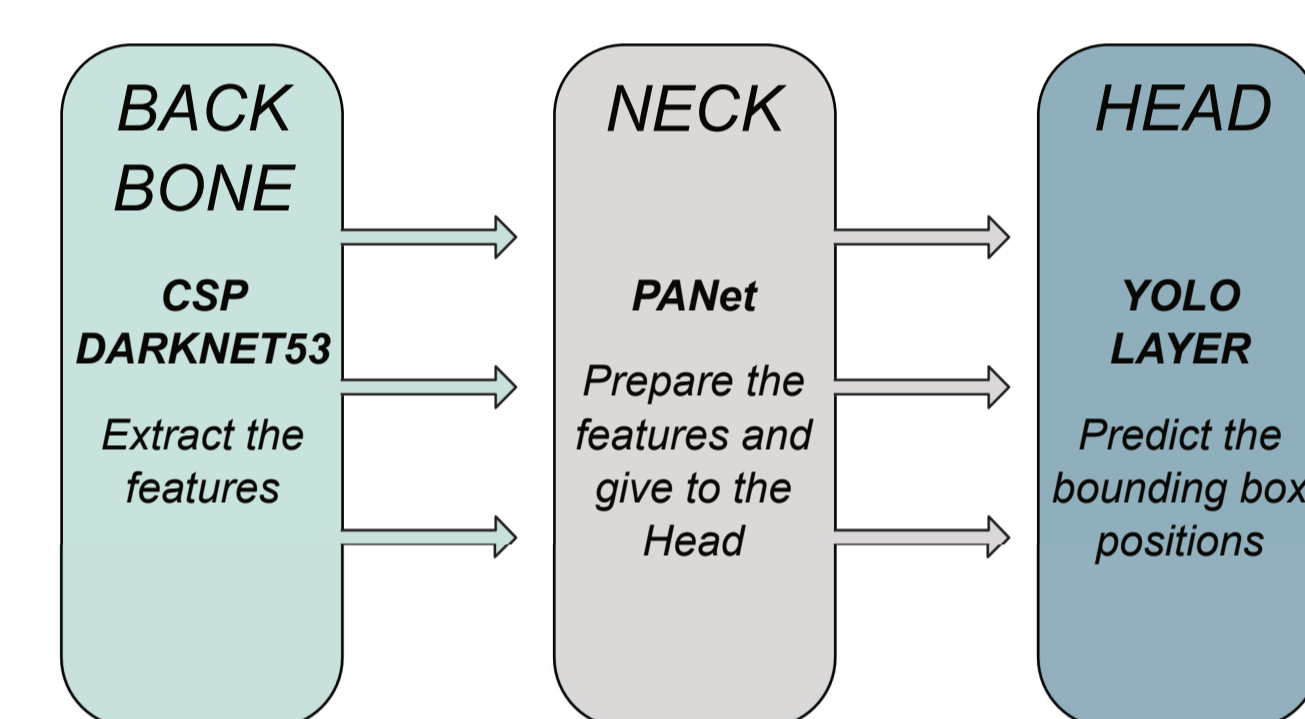
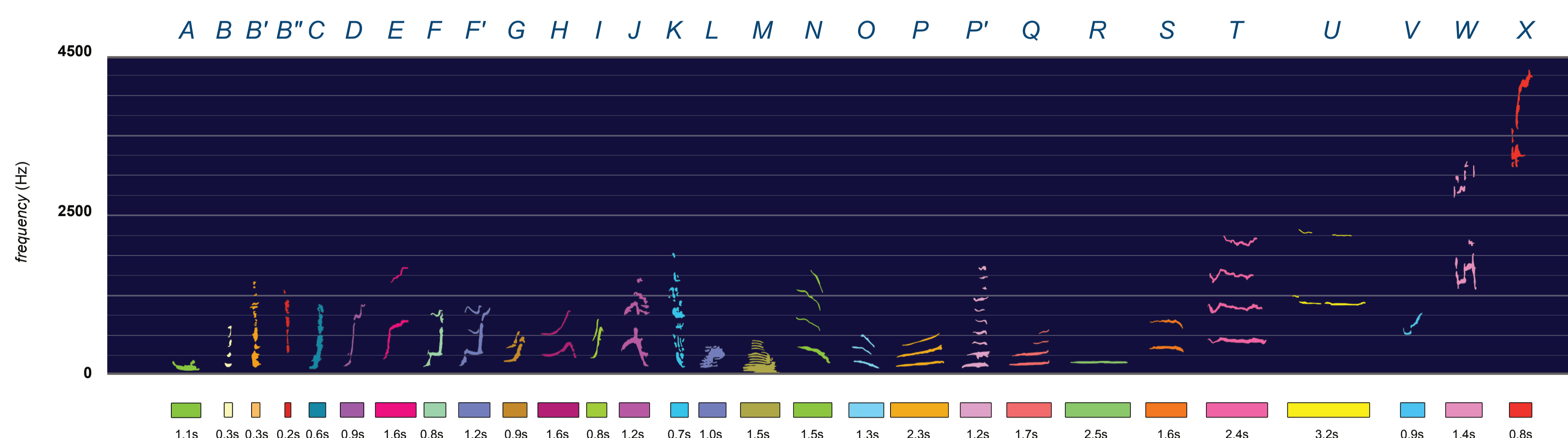


Fig. 1: Vocal repertoire of the Caribbean Humpback Whales

## RESULTS

On the test set, the best **mAP@50** is **87.4%**. After running the model on more than 9,000 hours of recordings, we detected over 2,000,000 vocalizations. With these detections we are able to analyze occurrences, phrases, tempo and the evolution of the song.

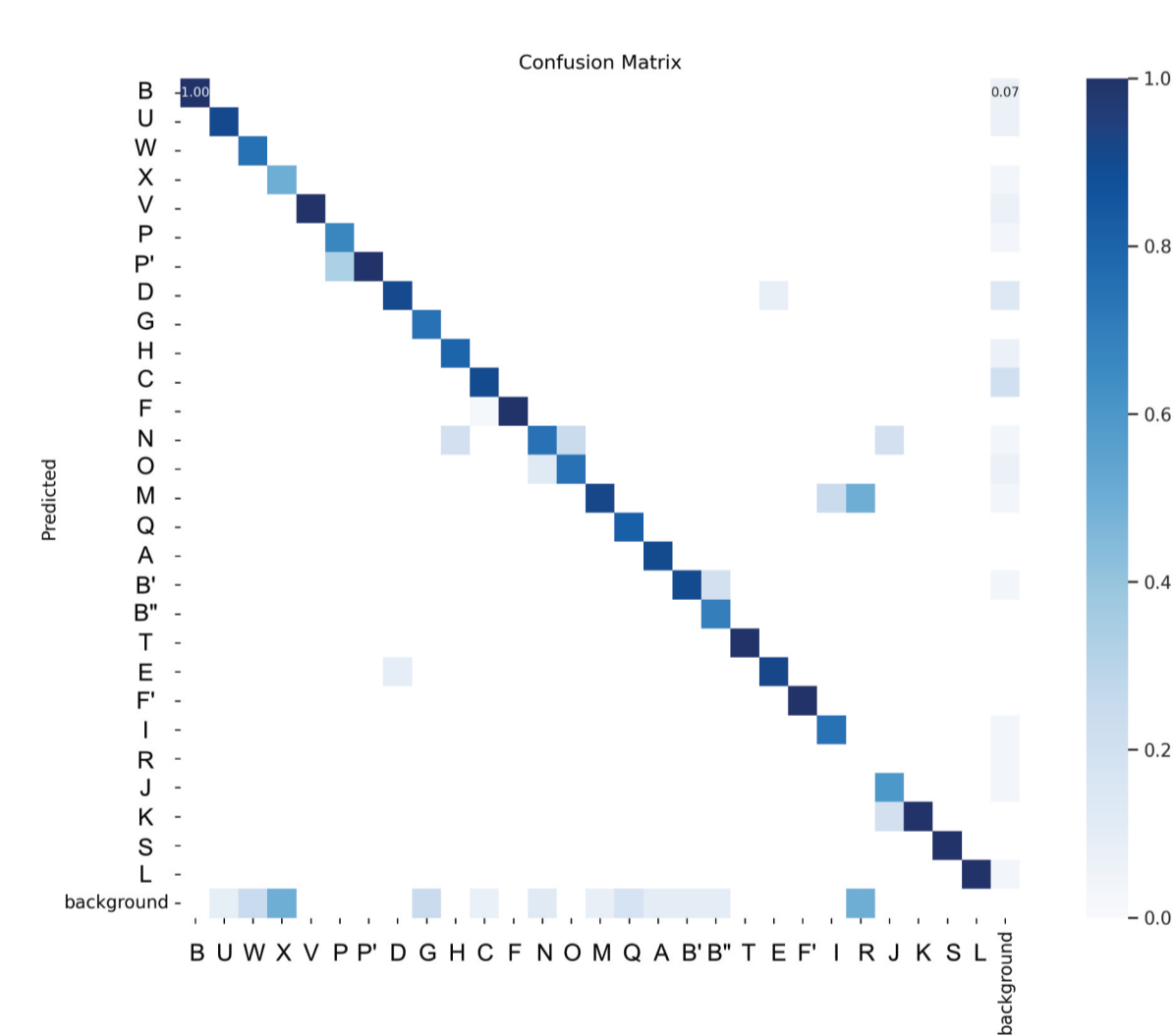
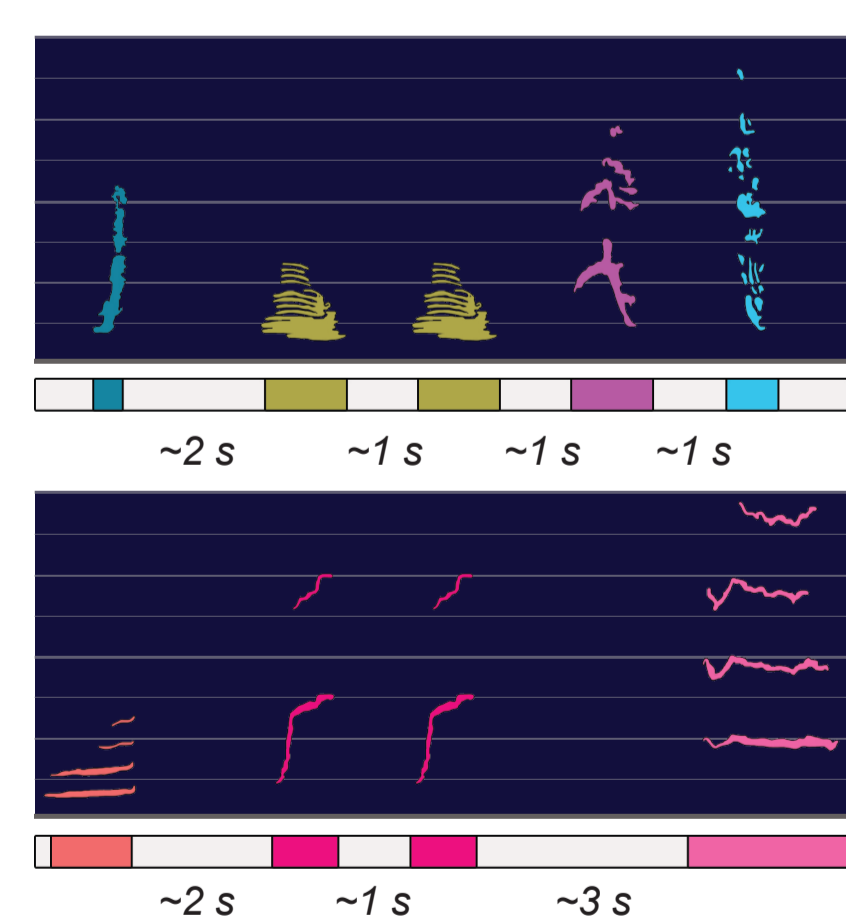


Fig. 2: Confusion matrix



**PHRASE 1 "CMMJK"** :  
 Occured in Bermuda at the **end of 2021 breeding season**  
 Occured in Bermuda at the **beginning of 2022 breeding season**

**PHRASE 2 "QEET"** :  
 Occured in Bermuda : **2021/02/24**  
 Occured in Guadeloupe Anse de Bertrand : **2021/02/25**  
**Same phrase, same tempo**, 1,800 km and 1 day appart

## DISCUSSION

- We have established a repertoire of **28 types** that we can **automatically detect**
- We found **16 different phrases**
- It seems that there are **more detections in the North of the Caribbean**, but this depends on the location of the station i.e. if the station is not correctly placed, this may mask the vocalizations
- 3 main vocalizations** were highlighted in the recordings (D, C and V) communication? song structure?

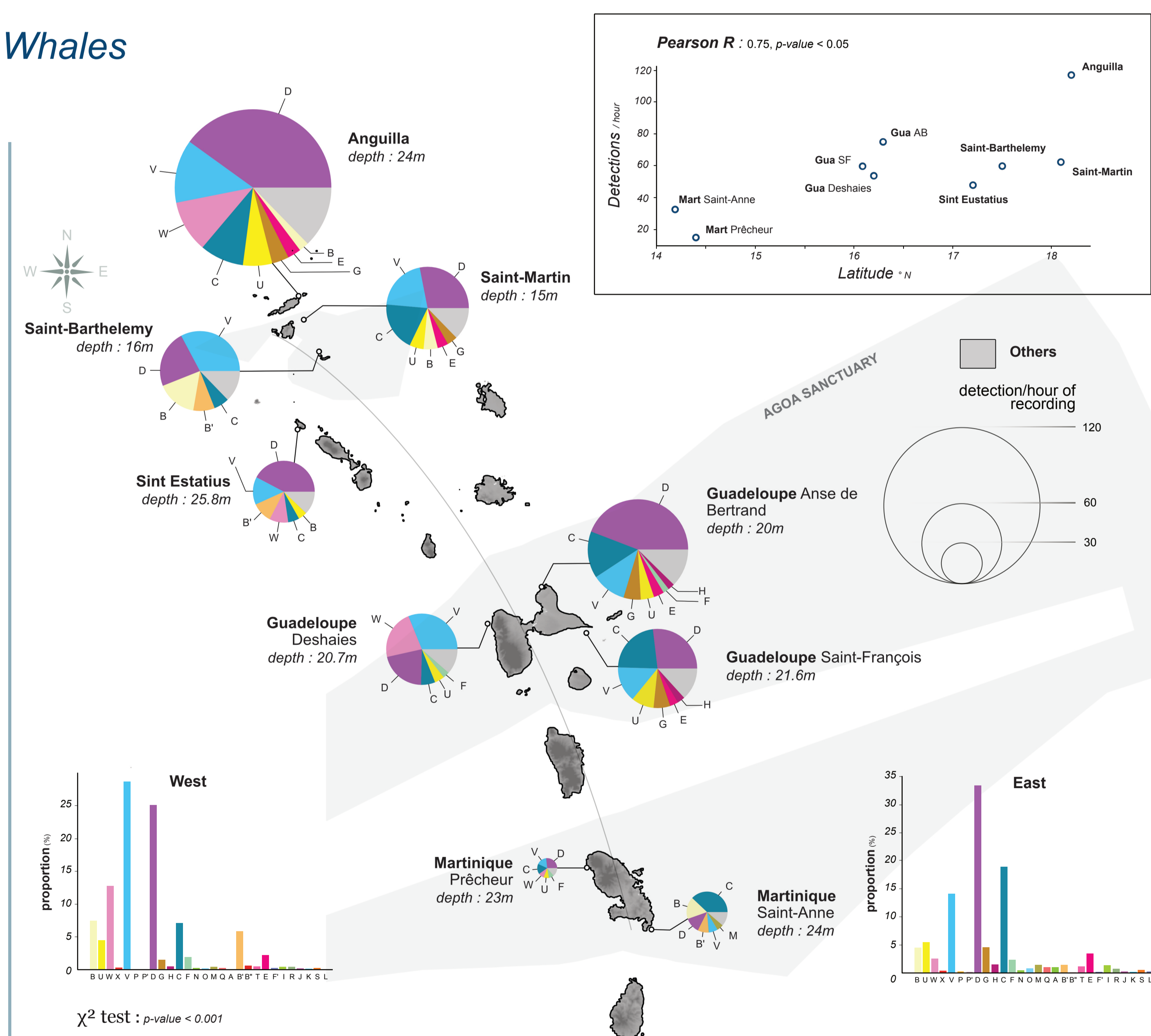


Fig. 3: Spatial distribution of vocalization rates showing a West vs East significant difference

The maximum detection was measured in Anguilla with **117 vocalizations/hr of recording**, while only 15/hr of recording were measured in Martinique Prêcheur. Although there are differences in vocalization rates, there seems to be a **majority of D, C and V types**, while others are rarer, which suggests that these vocalizations are important in communication or song.

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