Economic Assessment of Risks in Maritime Navigation across the Greater Caribbean Region (GCR)

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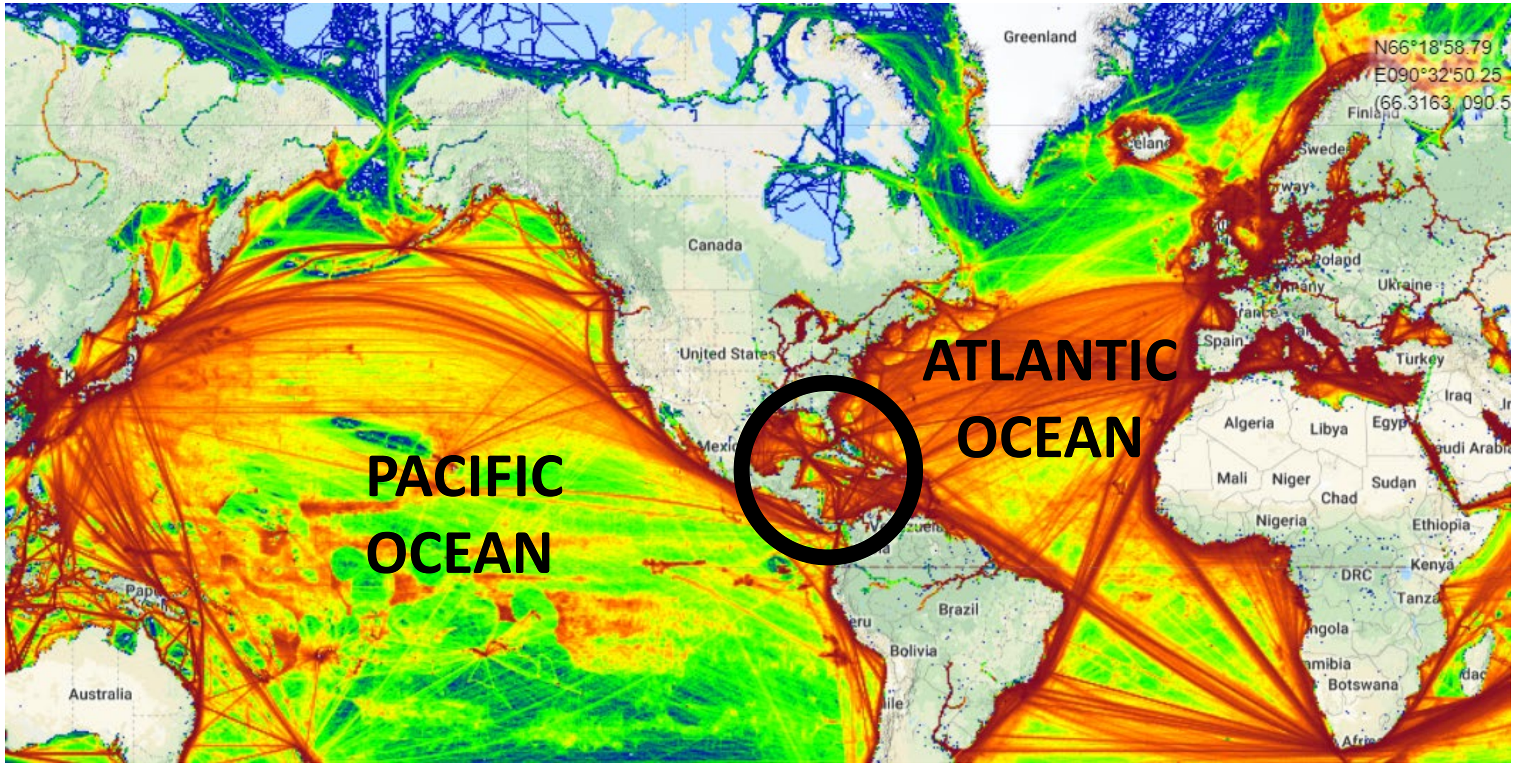
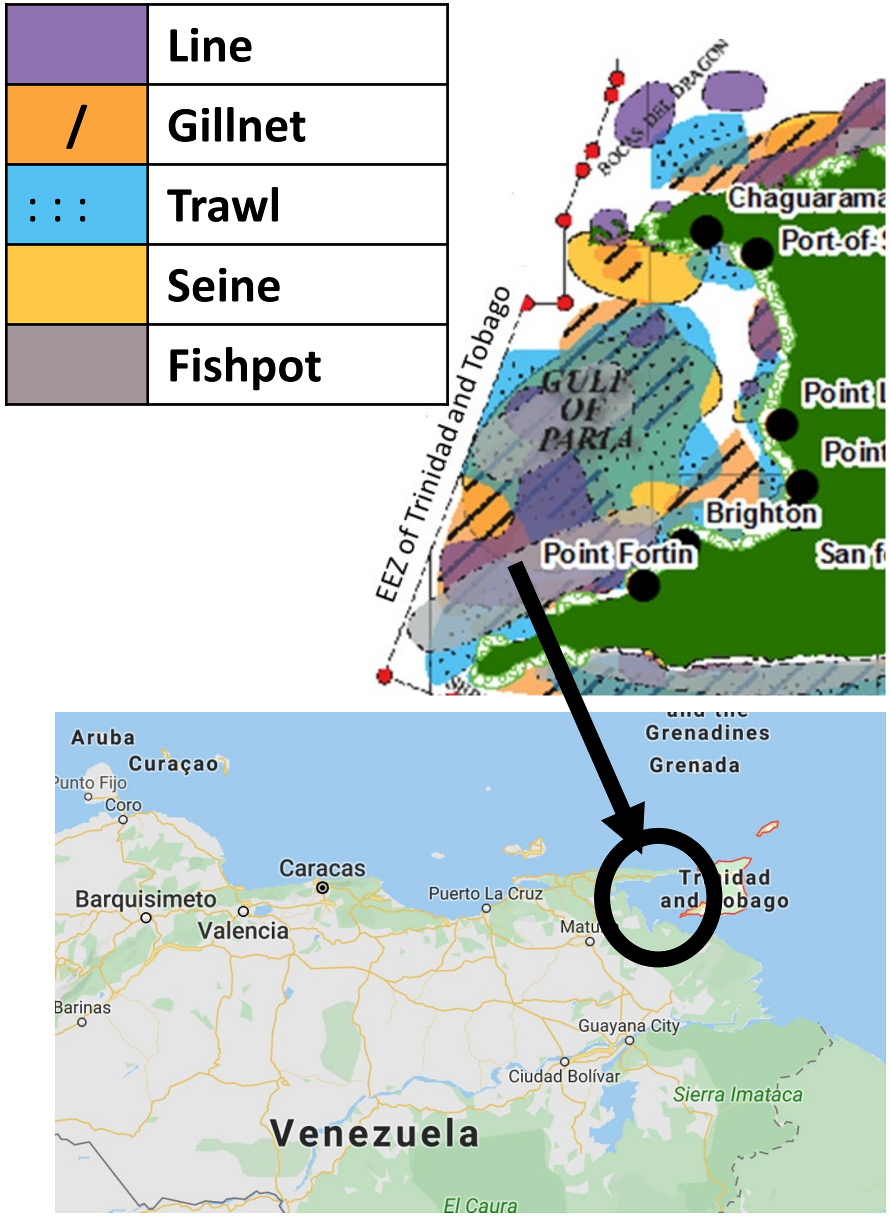


Introduction to this Study

- Maritime navigation is important to the Greater Caribbean Region (GCR) because it facilitates economic expansion.
- However, the environment, economy and culture of the region are at risk of unwanted events which can have short- or long-term consequences.
- This study therefore involves an economic assessment of risk in maritime navigation across the GCR.



Structure of the Presentation

1. Introduction
2. Significance
3. Strategies tested
4. Preliminary results
5. Method being formulated
6. Ongoing research

History of Maritime Accidents across the GCR

Ninety-three accidents were reported across the GCR over the last 18 years including:

i. 9 foundered
ii. 11 collisions
iii. 11 capsized
iv. 14 groundings

The World's largest ship-based oil spill took place within Trinidad & Tobago's EEZ, 1979.

Significance of the Study

The results will contribute to the monitoring and management of maritime navigation by supporting the:

i. Prioritization of resources

ii. Reduction of risk

iii. Improved security of the marine environment

iv. Expansion of international trade opportunities

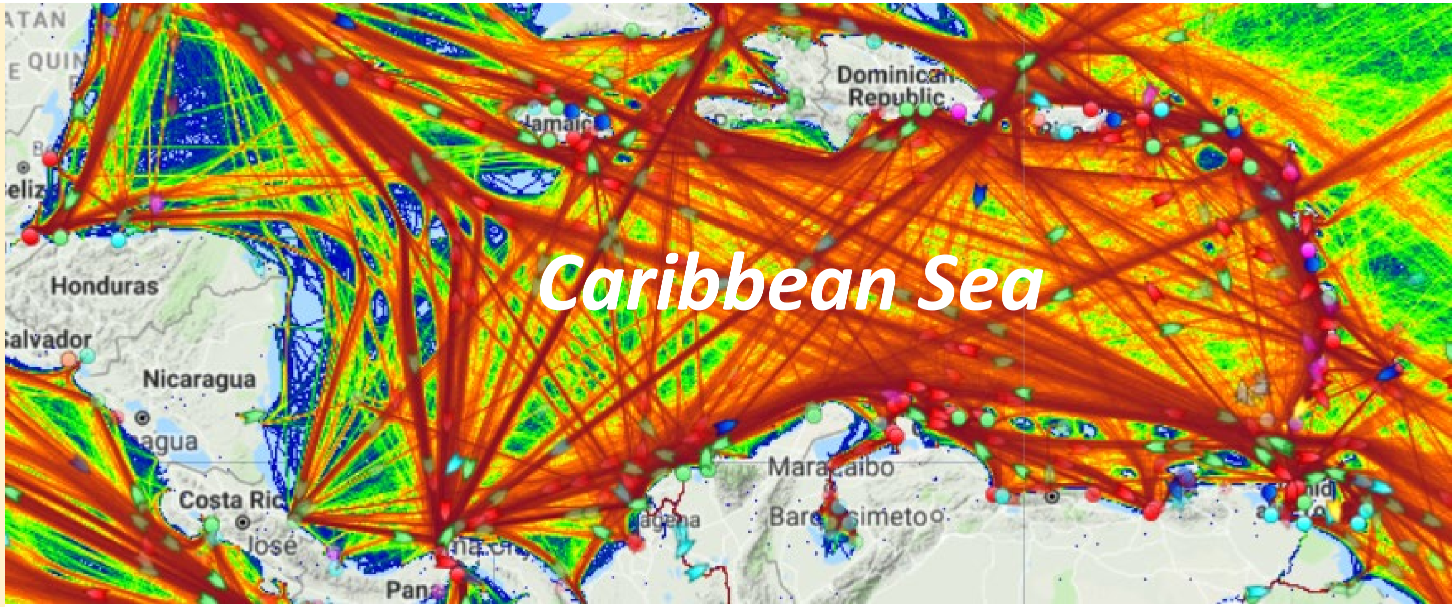
Aim and Objectives

Aim:

To conduct an economic assessment of risks in maritime navigation across the Greater Caribbean Region (GCR)

Objectives:

1. Formulate a risk assessment strategy
2. Generate an economic model to estimate losses associated with maritime accidents



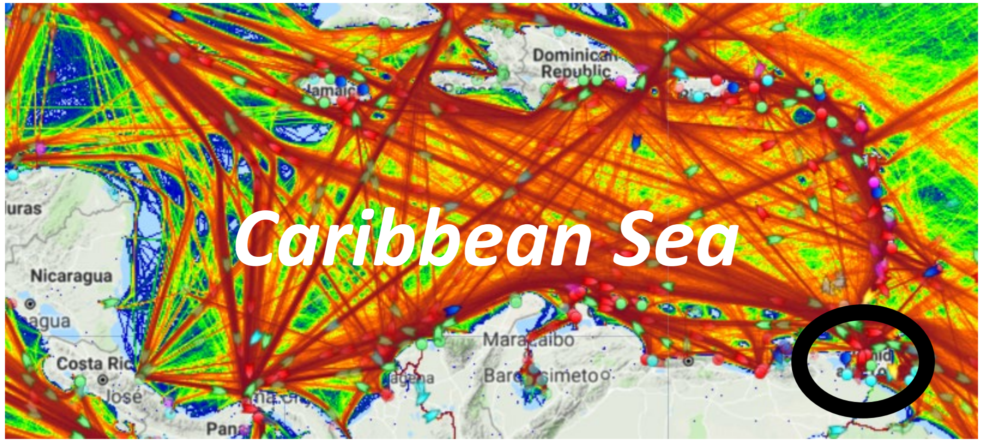
Source: Marine Traffic

Commonly Used Strategies for Conducting Risk Assessments

Strategies for risk assessment were developed by maritime departments including:

1. **IALA Waterway Risk Assessment Programme (IWRAP)**
2. **Land Information New Zealand (LINZ)**
3. Canadian Hydrographic Service
4. Arctic Region Hydrographic Commission
5. National Oceanic and Atmospheric Administration

IALA considers traffic flow while the others used traffic density.



Source: Marine Traffic

Economic Characteristics of the Gulf of Paria

The Gulf of Paria to the west of Trinidad is of economic, cultural and environmental importance because:

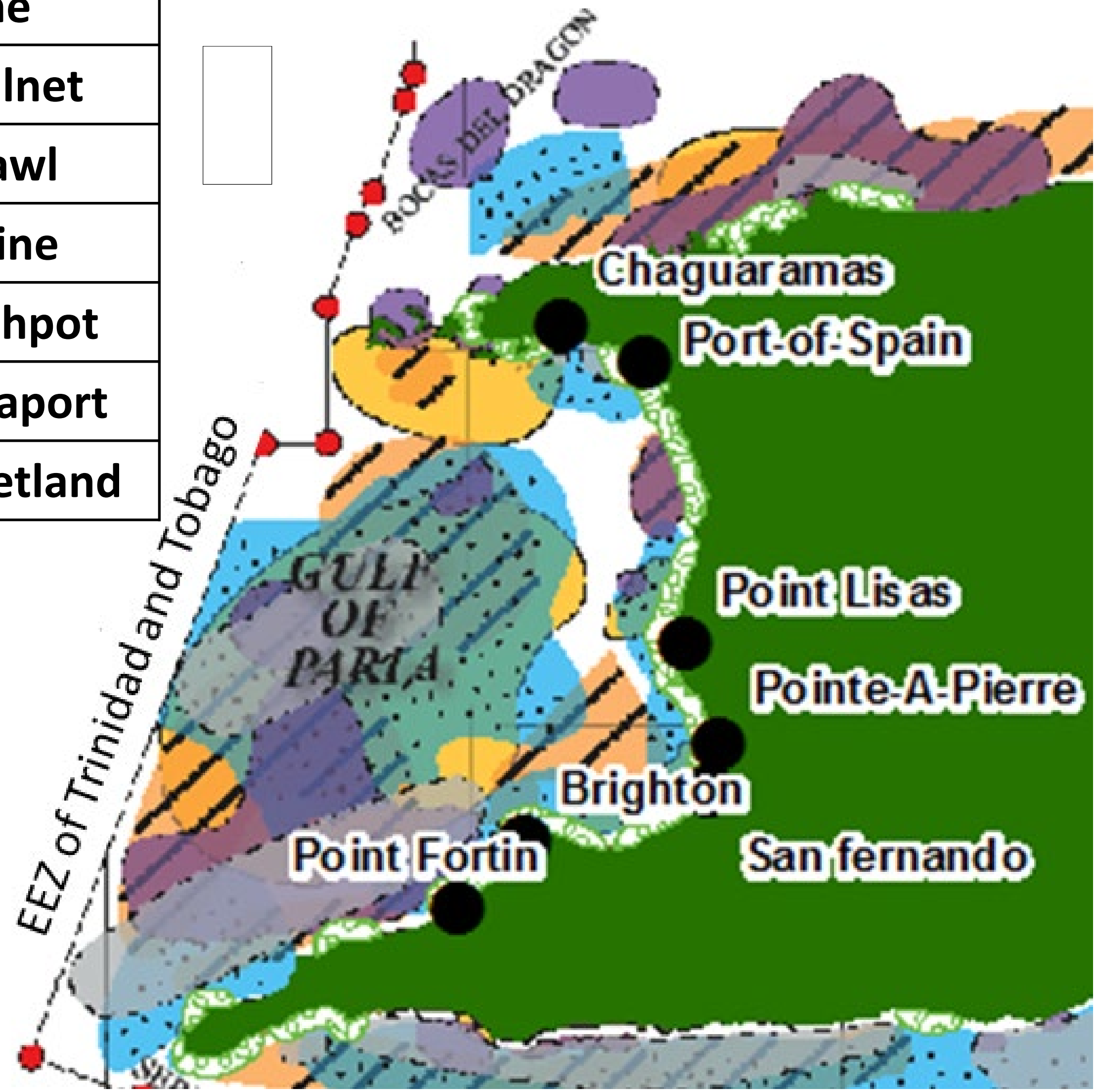
i. Trade - seven seaports

ii. Resources - marine tourism

iii. Fishing - 8 fish landing sites

iv. Wetlands - Caroni Swamp protected under the Ramsar Convention

	Line
/	Gillnet
: : :	Trawl
	Seine
	Fishpot
●	Seaport
	Wetland

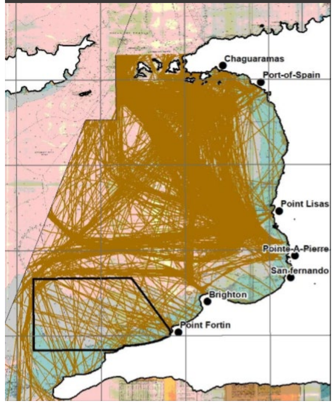


Description of Vessel Traffic across the Gulf of Paria

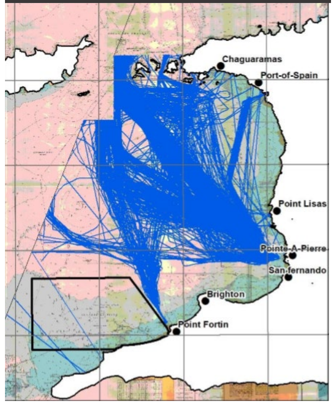
Vessel Type	Number of Transits over six months
Cargo	3,367
Tanker	2,690
High Speed Craft	2,033
Passenger	1,268
Restricted Maneuverability	610
Recreational	207

AIS is a requirement for vessels over a particular size

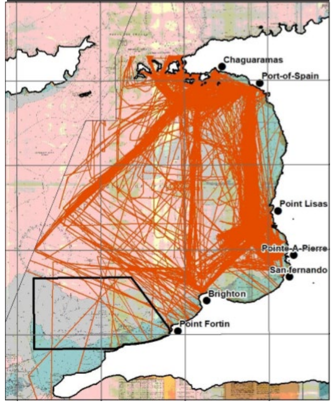
Transit of Cargo Vessels



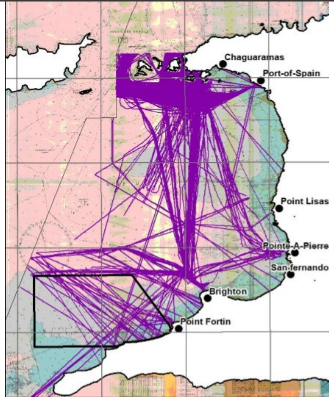
Transit of Tanker Vessels



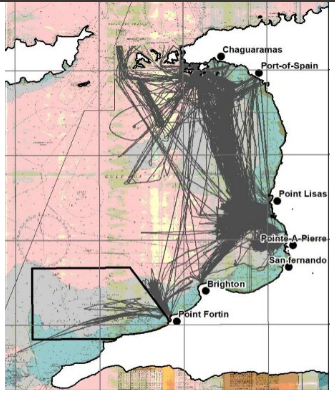
Transit of High Speed Crafts



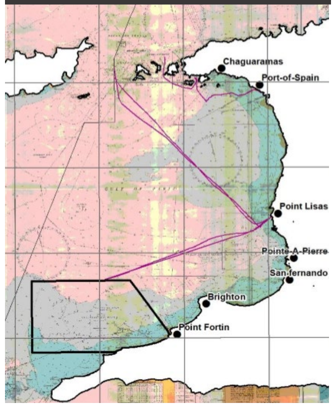
Transit of Passenger Vessels



Transit of Vessels with Restricted Maneuverability



Transit of Recreational Vessels



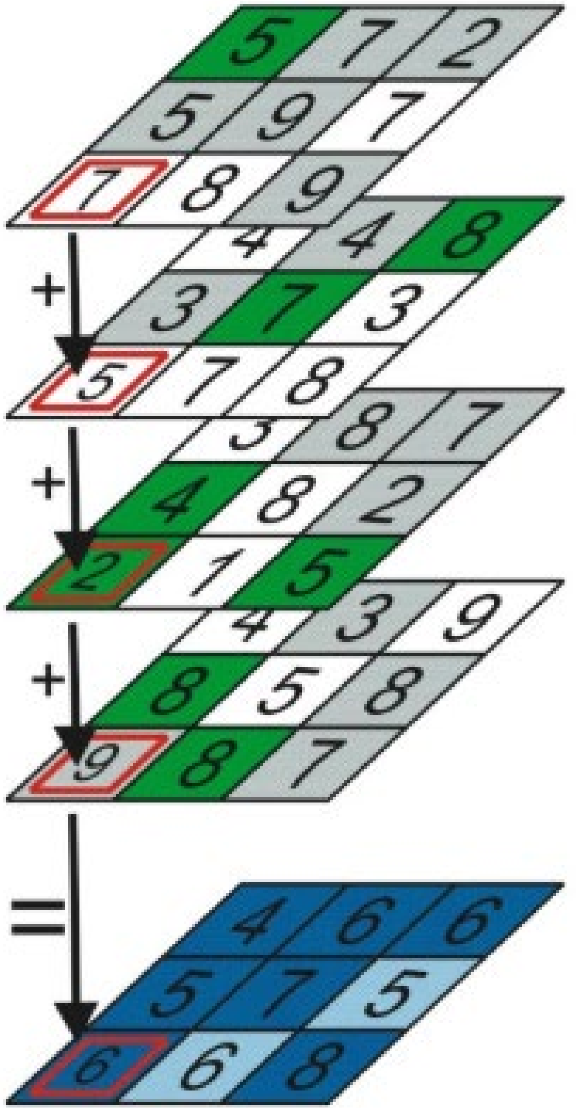
There are a lot of fishing vessels however they do not use AIS so as to maintain the privacy of their fishing locations

General Outline of the Hydrographic Risk Assessment Strategy developed by Land Information New Zealand (LINZ)

1. Applies **data** from satellite or terrestrial automatic identification systems.

2. Applies a **weighted modelling** approach – The scores are acquired from expert judgement.

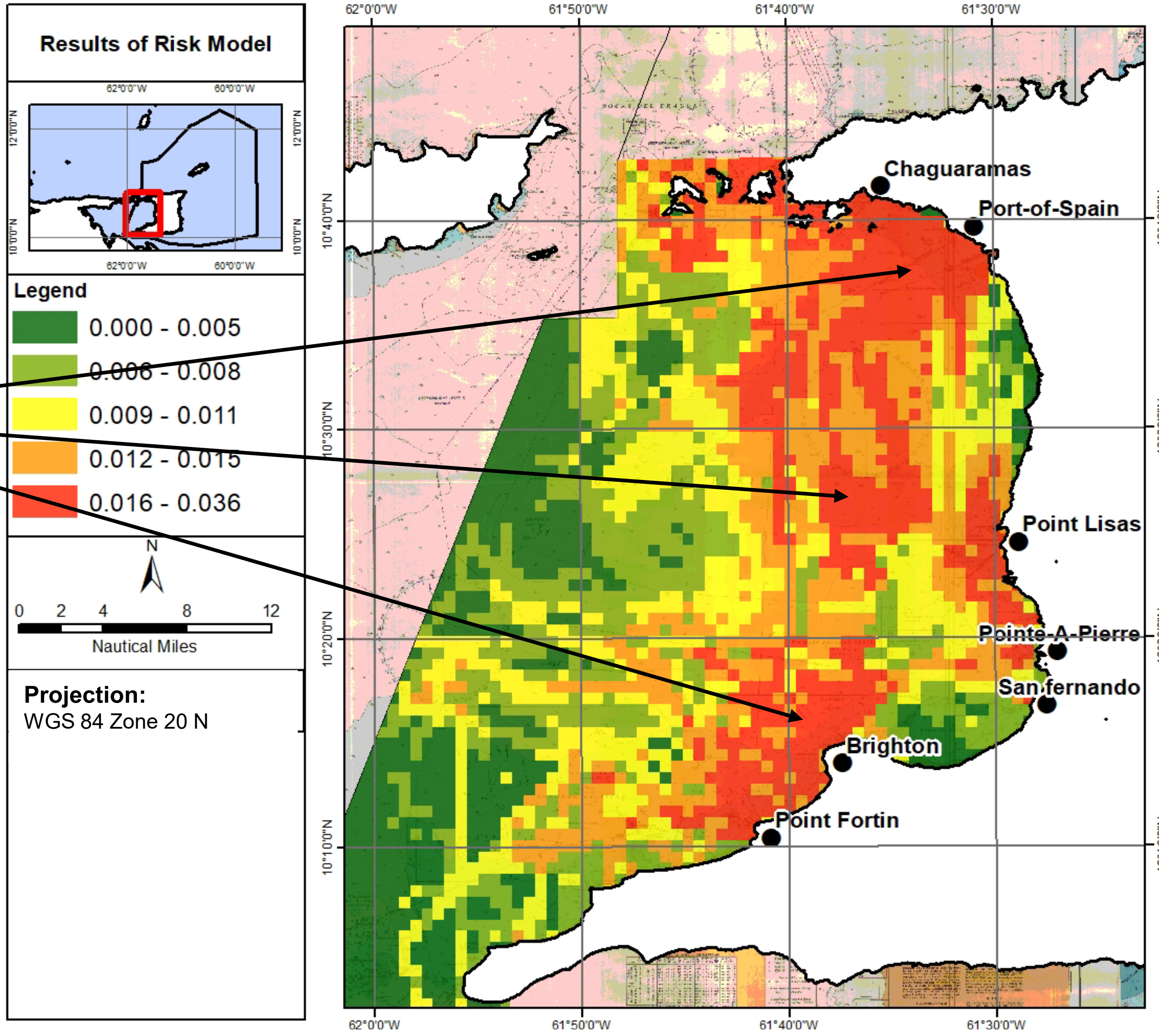
3. Represents the relative level of risk on a **heatmap**.



Results of the Hydrographic Risk Assessment developed by Land Information New Zealand

There is risk in maritime navigation across the GOP.

Levels of Risk in Maritime Navigation	
	Catastrophic
	High
	Moderate
	Low
	Insignificant



Under the LINZ strategy, no units are associated with the risk value.

General Outline of the Strategy Developed by the IALA Waterway Risk Assessment Programme (IWRAP)

IWRAP calculates the probability of grounding, allision or collision based on:

1. The average number of potential accidents (near misses), assuming that no evasive action is taken (blind navigation).

2. Then adjusts this number by multiplying it with the **probability that an evasive action fails.**

Probability an evasive action fails

Condition	Causation Factor
Head on collision	0.5×10^{-4}
Overtaking collision	1.1×10^{-4}
Crossing collision	1.3×10^{-4}
Collisions in bend	1.3×10^{-4}
Collisions in merging	1.3×10^{-4}
Grounding – forgot to turn	1.6×10^{-4}

Results of the Strategy Developed by the IALA Waterway Risk Assessment Programme (IWRAP)

- The approach channels to Port of Spain and Point Lisas are at risk in maritime navigation

- There is pilotage in these areas

Collisions are expected to occur every 149 years

Economic Assessment of Risks in Maritime Navigation across the GCR

3 Criteria are assessed:

i. **Traffic -** historical AIS data are statistically analyzed to simulate the potential increase in ship traffic
   - probability of collisions and groundings based on: ship type, age and flag

ii. **Hazards** – factors which can contribute to collisions and groundings

iii. **Consequence** – resources which can be affected by collisions and groundings

These criteria are combined using a weighting strategy. There are multiple levels of weighting, at the highest level:

Traffic – 25%

Hazards – 25%

Consequences – 50%

Factors in the hazard and consequence criteria are weighted as part of their own category.

Risk = likelihood x consequences

= (traffic x hazards) x (consequence)

Likelihood (traffic and hazards) are measured as accidents per year

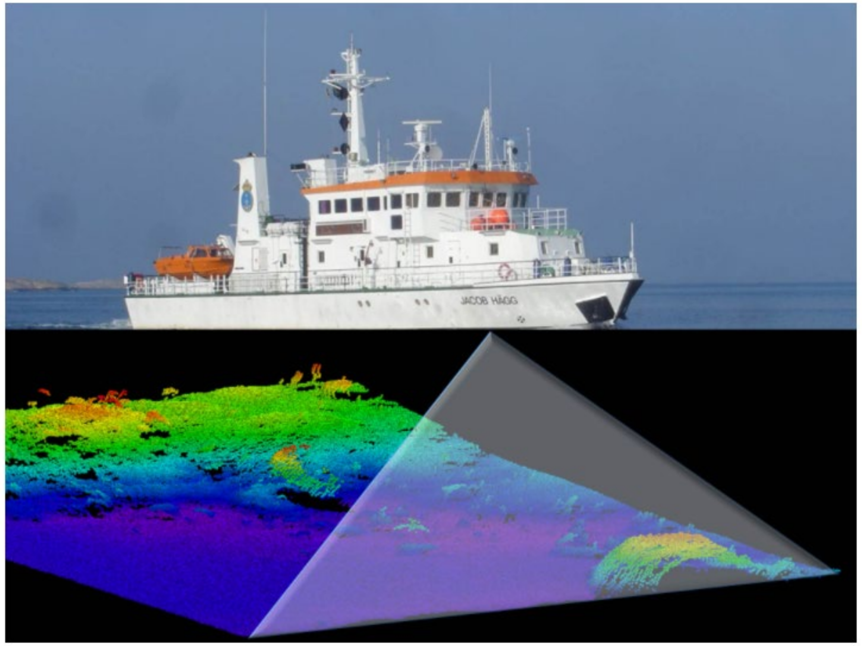
Consequence is measured as the value of resources/benefit of averting and accident per year

Risk is measured as cost of accidents per year

Economic Assessment of Risks in Maritime Navigation across the GCR

- The final risk value indicates the annual probability of collisions and groundings and the annual benefit of averting the accident.

- This value is well suited to recommend risk control options, for example the prioritization to hydrographic surveys.

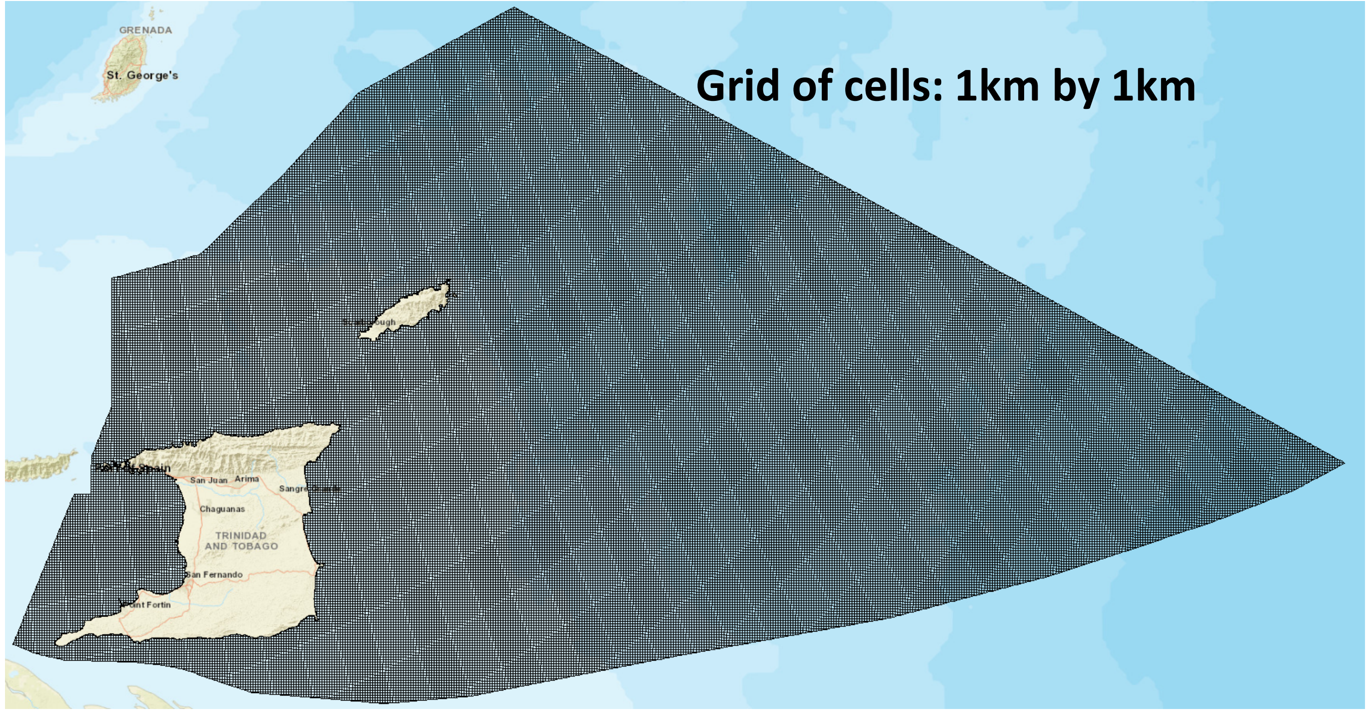


Development of the traffic criteria

- Errors in satellite AIS data are corrected using public databases.
- The study area was divided into a grid of cells of 1km by 1km to be used as a common framework to calculate and map the final risk to maritime navigation.

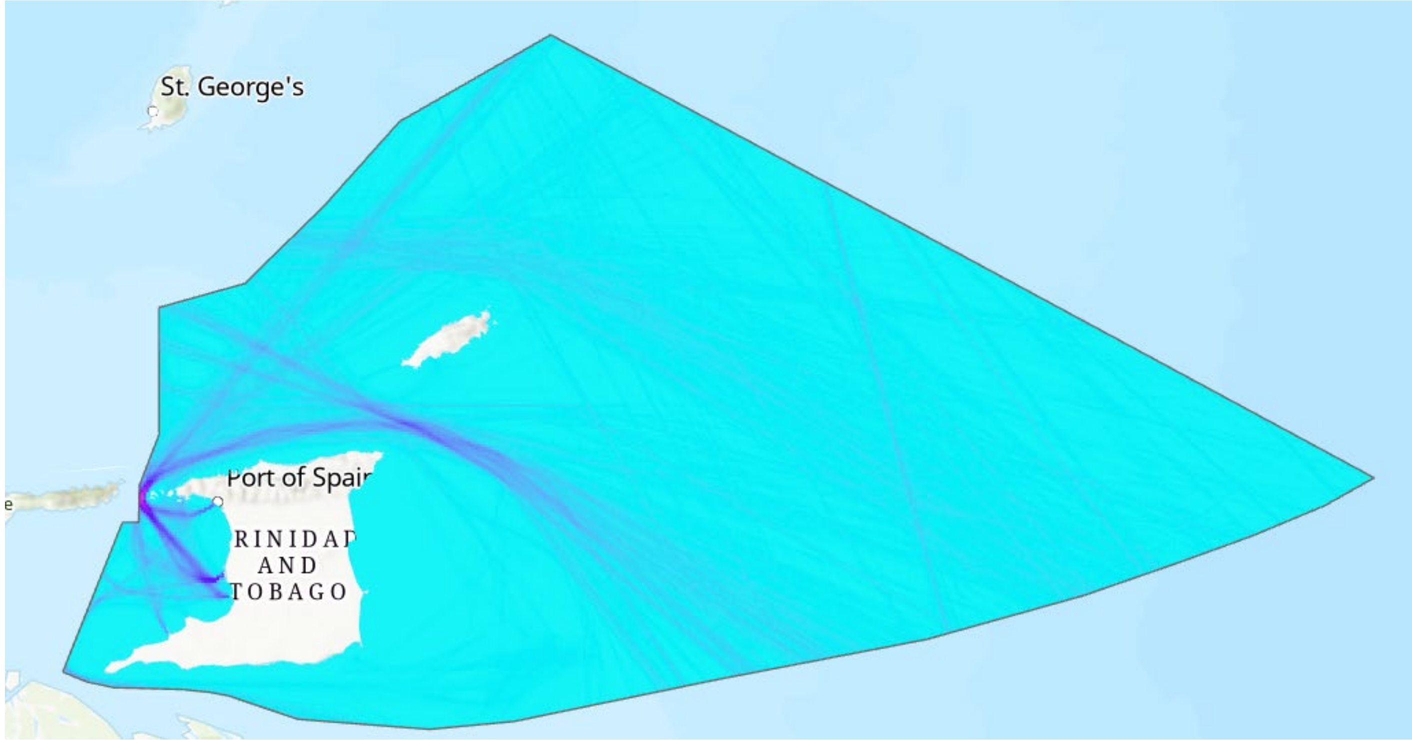
The year this ship was built was not provided in the AIS dataset

KASTELLI WAVE	209723000	2011
UBC MONTEGO BAY	209747000	0
UBC MONTEGO BAY	209747000	0
UBC MONTEGO BAY	209747000	0
UBC MONTEGO BAY	209747000	0
ORCHID	209759000	0
VENUS HORIZON	209786000	2012
WARNOW WHALE	209862000	2007
WARNOW WHALE	209862000	2007

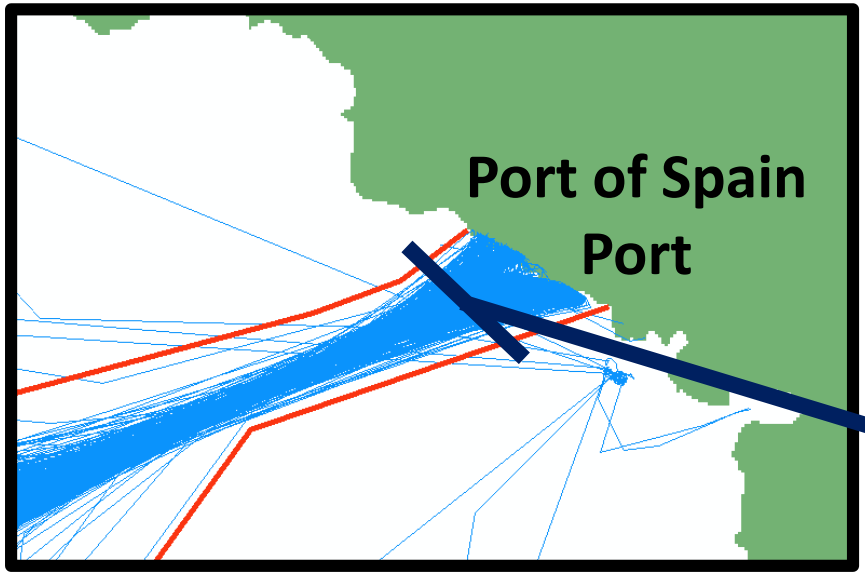


Development of the traffic criteria

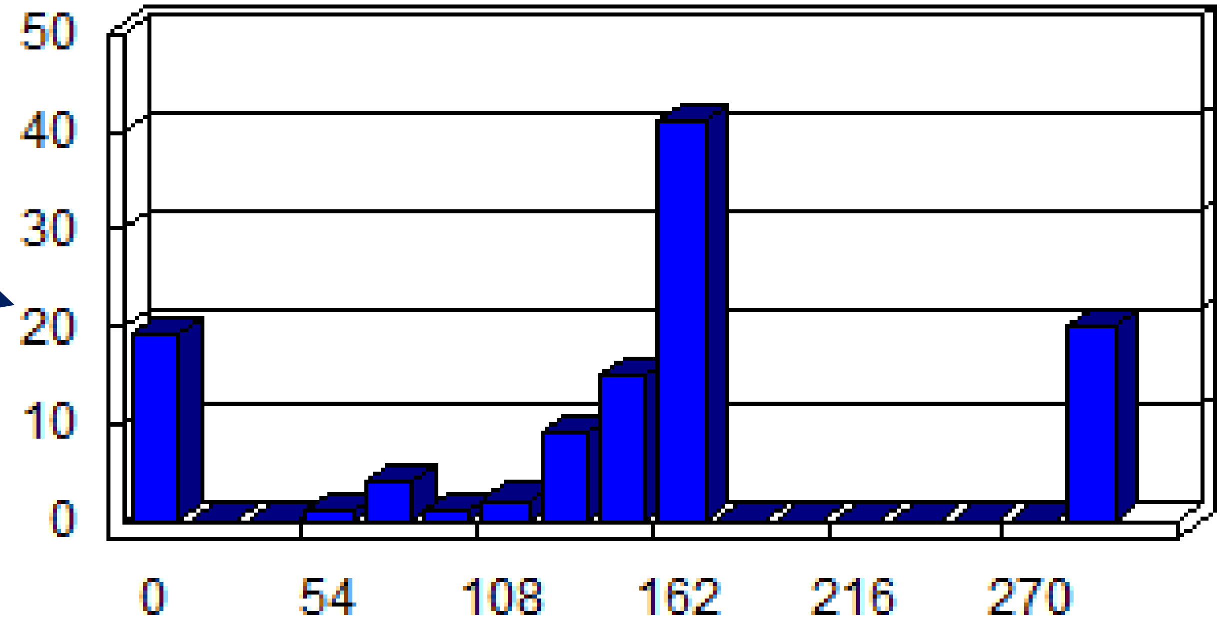
- Main shipping routes are identified.
- The following are statistically analyzed for each route:
    1. Location and frequency of vessel arrivals and departures
    2. Ships' attributes along each route



Example: statistical analysis of attributes of vessels entering the port at Port-of-Spain
(Using a Sample of 1,000 Randomly Selected Traffic Events, from the year 2016)



Frequency Distribution of the Length of Vessels visiting the Port of Spain Port



Vessel Type	Frequency
Cargo	84
Tanker	12
Research	1
Passenger	15

Count: 112 different vessels
Mean length: 151m
Standard Deviation: 89

Development of the traffic criteria

Spatiotemporal simulation of various scenarios of vessel transits with ship domains, are done along each route.

```
#------------------------------------CREATE TIMESTAMPS------------------------------------

#Randomly generate the number of timestamps based on the number of points generated from the lines

N = numberTrafficEvents # Number of randomly selected traffic events
T = 24.0   # Epoch
lmbda = N/T/60/60 # Frequency of transit per second
lmbda
x = np.arange (count)
y = -np.log(1.0 - np.random.random_sample(len(x))) / lmbda #randomly generate timestamps
x_out = x + 1
outputArray = np.column_stack([x_out,y])
np.savetxt("outputArray5.csv", outputArray, delimiter=",") # export as a .csv file in the visual studio folder.

#np.set_printoptions(threshold=np.nan) #print timestamps in the terminal, without ellipses
#y[:1083511] #number of timestamps - this will print the timestamps in visual studio termminal window with ellips
```

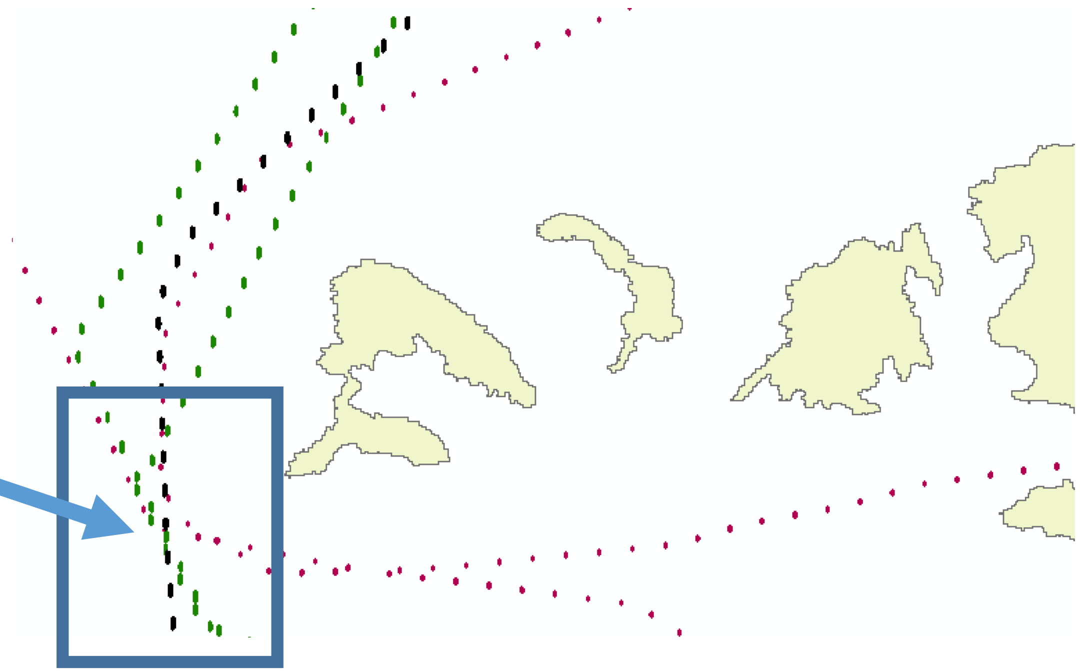
Development of the traffic criteria

Simulation of three cargo vessels leaving Port of Spain.

Ship domains are simulated based on the dimension of the vessels.

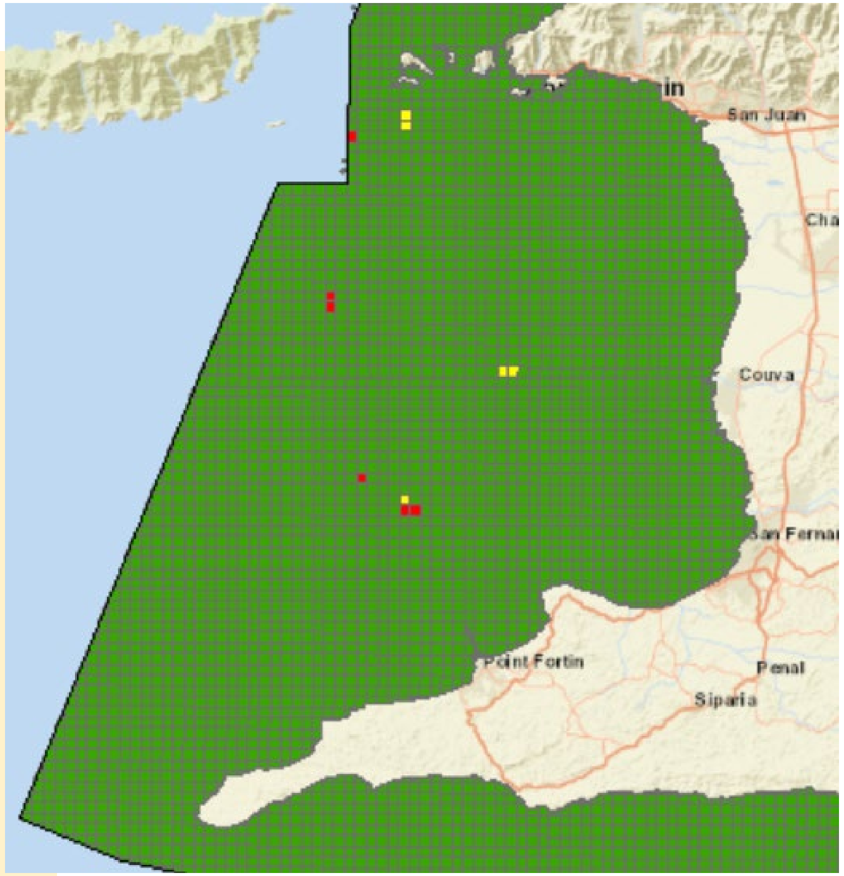
Collision candidates can be observed in the Bocas area.

Collision candidates are identified as overlapping ship domains



Development of the traffic criteria

- The number of collision and grounding candidates per sq km are multiplied by a causation factor value, based on the type of vessels.
- A causation factor is the probability that the vessel fails to make an evasive action to avoid the grounding or collision.
- The quantile data distribution method is applied across the study area, to distribute the results across a five-point scale and assign a score of from 1 - 5.
- A score of one means the likelihood of collision or grounding is very low and 5 means the likelihood is catastrophic



Catastrophic	Very high	High	Low	Very low	No Data
5	4	3	2	1	0

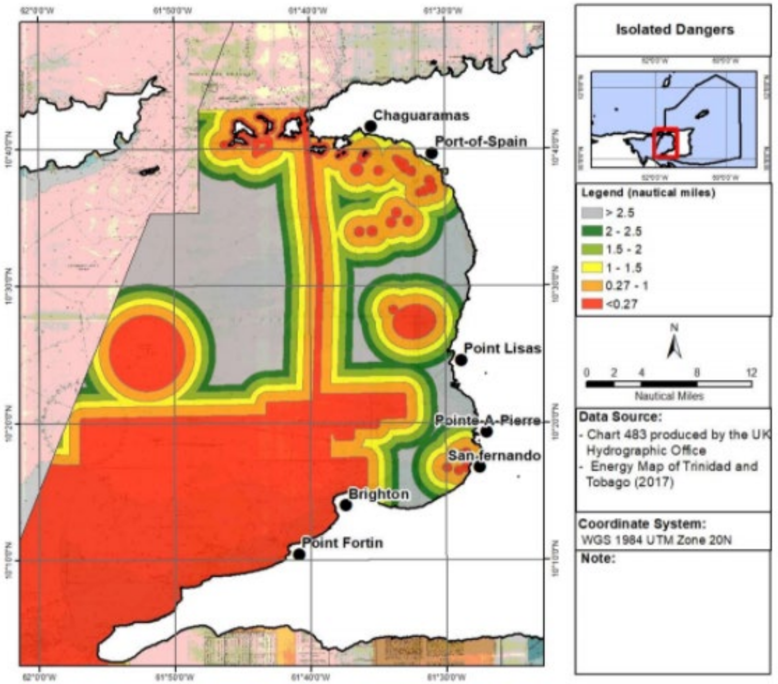
Development of the hazard criteria

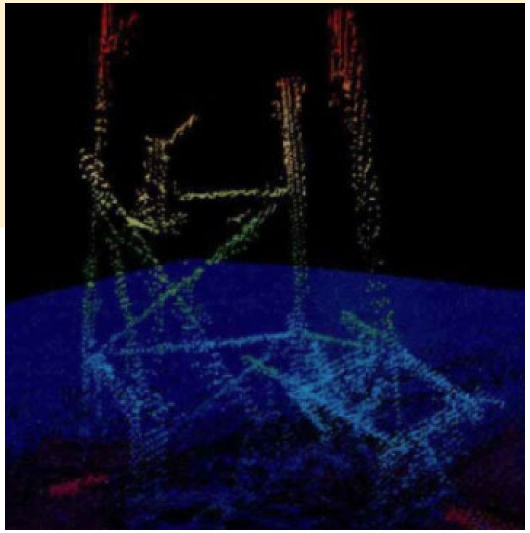
- Hazards which are likely to cause a collision or grounding are selected.

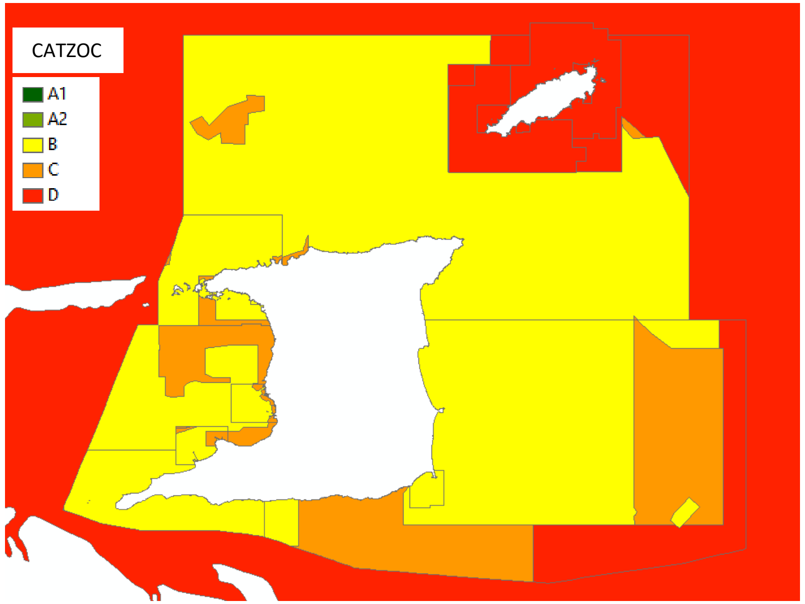
- A score is assigned per sq km, based on the likelihood of hazards to contribute to a collision or grounding.

Hazards include:

1. Charting – chart quality, survey age, chart adequacy
2. Route characteristics
3. Met-ocean conditions
4. Navigational hazards
5. Mitigation
6. Bathymetry





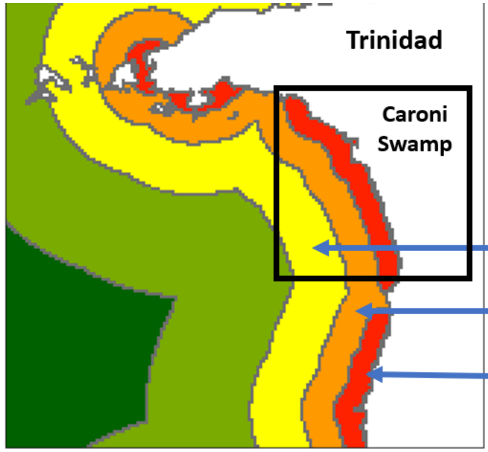


Catastrophic	Very high	High	Low	Very low	No Data
5	4	3	2	1	0

Development of the consequence criteria

- Market and non-market valuation techniques are used to estimate the value of marine and coastal areas, in terms of potential economic losses per year.
- The quantile data distribution method is applied across the study area, to distribute the value of the marine and coastal areas into five categories and assign a score per square km.

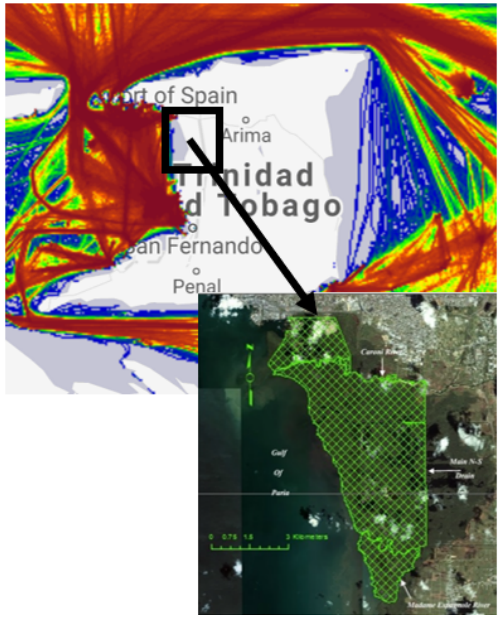
3



Severity of Impact/ Consequence Score		Distance from Swamp
1	Insignificant	5 – 10 nm
2	Minor	2 – 5 nm
3	Severe	1.5 – 2 nm
4	Major	1 – 1.5 nm
5	Catastrophic	< 1 nm

Source: LINZ

1



- Owned by the State
- Home to more than 200 species of birds
- Ramsar site
- Many different species of mammals
- Passes required for hiking and boat tours

- 1,200 USD/hectare/year x 3,258 hectares
- The Caroni Swamp is valued at 3mn USD/year.
- If 10 % of the Caroni Swamp is damaged: 0.3 mn USD

2

Severity of Impact/Consequence Score		Service Disruption Criteria	Economic Criteria (USD)
1	Insignificant	No significant disruption	Losses less than $1,000
2	Minor	Some loss of services	Losses $1,000 - $50,000
3	Severe	Sustained (24h) disruption	Losses $50 K to $5M
4	Major	Sustained (1 – 30day) disruption	Losses $5M – $50M
5	Catastrophic	Closure of facility for months	Losses in excess of $50M

Due to limited resources

Source: IALA

Calculation of the Final Risk Value to Inform Risk Control Options

RISK VALUE MATRIX		LIKELIHOOD				
		Very Rare (1)	Rare (2)	Occasional (3)	Frequent (4)	Very frequent (5)
CONSEQUENCE	Catastrophic (5)	5	10	15	20	25
	Major (4)	4	8	12	16	20
	Severe (3)	3	6	9	12	15
	Minor (2)	2	4	6	8	10
	Insignificant (1)	1	2	3	4	5

Moderate Risk

Reduce to As Low As Reasonably Practicable (ALARP) level using Risk Control Options.

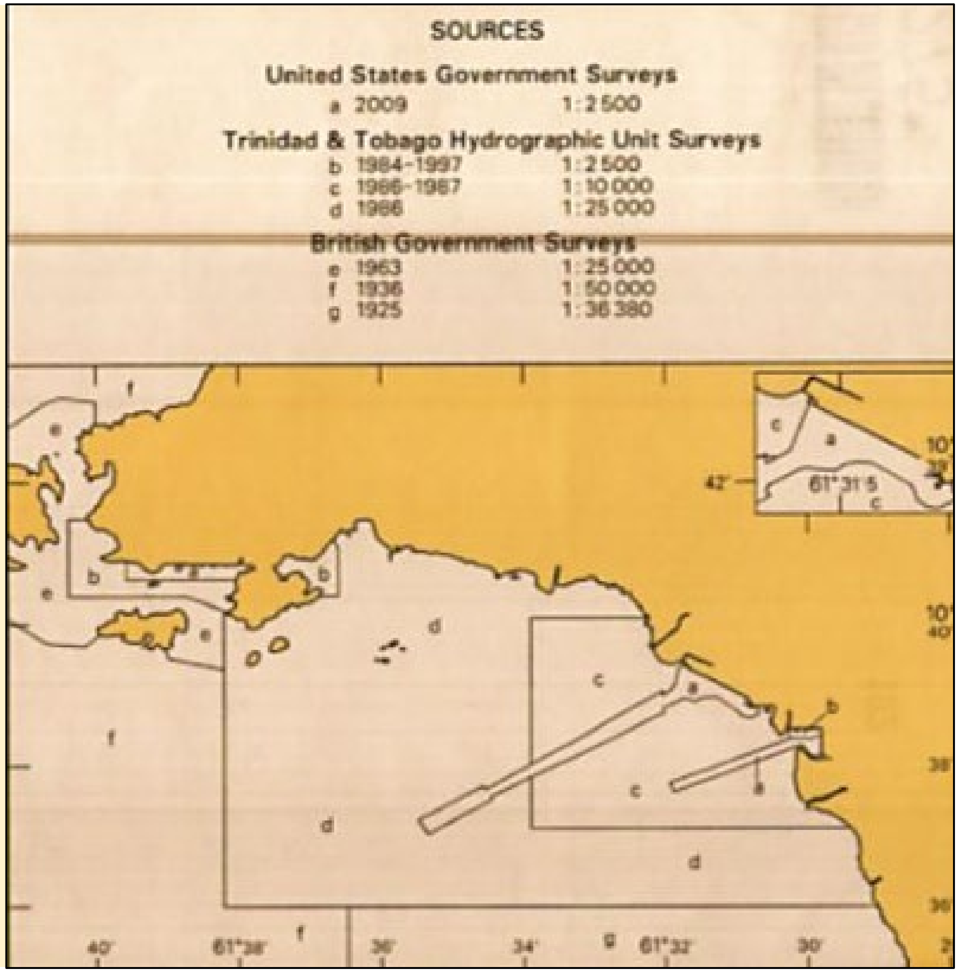
ALARP

Adapted from IALA

Main Outputs from the Strategy being Developed – Economic Assessment of Risks in Maritime Navigation

The strategy can provide:

- Detailed information about the circumstances of collision and grounding candidates and the value of marine and coastal areas where collision candidates are identified
- A risk value per square kilometer, which is well suited to make decisions about risk control options



Limitations of the Strategy

- Ship dynamics when the vessel is turning are not modelled, for eg: turning radius
- Met-ocean conditions are not modelled
- Ship speed is constant between waypoints
- Granularity of the results is one square kilometer
- Errors in the AIS dataset, for example: inaccurate ‘ship status’, incomplete attribute information

Benefits of the Model – Economic Assessment of Risks in Maritime Navigation

- Uses satellite AIS data (terrestrial AIS data is unavailable in many developing economies)

- Calculates a final risk value:

Calculates probability of collisions and groundings per sq km, per year

Calculates consequence of collisions and groundings in terms of economic losses per sq km, per year.

- The final risk value well suited to recommend risk control options

Ongoing Objectives

The immediate objectives are to:

- Calculate the final outputs for Trinidad and Tobago and validate the results based on stakeholder consultation.

Note: the locations of collision and rounding candidates correspond to the results acquired from IWRAP MK II.

- Extend the strategy to territories across the Greater Caribbean Region.

Conclusion

- A universal strategy for hydrographic risk assessment is unavailable at this time because each marine operating environment is different.

- Economic Assessment of Risks in Maritime Navigation provides a risk assessment strategy which is suitable for the operating environments in developing states:
  1. Uses satellite AIS data (T-AIS is unavailable in many developing areas).
  2. Simulates the most likely ship traffic as well as other possible scenarios
  3. Calculates the risk value per sq km which can be used to inform risk control options.

For more information:

https://iho.int/uploads/user/pubs/ihreview_P1/IHR_May2020.pdf

Articles

BENEFITS OF ASSESSING RISK IN MARITIME NAVIGATION USING IALA AND LINZ METHODS

By D. Seepersad [1,2], O. Erikson [2], A. Greenland [3], K. Miller [1]

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3 - New Zealand Hydrographic Authority, Land Information New Zealand (LINZ).

Abstract

Introduction of the Automatic Identification System (AIS) for shipping has led to use of archived data in risk assessment for maritime navigation. The IWRAP software from the International Association of Aids to Navigation and Lighthouse Authorities (IALA) makes use of statistics derived from AIS data to determine likelihood of collision and grounding events in waterways where maritime traffic follows regular routes. Alternatively, the New Zealand Hydrographic Authority implemented a weighted overlay in a Geographic Information System (GIS) using AIS data together with further geographical information of a waterway to determine risk. These methods are tested in Trinidadian waters of the Gulf of Paria to identify benefits. It is concluded that each method offers a different contribution to the decision making process for improvement to the safety of navigation.

Résumé

L'introduction du système d'identification automatique (AIS) pour la navigation a conduit à l'utilisation de données archivées dans l'évaluation des risques pour la