Whale watching AIS Vessel movement Evaluation (WAVE)

Whale watching operations in Canada's Pacific Region

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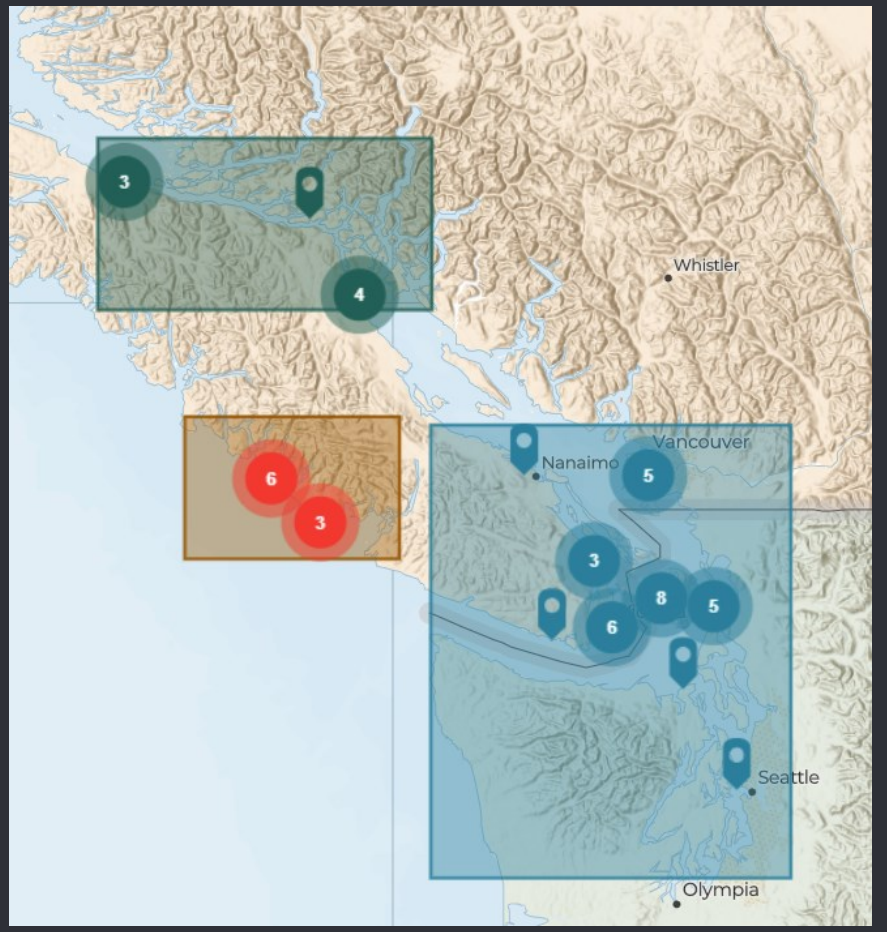
Introduction

In Canada's Pacific Region, commercial whale watching operations started in the 1980's in the north of Vancouver Island. Since then, the industry has grown exponentially in the area.

Currently, there are *49 whale watching companies* operating in the Salish Sea, west and north coast of Vancouver Island. There is also a whale watching company based in Prince Rupert.

This presentation focuses on commercial whale watching companies operating in the southern waters of the Salish Sea (in blue) and in the west coast of Vancouver Island (in red).



Whale watching management measures

During the last four years several measures have been introduced, both mandatory and as guidelines, to manage and reduce the negative effects of whale watching activities on local marine mammal species, particular the Southern Resident Killer Whale population.

The majority of these measures apply to both commercial and recreational whale watching activities.

Timeline of whale watching management measures

2018

VESSEL APPROACH DISTANCE (VAD)

- *NOAA:* Mandatory 200yd VAD from killer whales & 100yd around other cetaceans in U.S. waters
- *DFO:* Mandatory 200m VAD for killer whales & 100m around other cetaceans in Canadian waters

VESSEL EXCLUSION ZONES

- *MOECC:* Vessels prohibited within Race Rocks Ecological Reserve when cetaceans present
- *WDFW:* Guideline for vessels to avoid No-Go Zones: ¼ mile offshore east San Juan & ½ mile around Lime Kiln

SPEED RESTRICTIONS

- *PWWA:* Guideline for vessels within 1km of cetaceans to reduce speed to < 7 knots
- *Be Whale Wise:* Guideline for vessels within 400m of cetaceans to reduce speed to < 7 knots

TIME LIMITATIONS

- *PWWA:* Guideline for vessels to limit viewing time to 60 min (or 30 min if >10 PWWA vessels present)
- *Be Whale Wise:* Guideline for vessels to limit viewing time to 30 min

2019

VESSEL APPROACH DISTANCE (VAD)

- *WDFW:* Mandatory 300 yd VAD from SRKW
- *DFO:* Mandatory 400m VAD from killer whales in SRKW critical habitat from June 1 - Oct 31

VESSEL EXCLUSION ZONES

- *Transport Canada:* Mandatory interim sanctuary zones around E coast of Saturna Island, SW coast of North Pender Island and Swiftsure Bank from June 1 - Oct 31
  (some changes in location & duration of exclusion zones in 2020 & 2021)

SPEED RESTRICTIONS

- *WDFW:* Mandatory for vessel within ½ nm of SRKW to reduce speed to < 7 knots
- *Be Whale Wise:* Guideline amended to align with PWWA 1km slow down

AIS REQUIREMENTS

- *Transport Canada:* AIS mandatory on every vessel on a voyage if certified to carry >12 passengers or ≥8m in length & carrying passengers. AIS units can be Class A or B.

2020

COVID-19 RESTRICTIONS

- *Government of Canada:* US based whale watching vessels are prohibited from entering Canadian waters (ended on Aug 8, 2021)
- *PWWA:* Guideline for no border crossing for CA & US based vessels

2021

VESSEL APPROACH DISTANCE (VAD)

- *DFO:* Mandatory 400m VAD from killer whales in all southern BC coastal waters

LICENCING PROGRAM

- *WDFW:* Washington whale watching operators must have a licence to operate starting May 1, 2021

AIS REQUIREMENTS

- *WDFW:* All motorized vessels used for commercial whale watching must be fitted with an AIS unit (Class A or B)

Glossary

MOECC	British Columbia Provincial Government, Ministry of Environment
DFO	Canadian Federal government, Department of Fisheries and Oceans
NOAA	U.S. Federal Government, National Oceanic and Atmospheric Administration
PWWA	Pacific Whale Watching Association
SRKW	Southern Resident Killer Whales
WDFW	Washington State, Washington Department of Fish and Wildlife

Sources:

Be Whale Wise www.bewhalewise.org

Canada Gazette (Part II, V.153, N.9) https://gazette.gc.ca/rp-pr/p2/2019/2019-05-01/html/sor-dors100-eng.html

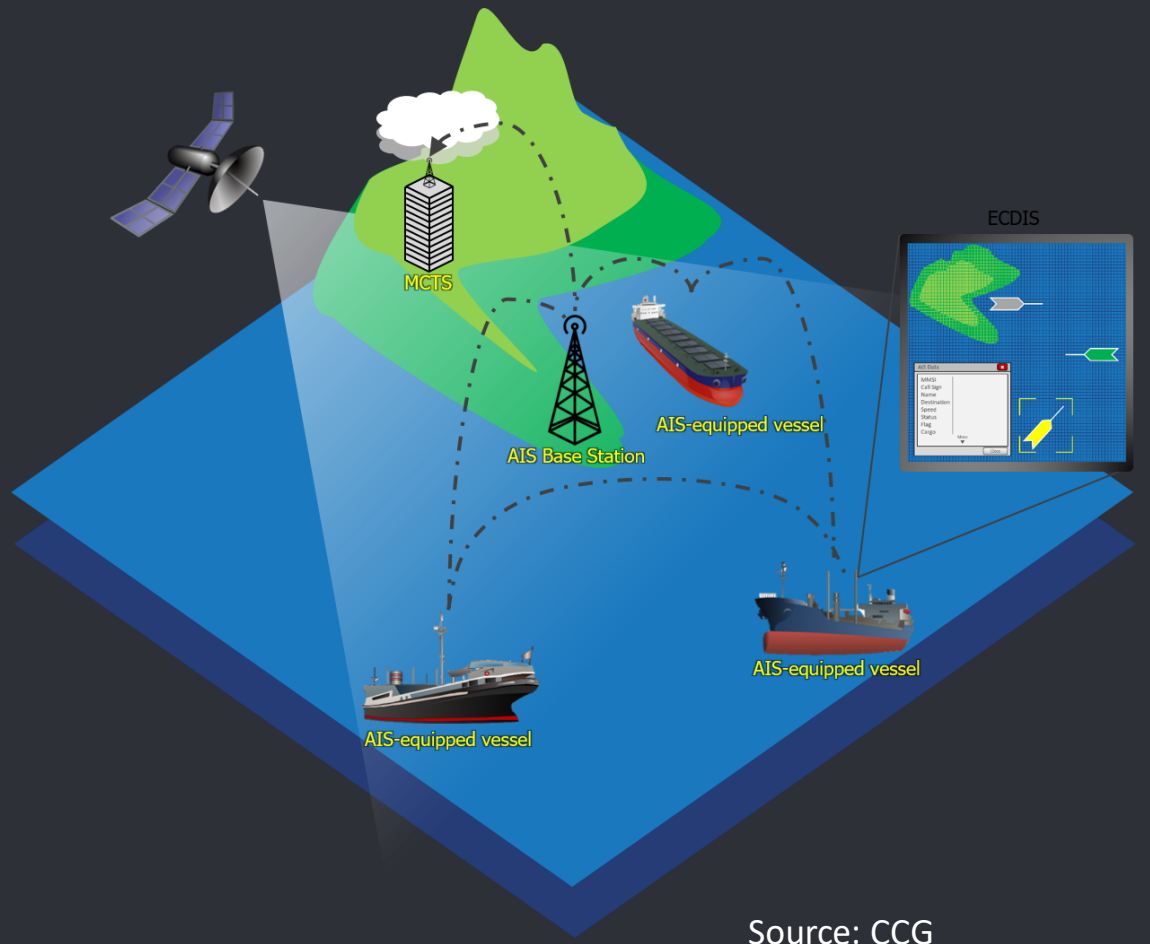
Fraser et al. 2020 https://doi.org/10.1016/j.marpol.2020.104171

WDFW. Commercial Whale Watching Licensing Program https://wdfw.wa.gov/licenses/commercial/whale-watching#ais

AIS Technology

Automatic Identification System or AIS is an automated and autonomous system that increases navigational safety and collision avoidance by transmitting vessel position data, voyage data, and vessel identification information to nearby vessels and receivers on land and on satellites.

In 2019, the WAVE project equipped commercial whale watching vessels with AIS transponders provided by exactEarth.



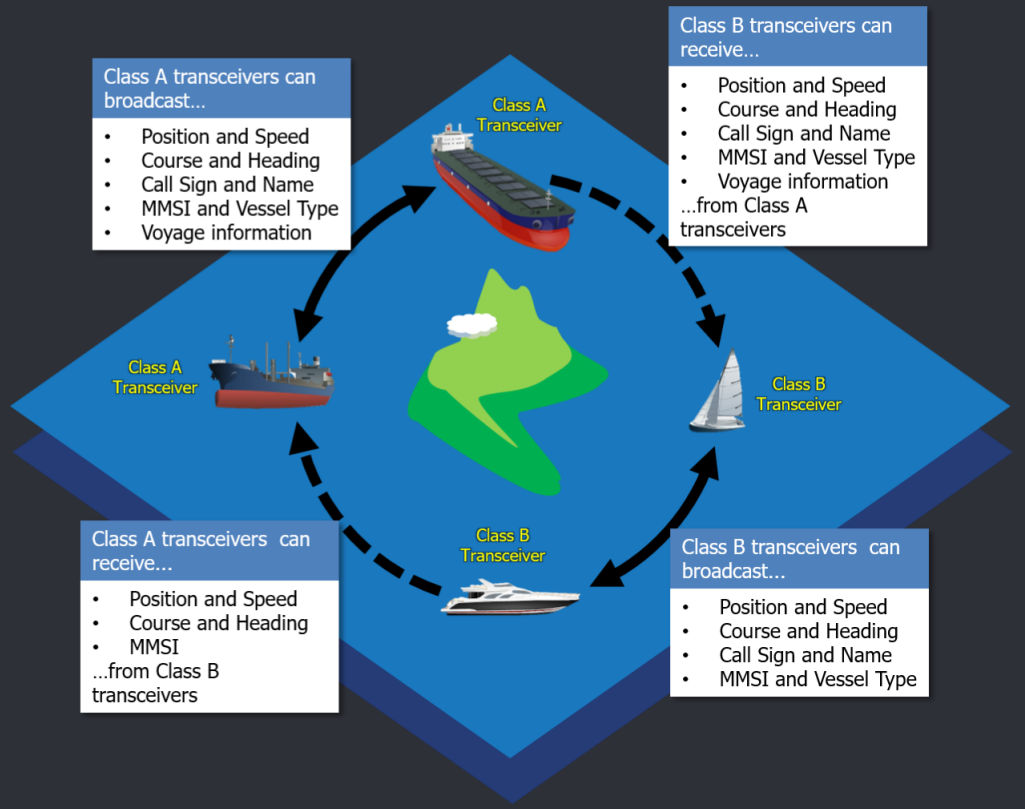
Source: CCG

AIS Transponders

AIS transponders are able to send out vessel positions and other vessel information to other vessels and receivers on land or on satellites. Most transponders can also receive AIS positions from nearby vessels.

There are three different types of AIS transponders: **Class A, Class B and Class B+**. The main difference between these transponders are their transmitting power, transmission frequency and type of messaging system.

In 2019, Canada introduced a new AIS carriage regulation stating that commercial whale watching vessels certified to carry 12 or more passengers or 8 meters long or more must carry an AIS transponder, either Class A or B. *For more information on AIS carriage regulations here.*



Source: Comparison Class A with Class B (Source: CCG)

AIS Transponders

Class A

- Mandatory on most commercial vessels
- Transmitting Power = 12.5 watts (high transmitting range)
- Positions transmitted every 2 to 10 seconds
- STODMA
- Supports message 27 (long range/satellite AIS)

Class B

- Optional / Suitable for recreational and small vessels
- Transmitting Power = 2 watts (small transmitting range)
- Positions transmitted every 30 to 180 seconds
- CSTDMA
- Poor Satellite AIS reception

Class B+

- Optional / Suitable for recreational and small vessels
- Transmitting Power = 5 watts (medium transmitting range)
- Positions transmitted every 30 seconds
- STODMA
- Supports message 27 (long range/satellite AIS)

AIS Data Providers

In Canada, there are several AIS data providers. Here we describe three AIS data providers that were explored at different stages of the project:

- **exactEarth (now Spire)** is the leading provider of satellite AIS.
- **AISHub** is an AIS data sharing centre that provides access to free real-time raw AIS data to AISHub members. The WAVE project installed an AIS receiver at University of Victoria and became a member to access real-time AIS data in the area.
- **Canadian Coast Guards (CCG)** manages the largest network of terrestrial AIS receivers in Canada.

We identified CCG terrestrial AIS as the best data to use in WAVE, because of its spatial coverage and temporal resolution. In late 2020, we sign an agreement with Ocean Networks Canada to access historical AIS data (2018-2021) to use in the project.

AIS Receiver at UVic (2019-2021).
Source: Norma Serra

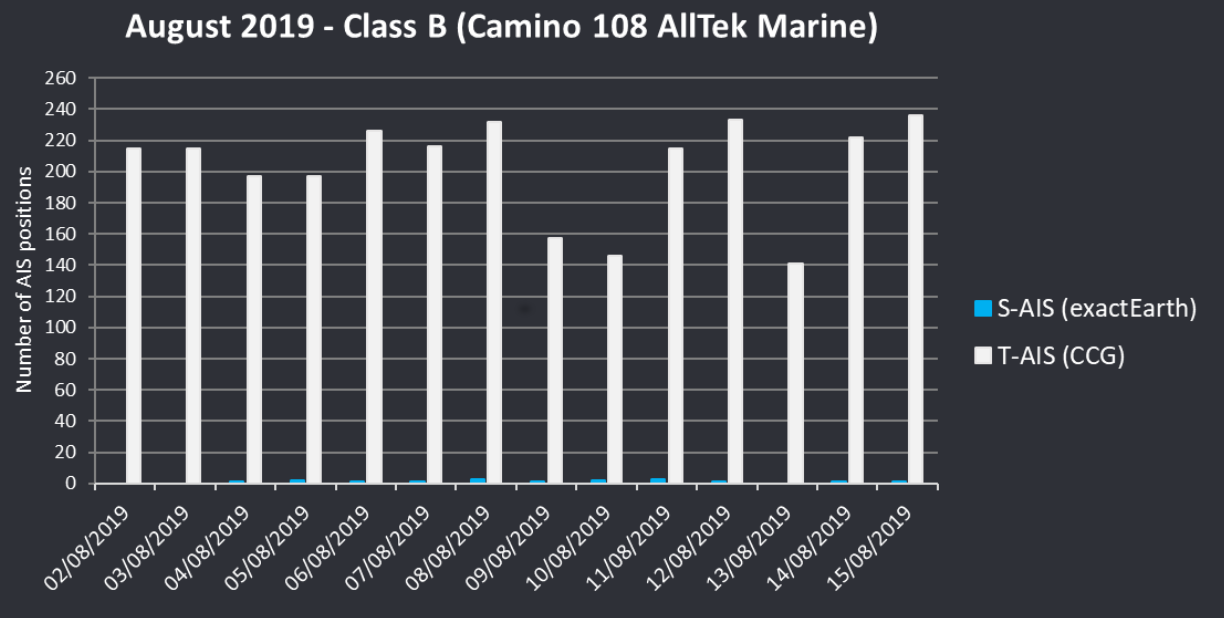
AIS Data Providers

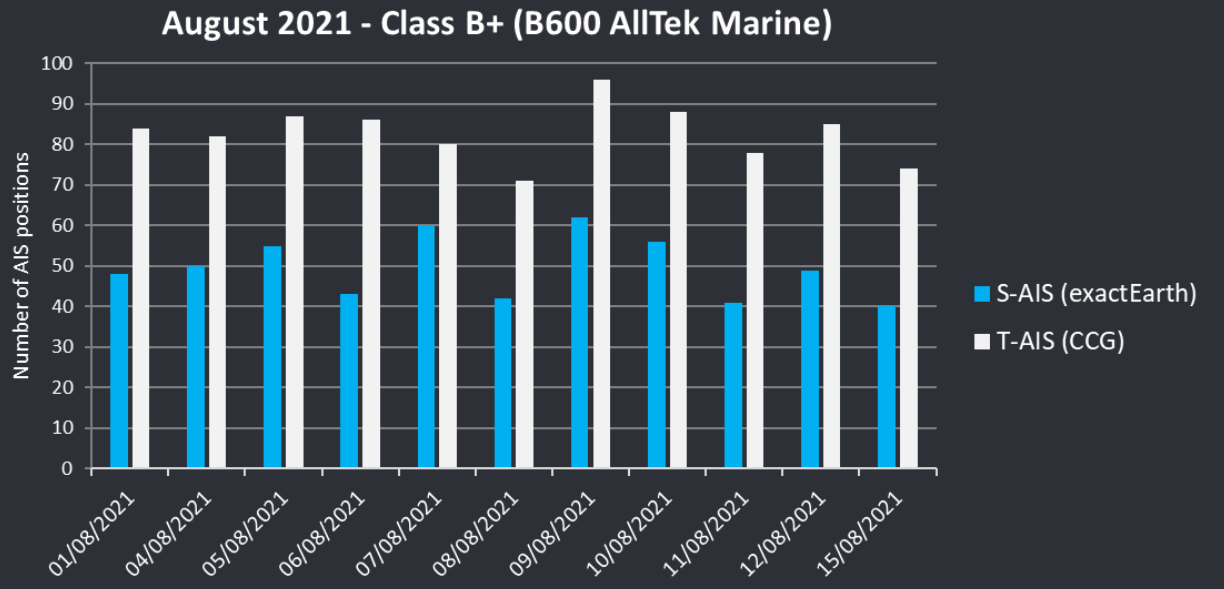
Source	Type	Accessibility	Resolution	Spatial Extent	Temporal Extent
exactEarth (now Spire)	Satellite AIS	Free and easy access thanks to project agreement	Minimum resolution between messages 3 min	Adequate	2018 - 2021
AIS Hub	Terrestrial AIS	Free (but needed to contribute data in order to access data)	Minimum resolution between messages 30 sec	Poor (only handful of receivers in the area)	2019 – 2021
CCG	Terrestrial AIS	Free (but lengthy process to acquire data via ONC)	Minimum resolution between messages 30 sec	Adequate	2018 – 2021

In-depth look at Class B and Class B+ devices operability in Canada's west coast.

The top graph shows the number of messages received by terrestrial and satellite receivers from a Class B and the bottom graph from a Class B+ transponders fitted on the same vessel during two different time periods, August 2019 and August 2021 respectively, and operating on the west coast of Vancouver Island.

Although terrestrial receivers (T-AIS from CCG) show a higher reception rate than satellite receivers (S-AIS from exactEarth) in both instances, the number of messages received by S-AIS is noticeable higher when a Class B+ transponder was used. Class B+ transponders have a higher transmission power and transmit message 27s. These messages are transmitted on different channels than other AIS messages, and are less affected by noise from other radio frequencies.





Vessel Data

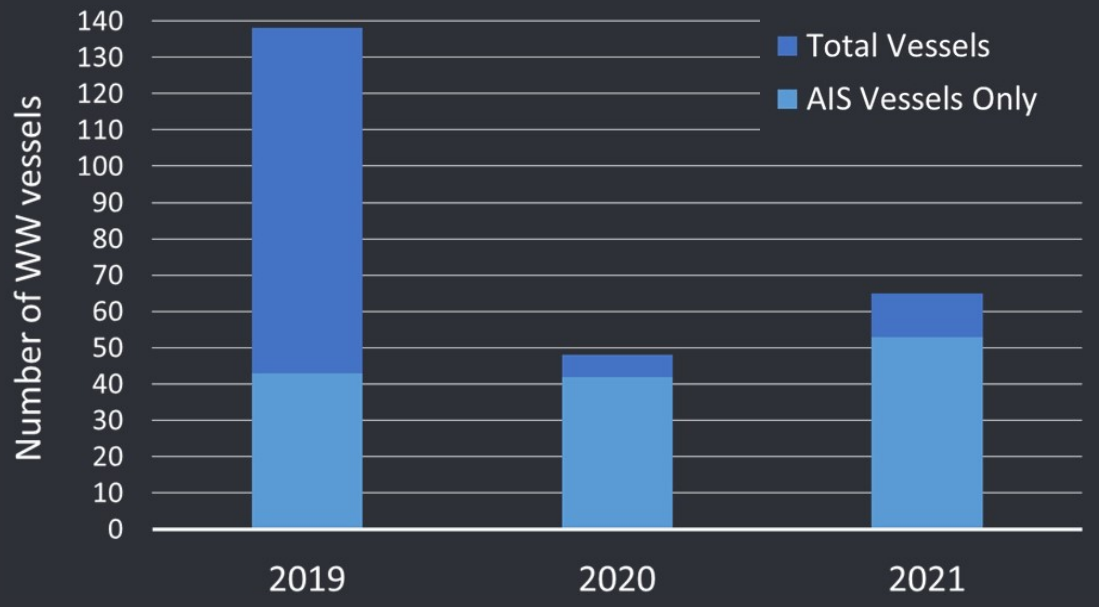
South Salish Sea

Before the COVID-19 pandemic (2019), more than 100 commercial whale watching vessels were actively operating within the southern waters of the Salish Sea. In 2020 and 2021, the number of vessel engaged in whale watching in the Salish Sea was reduced dramatically*.

The number of vessels equipped with AIS transponders and operating in the Salish Sea incrased since 2019; particularly within the Canadian fleet after the introduction of new AIS carriage regulations for passenger vessels.

This information is important to understand how well AIS data represents the commercial whale watching fleet and how this representation varies through time.

Data source: Soundwatch Boater Education Program

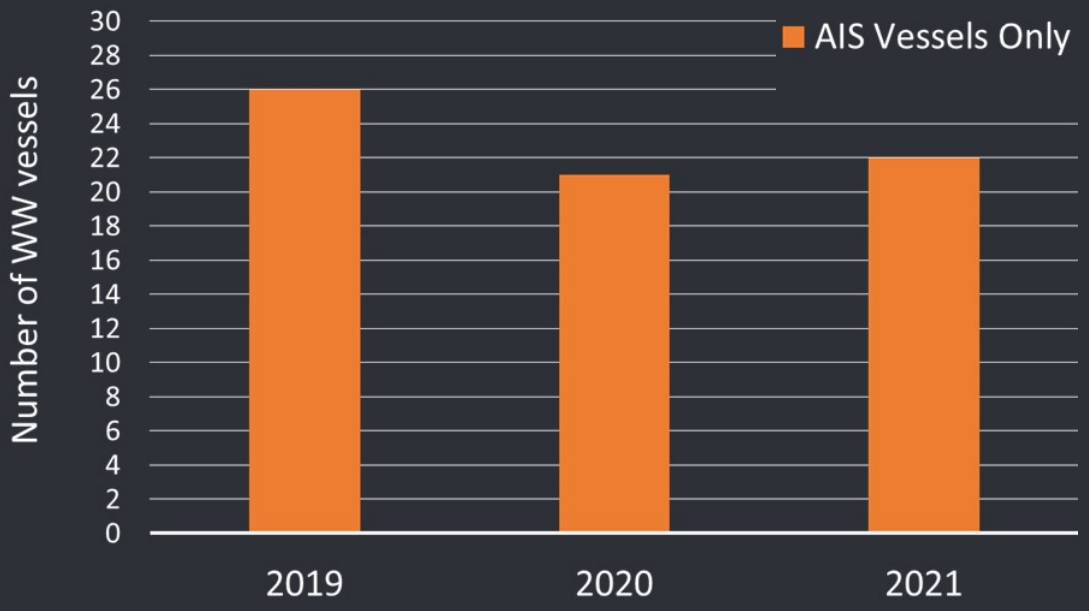


Vessel Data

West Coast Vancouver Island

The number of commercial whale watching vessels equipped with AIS and operating in the west coast of Vancouver Island decreased due to COVID-19 travel restrictions in 2020 and 2021 compared to 2019.

No data is currently available about the number of vessels operating in these waters and not equipped with AIS.



Data Analysis

To conduct our analysis we used CCG terrestrial AIS data provided by Ocean Networks Canada from 2019, 2020 and 2021.

Whale watching trips and potential whale watching events were derived from AIS data based on a set of criteria.

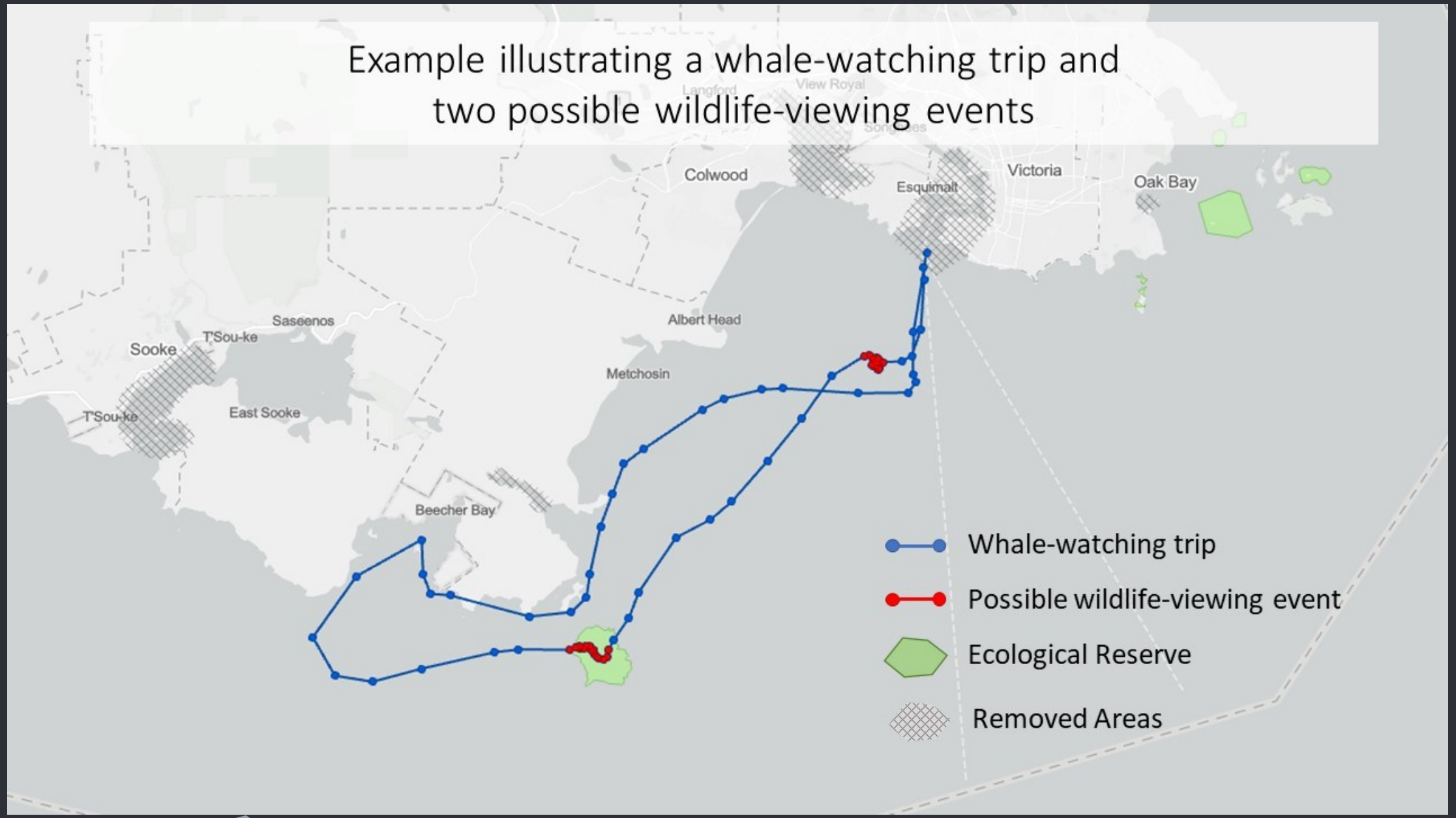
What defines a whale watching trip?

A '*whale watching trip*' is an AIS derived vessel track from known a commercial whale watching vessel, with a start and end point at a home port. Whale watching trips are at least 2 hours long but less than 5.5 hours, and they must have at least one potential wildlife-viewing event.

What defines a potential wildlife-viewing event?

A '*potential wildlife-viewing event*' is a set of AIS points during which known commercial whale watching vessels are likely engaged in wildlife viewing or searching for wildlife. The duration of potential wildlife-viewing events was set between 10 min and 60 min long, and with a maximum speed of 12 knots.

Example illustrating a whale-watching trip and two possible wildlife-viewing events



How were potential wildlife-viewing events identified?

A study was conducted to evaluate the accuracy and utility of existing classification models to detect when commercial whale watching vessels were engaged in observing wildlife using AIS. These models detect vessel behaviour through machine learning, which can automatically classify data patterns that can be used to make decisions under uncertainty.

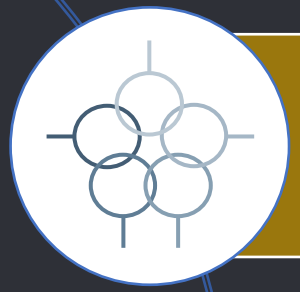
Three classification models were assessed using a dataset of 20 whale watching trips from the same vessel and with known wildlife-viewing events*:

- **Density-Based Spatial Clustering Application with Noise (DBSCAN)**, which partitions spatial data into clusters based on the density of AIS points.
- **Hidden Markov Model (HMM)**, which is a state-based stochastic model that represents a probability distribution for a sequence of AIS points.
- **Logistic Regression (LR)**, which is a discriminative classification algorithm widely used for binary classification problems. It also provides a measurement of how influential each AIS variable is on the LR model.

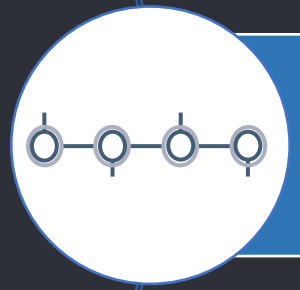
**Data source: Molly Fraser, 2000. Learn more about here work here .*

How were potential wildlife-viewing events identified?

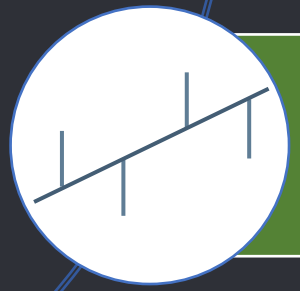
Classification Models



Density Based Spatial Clustering Application with Noise



Hidden Markov Model



Logistic Regression

Variable Selection

Vessel Location

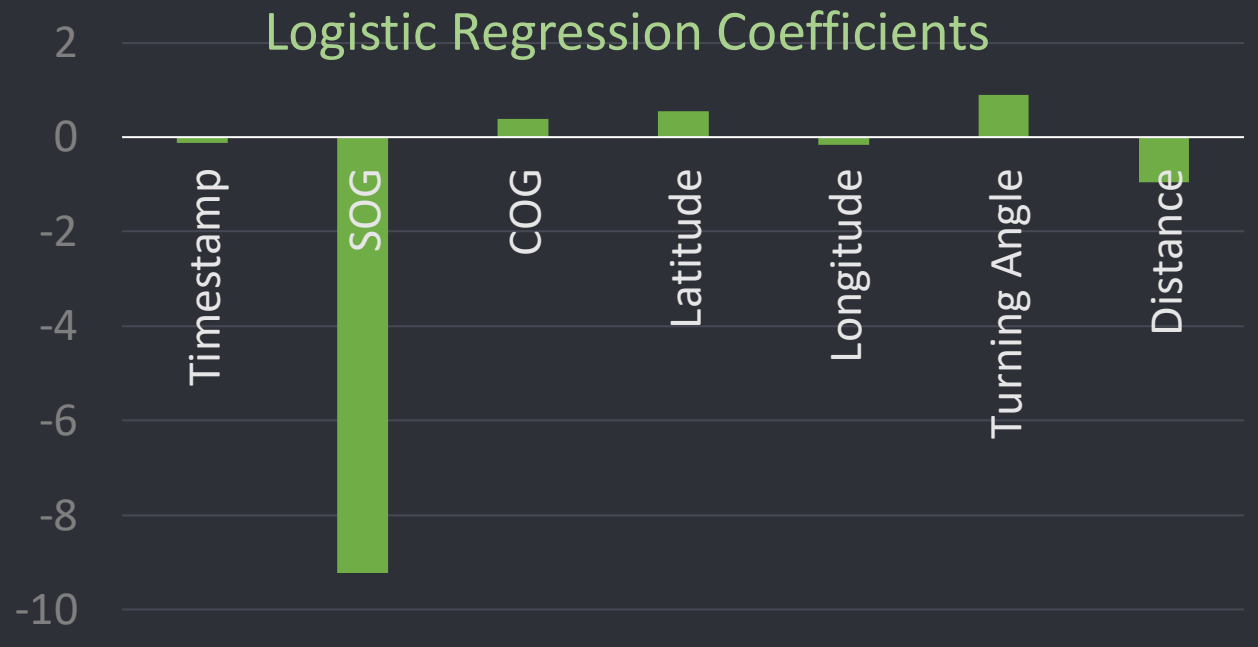
Speed Over Ground

Timestamp, Speed Over Ground, Course Over Ground, Latitude, Longitude, Turning Angle, Distance

Model Selection

Statistical measures representing model performance supported the use of the HMM for detecting potential wildlife-viewing events.

The LR coefficients found the *speed over ground* (SOG) AIS variable to be the most influential, supporting its use for the HMM probability distributions.



	DBSCAN	HMM	LR
Overall Accuracy	0.85	0.89	0.89
F-Score	0.82	0.87	0.86
ROC AUC Score	0.86	0.91	0.90
Kappa Coefficient	0.69	0.78	0.77

How was the Hidden Markov Model applied to the whole fleet?

Machine learning can be:

- **Supervised**, which uses prior knowledge on whale watching vessel movements and when they were observing wildlife, or
- **Unsupervised**, which finds patters within the AIS data without prior knowledge.

Without a sufficient amount of information on *when* and *where* whale watching vessels were engaged in wildlife-viewing for the entire fleet, it was important to determine if the unsupervised HMM would perform as well as a supervised HMM.

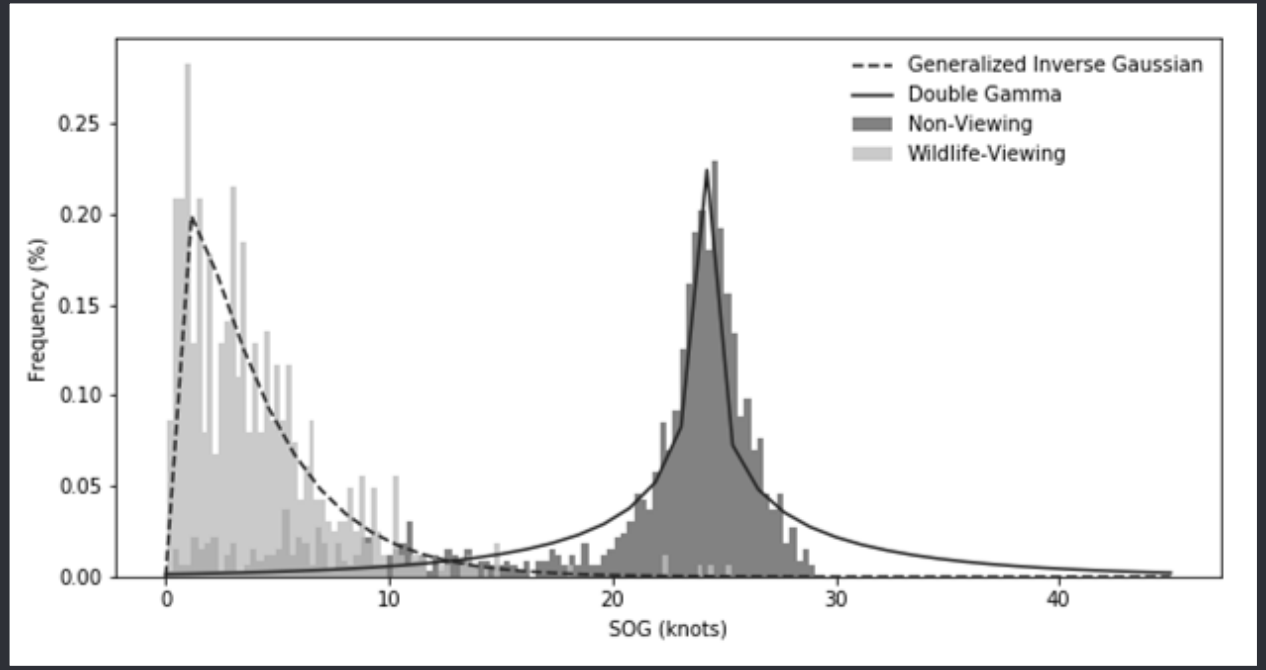
Statistical tests proved that **t**he unsupervised HMM performed sufficiently well when compared with the supervised HMM, and hence it was used to automatically detect potential wildlife-viewing events for the whole fleet over multiple years.

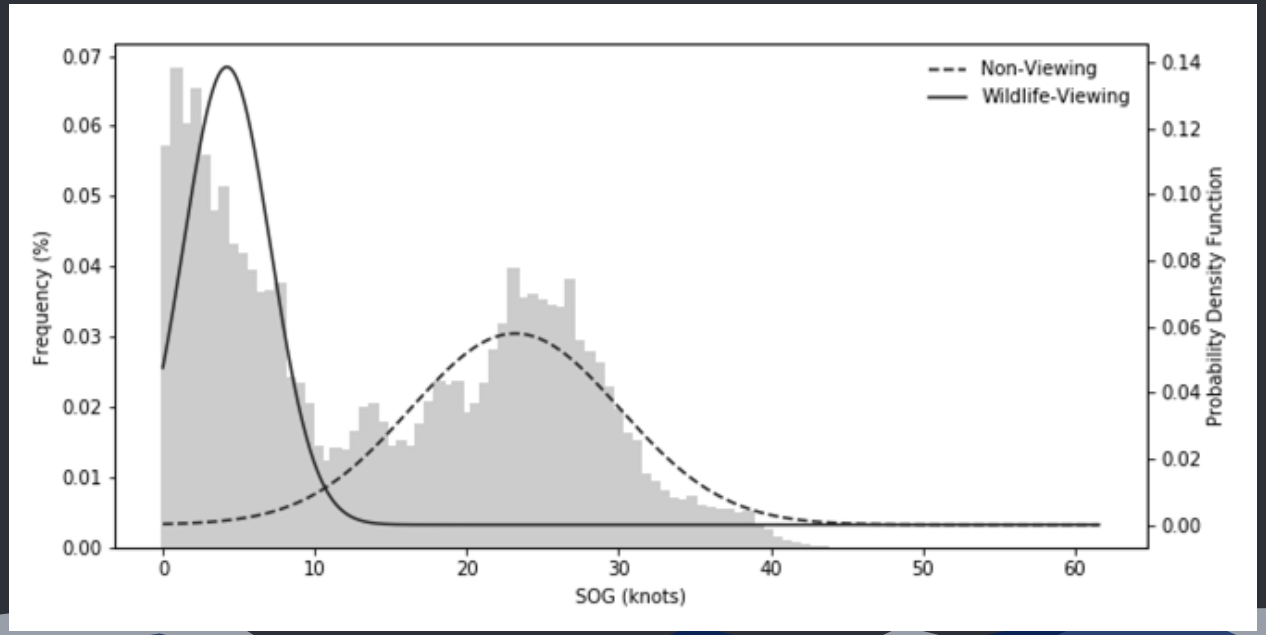
Learn more about Andrea Nesdoly's work here .

Hidden Markov Model Approaches

Supervised

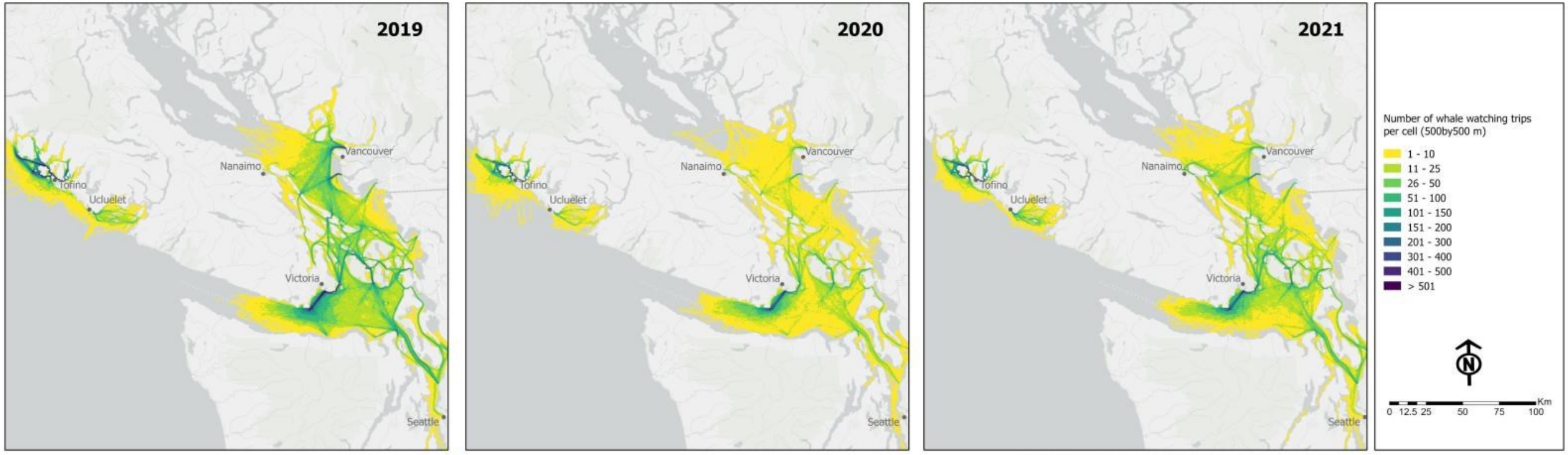
Unsupervised





Results – Spatial Trends

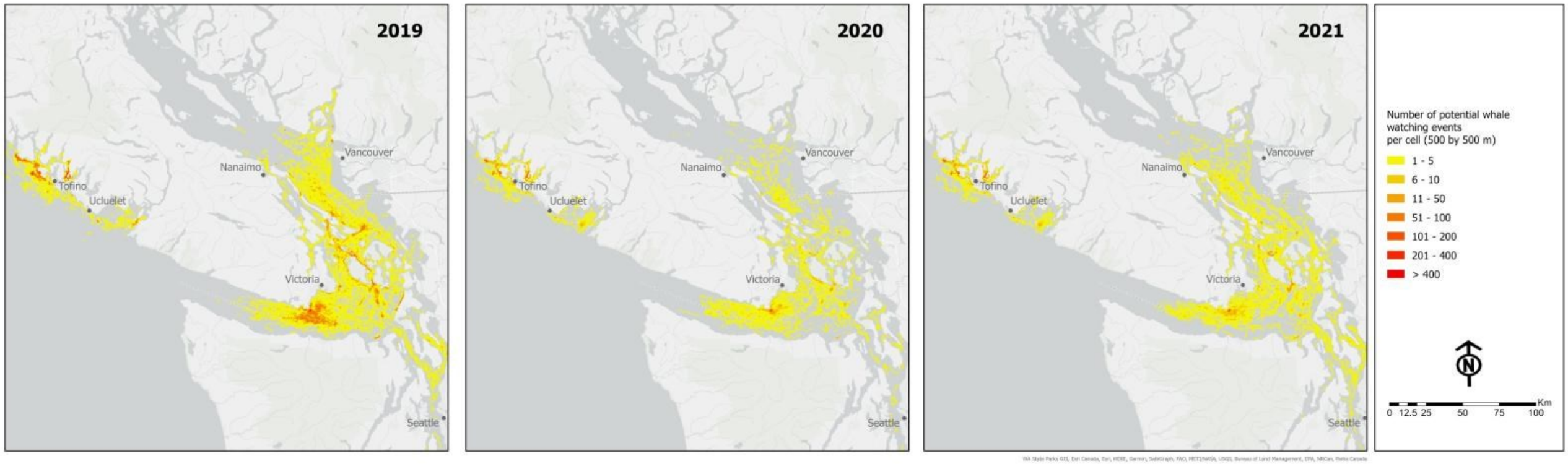
Density of whale watching trips per year (2019 to 2021) for vessels transmitting AIS and operating in the southern waters of the Salish Sea and west coast of Vancouver Island. The number of commercial whale watching trips decreased from 2019 to 2020, followed by a slight recovery in 2021.



Results – Spatial Trends

Distribution of potential wildlife-viewing events per year (2019 to 2021) for vessels operating in the southern waters of the Salish Sea and west coast of Vancouver Island.

There is a noticeable reduction in the number of potential wildlife viewing events in 2020 and 2021 compared to 2019. Hotspots of wildlife-viewing events are present throughout the area, and some present every year.



Applications

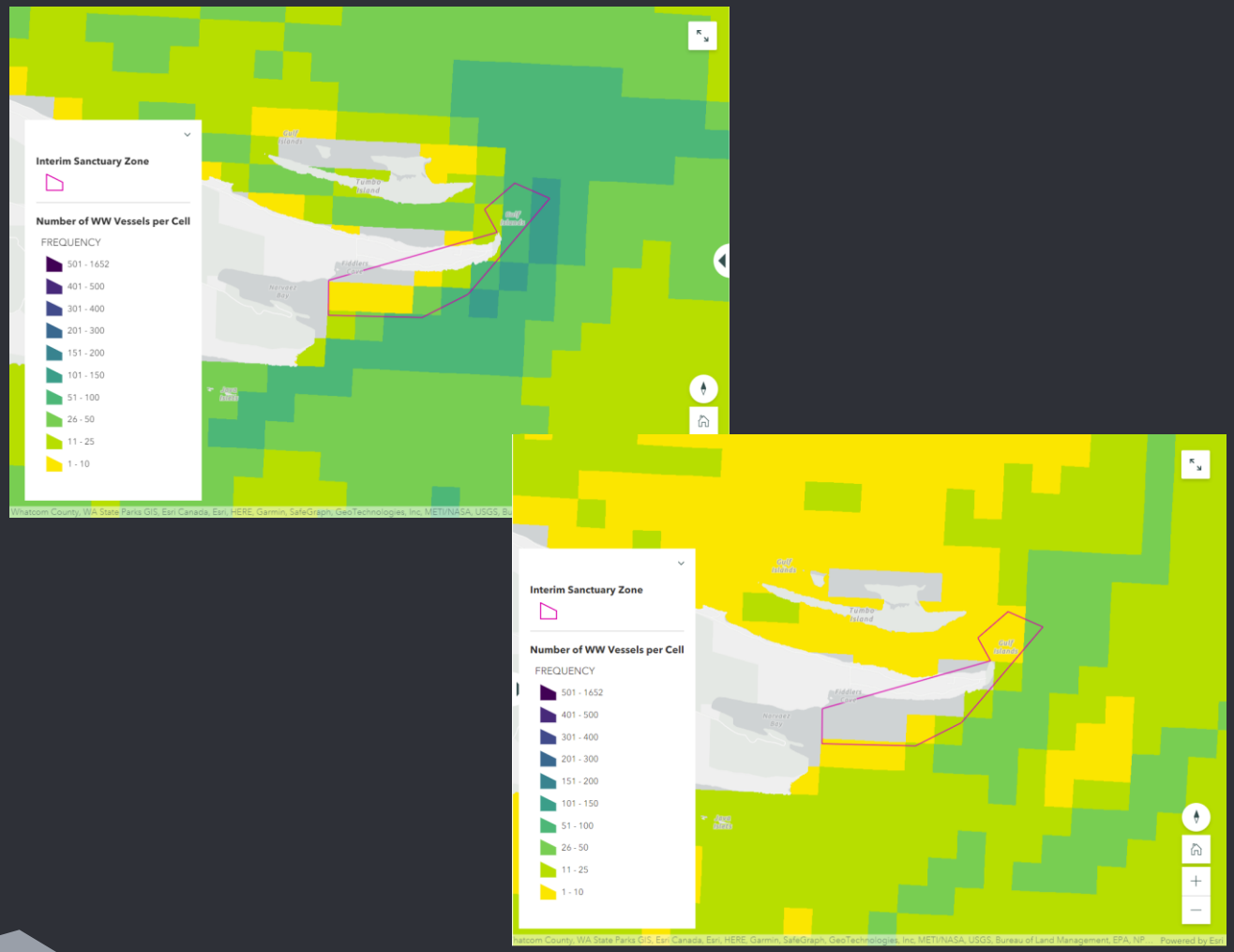
Analyzed AIS data from commercial whale watching vessels can be used in several applications. Here we present a few examples:

1. Monitoring Compliance
2. Assessing tourism pressures to sensitive or protected areas and how they change over time.
3. Insights into wildlife distributions and trends

1. Monitoring Compliance

AIS data can be used to assess the compliance of conservation measures, such as the implementation of no-go zones where vessel traffic is not permitted.

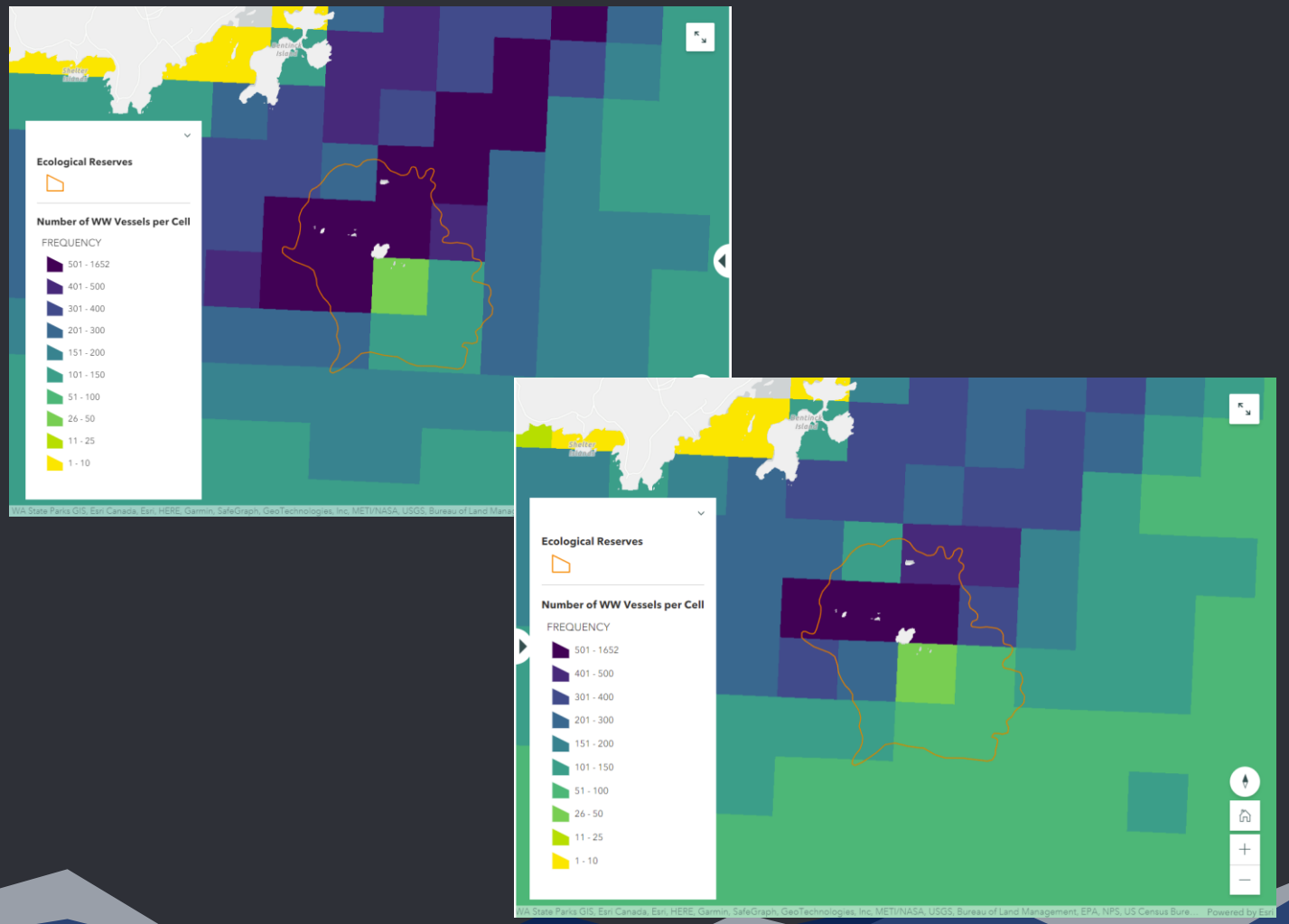
Here we show a decrease in the presence of vessels inside Saturna's Island Interim Sanctuary Zone (ISZ) between 2019 (top map), when ISZs were first introduced, and 2021 (bottom map).



2. Assessing tourism pressures to sensitive or protected areas and how they change over time.

Race Rocks Ecological Reserve is the most visited area by commercial whale watching operators in the Salish Sea. The rocks and surrounding waters have a unique richness and diversity of marine life, including sea lions, seals, elephant seals, sea birds, killer whales and humpback whales.

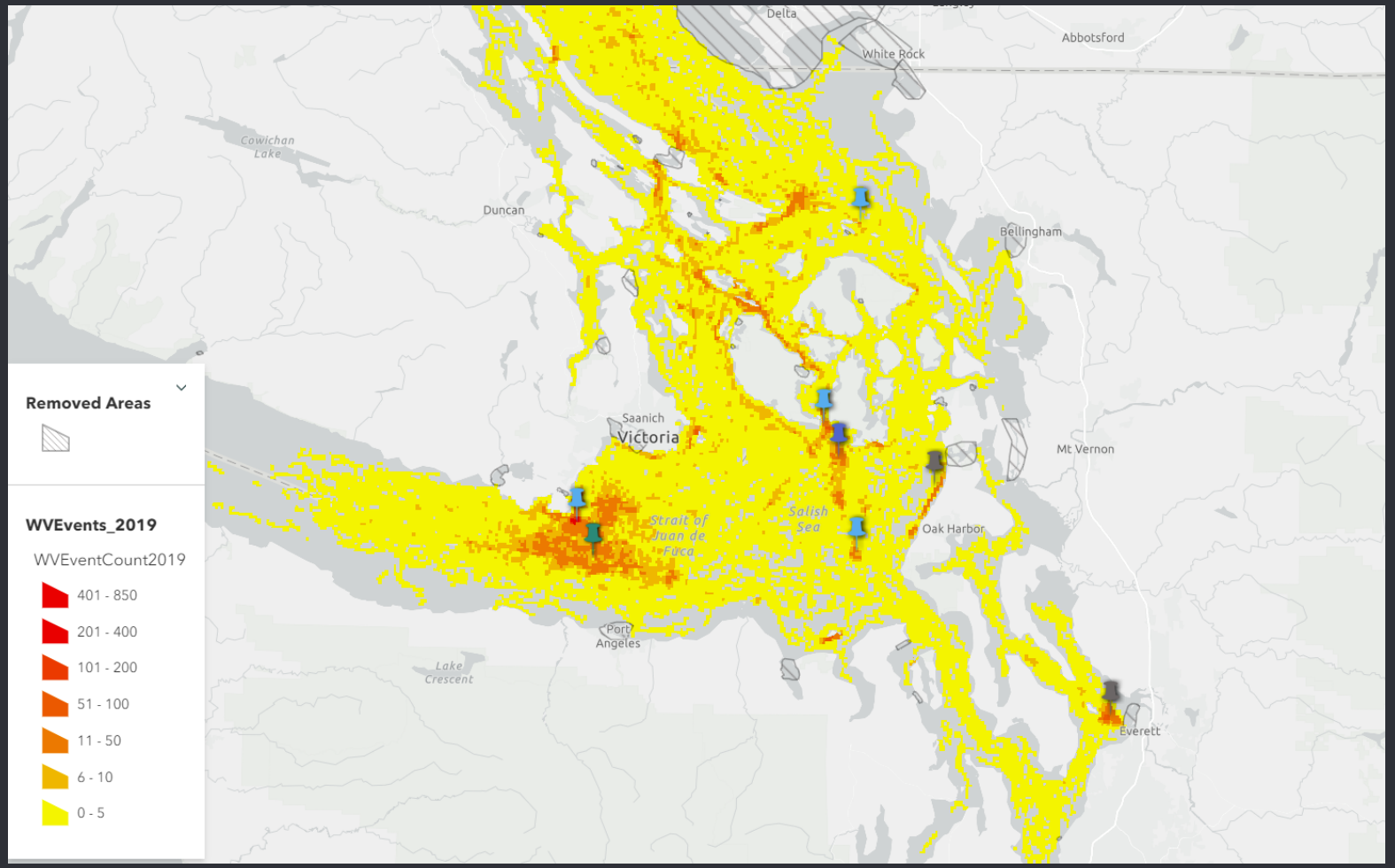
In 2019 (top map), this area received more than 1,000 visits by commercial whale watching vessels (carrying AIS). Due to the COVID-19 pandemic, the number of visits decreased in 2020 and 2021 (bottom map) to about 700 visits a year.



3. Insights into wildlife distributions and trends

Wildlife-viewing events in conjunction with knowledge from naturalists onboard whale watching vessels can provide insights into wildlife distributions and trends.

- Sea Lion Sightings
- Minke Whales Sightings
- Grey Whales Sightings
- Humpback Whales Sightings



Summary


Good understanding of the different types of AIS transponders (Class A vs B vs B+), AIS data providers (T-AIS vs. S-AIS), and their pros and cons, is key when analyzing and interpreting AIS data
Machine learning and data mining are fundamental tools for maximizing the potential of AIS data.
Spatial data on commercial whale watching activities can inform many applications. E.g., assessment of conservation measures, assessment of stressors by vessel activity, marine spatial planning, fleet management, vessel risk assessment, ...
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MEOPAR

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Participating whale watching operators:

The Whale Centre

Remote Passages Marine Excursions

Whales ~ Bears ~ Hot Springs ~ Kayaking

Ocean Outfitters

Whale & Wildlife Watching Eagle Wing Tours

Jamie's Whaling Station & Adventure Centres

ocean ecoventures

Subtidal Adventures