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# FROM MASSIVE DETECTIONS AND LOCALISATIONS OF ORCA AT ORCALAB OVER THREE YEARS TO REAL-TIME SURVEY JOINT TO ENVIRONMENTAL CONDITIONS

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## ABSTRACT

Orcas (*Orcinus orca*) can produce 3 types of signals: clicks, whistles and vocalizations. This study focuses on orca vocalizations from northern Vancouver Island (Hanson Island) where the NGO Orcalab developed a multihydrophone recording station to study orcas. The acoustic station is composed of 5 hydrophones and extends over 50 km<sup>2</sup> of ocean. Since 2015 our team is continuously streaming the hydrophone signals, yielding nearly 50 TB of synchronous multichannel recordings. We trained a Convolutional Neural Network (CNN) to detect orca vocalizations, by transfer learning from a bird activity dataset. We relate the detected presence and absence of the orca vocalizations to the time of the day, the moon phases and the tides. This real-time detector opens new insight on these streamed submarine recording, allowing online automatic survey of the orca in the whole area. It thus assess in which area the orcas are present. It then could be used to monitor the effect of traffic pressure and anthropophonic pollution on this species. We finally discuss towards the installation of small quadraphonic system acoustic device to complete and detail these observations from Orcalab, in order to get more precise relative positions of the orcas.

## 1. INTRODUCTION

One of the best ways of studying animals that produce signals in an underwater environment is to use Passive Acoustic Monitoring (PAM). Acoustic monitoring is used to study marine mammals in oceans, and gives us information for understanding cetacean life, such as their behaviours, movement or reproduction. Automated analysis for captured sound is essential to deal with large quantities of data.

This study focused on orca (*Orcinus orca*) in North of Vancouver Island, Canada, in collaboration with Orcalab ONG (OL) which developed a multi-hydrophone recording station around Hanson Island to study orca.

The northern resident killer whale population is composed of different “pods” composed of different matriline [1],

and some pods attend Hanson Island due to the concentration of salmon. This community consists of more than 200 individuals known (in 2005), and is divided into three acoustic clans [2]. Globally, orca vocalizations are described in 3 different classes: clicks, whistles and pulsed calls [3], and each pod possesses a dialect composed of pod-specific calls (repertoire of 7–17 discrete calls). Actually, an automatic orcas detector was built, but it was not used on so many records [4].

According to our knowledge, up to now, lot of manual analyses (acoustic and visual inspection of spectrogram) were done on this population, plus preliminary automatic classification [5].

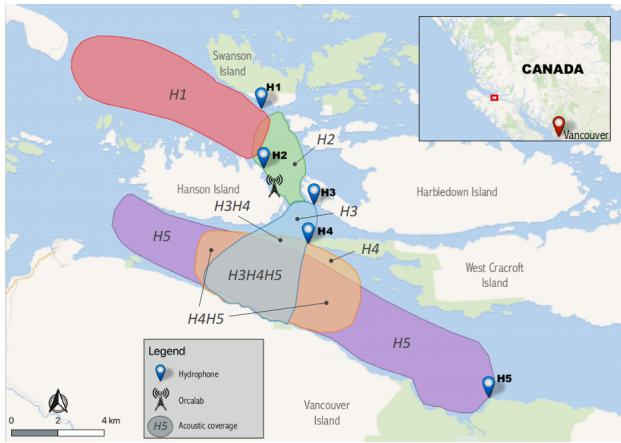
## 2. MATERIAL & METHODS

The acoustic station is composed of 5 hydrophones and extends over 50 km<sup>2</sup> of ocean (Fig.1). Since 2016 we enhanced these recordings with online full time 7/24 recording to LIS-LAB Dyni NAS storage at Toulon, France, yielding nearly 50 TB of multichannel recordings (in lossless compressed flac format). OL has also set up video stations and behavioural visual observations (group composition, behavioural state) were also obtained through a network of observers in OL.

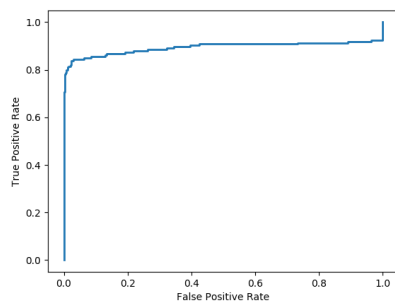
It is essential to develop scalable algorithms to classify and summarize with efficient manipulation tools this unique long-term dataset. In this paper, we investigate advanced methods to detect and automatically learn accurate features of orca calls automatically [6].

First, we propose to extract all calls from a subset of 3 months of recordings, using basic adaptive time frequency filters [6]. We built a dataset composed of 872 orca vocalization samples and 6801 noise samples (boats, rain, void, etc), which we split randomly with 20% for the test set, 60% for the training set and 20% for the validation set. With that in hand, we trained a CNN [7] to distinguish orca vocalizations (not clicks) from boats and background noise [8,9].

After training, when computing predictions, a threshold



**Figure 1.** Map of the area and the listening range of the 5 hydrophones. Map pins with H1 to H5 in bold print denote the hydrophone locations. Detection zones indicate which hydrophones can capture orca calls in a particular area, according to experience of ten years of audio-visual observations of the orcas by the Orcalab team.



**Figure 2.** Receiver Operating Characteristics of the trained deep learning detector.

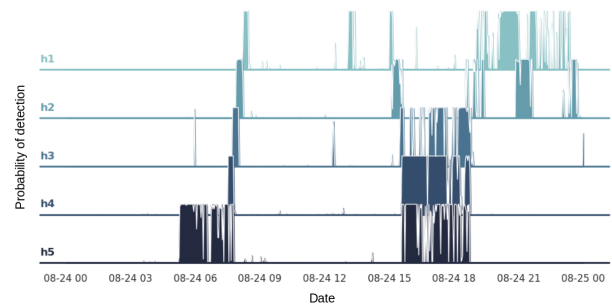
of 0.9 is applied to the probabilistic output of the model (Fig.2). This reduces the risk of false positives. Once trained, the model was run on 3 years of recordings (2015, 2016 and 2017) in 2 days of computation.

### 3. RESULTS

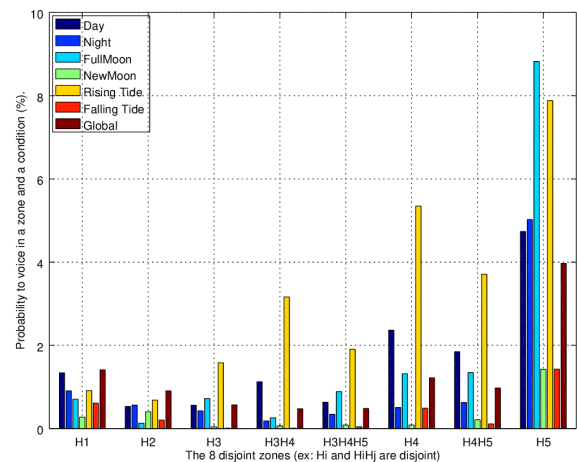
Detection results allow to estimate orca activity over time and hydrophone and infer likely movements of orcas, shown Fig.3. The trajectory from H5 to H1 can be deduced by the succeeding high detection rates of the hydrophones at 6 am the 24<sup>th</sup> of August. After this the group makes different round trips during the day.

Additional insights can be won by relating the occupancy of this site to the time of the day, the moon phases and the tide.

More precisely, we computed the probabilities to detect orca calls in each zone during a given time interval, shown in Fig.4. This result shows the global patterns of the orcas' voicing activity in time and space, based on the continuous 3 years of recordings. It reveals variations in the voicing activities of up to a factor of four between conditions and zones. The biggest variation concerns the influence of



**Figure 3.** Example of the evolution of the probability of call detection for each hydrophone during one day (August 24<sup>th</sup>, 2017). During the morning, a group of orcas comes from the East (Fig.1) on H5, and is moving on H4, H3, H2 then on H1. Different round trips are made during the day.



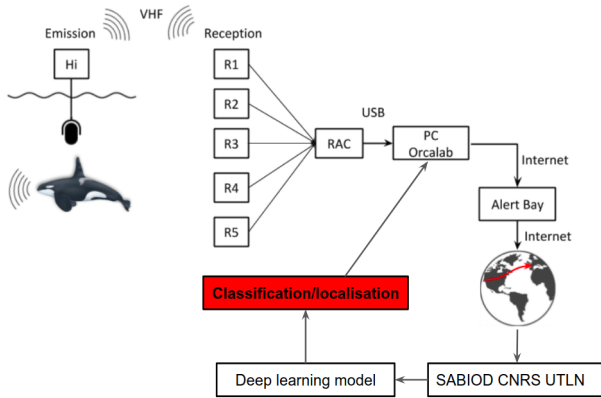
**Figure 4.** Probability of voicing of orca in a zone during a given condition. 'Global' refers to no specific condition. This probability is defined as the amount of recordings with orcas calls in a zone  $Z_i$  during a condition  $C_j$ , divided by the total amount of recordings in  $Z_i$  during  $C_j$ .

tide and moon in zone H5. In fact, this area is subject to strong currents during tidal hours. The Johnstone Strait is relatively deep (-450 m), so the trophic chain can change according to the moon phase [10] and influence the orca acoustic activities.

In addition to the statistics carried out on this species, this system could be set up for real-time detection and rough localisation of the orcas around Orcalab. This would allow eco-volunteers to lighten their working time, and maybe help to focus or select visual observations from the various camera placed in the area.

A summary diagram of such system is proposed Fig.5. It figures the orcas emissions and their collection by the hydrophones, compression and transfer to GPU computers to LIS (could be closer). Then the detection and classification, and finally the rough localisation of the orcas by comparisons of the detection. The different responses of our model could be accessible via a dedicated website accessible by password to avoid any usage by whale watch-

ing industry which could interfere with orcas.



**Figure 5.** Representation of the data acquisition, from recording until the detection and the localisation of the orcas.

#### 4. TOWARDS DETAILED LOCALISATION

One current extension of this research is linked to the installation of a small quadrasonic acoustic device on the shore in front of OL. It could improve the monitoring of the whales, by obtaining more precise tracks and observing behaviour in conjunction with ferries and other marine traffic. Therefore we developed at Toulon SMIoT team a high velocity sound card (5 channels x 1 MHz sampling rate x 16 bits) to study in detail orca movement and separate their voicings [11], still without interfering with animals. This antenna has been successfully placed in summer 2019 and current process show promising results.

#### 5. CONCLUSION

The massive recording of orca activities give new insights but also offer facilities to learn accurate automatic detector. Moreover, detailed acoustic observations from small hydrophone array joint to visual observations are also useful to better learn to classify automatically the orcas pods in the area [8, 9]. Correlating the orcas' activity (position, speed, density of calls) and group (pod) with the marine traffic and anthropogenic noises in a large scale could support the creation of local measures to mitigate the impact of human activity on the animals.

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