Risk Assessment and Mitigation Measures of Maritime Navigation in the Caribbean Sea

Amrika Maharaj

Department of Geomatics Engineering and Land Management (UWI)

amrika.maharaj@hotmail.com

Structure of the Presentation

- Introduction into Maritime Navigation
- Importance of conducting Risk Assessment
- Strategies used to reduced the risk to navigation
- Preliminary results
- Conclusion

Introduction to the Study

- The Caribbean is a busy shipping maritime environment representing a wide range of shipping activities.

- The shipping activities become more complex as large-scale offshore operations and maritime activities continue to increase.

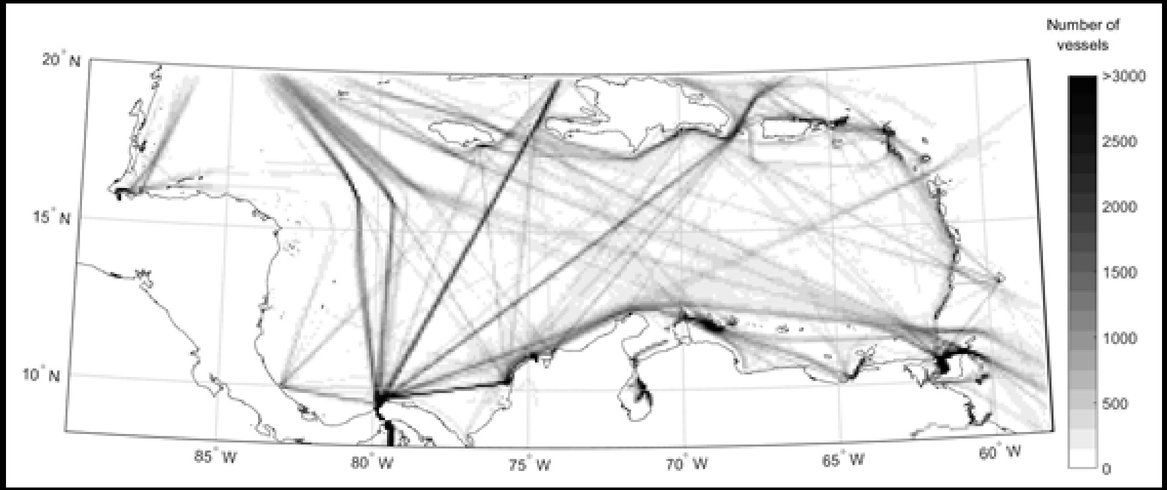

Figure 1 : Vessel Traffic density across the Wider Caribbean Region

Causes/Consequences of Maritime Accidents

Generic causes of Maritime Accidents:

Meteorological Conditions
Mechanical and Technical Issues
Human Errors
Malfunctioning aids to navigation
Inadequate charting (Bathymetry & Navigational Hazards)
Navigational Complexity

Consequences of Maritime Accidents:

Economic Loss- Overall decrease in transhipment of goods and services
Loss of life
Environmental Damage to sensitive areas
Damage to or Loss of property

Figure 2: Oil spill vessel accident, Tobago 1979.

Objectives of the Study

AIM: To develop a strategy that considers likelihood of an incident in relation to **vessel traffic flow** and **navigation information** available to the mariner.

OBJECTIVES:

- Assessment of shipping accidents globally to identify key contributing factors relating to ships and the environment to produce statistical evaluation for use in risk assessment
- Apply mitigation measures such as improved charting, AtoN’s and traffic management to re-assess risk
- Strategy for assessment of impact of risk reduction measures through the provision of tools and models that will support port development

Data available for this Research

1. Satellite Automatic Identification System (S-AIS) data for 2016.
2. Additional vessel information from online databases that are available, was used to construct a database with a spatial component.
3. Existing archives or reported accidents at sea was used to identify the casual factors that contributes to a maritime disaster.
4. Risk factors (United Kingdom Hydrographic Office)

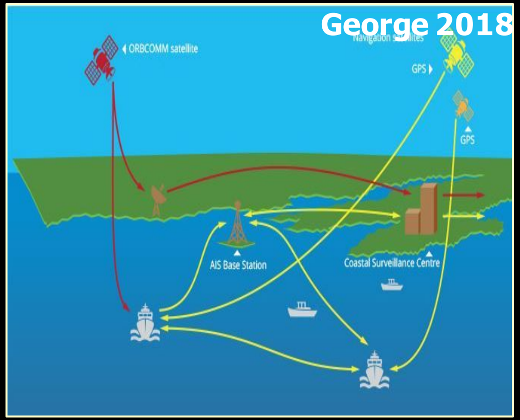

Figure 3 SAIS Communication

Figure 4: Accident Database (IMO 2021)

Predicting events with Artificial Neural Networks

Global Maritime Accidents (2002-2020)

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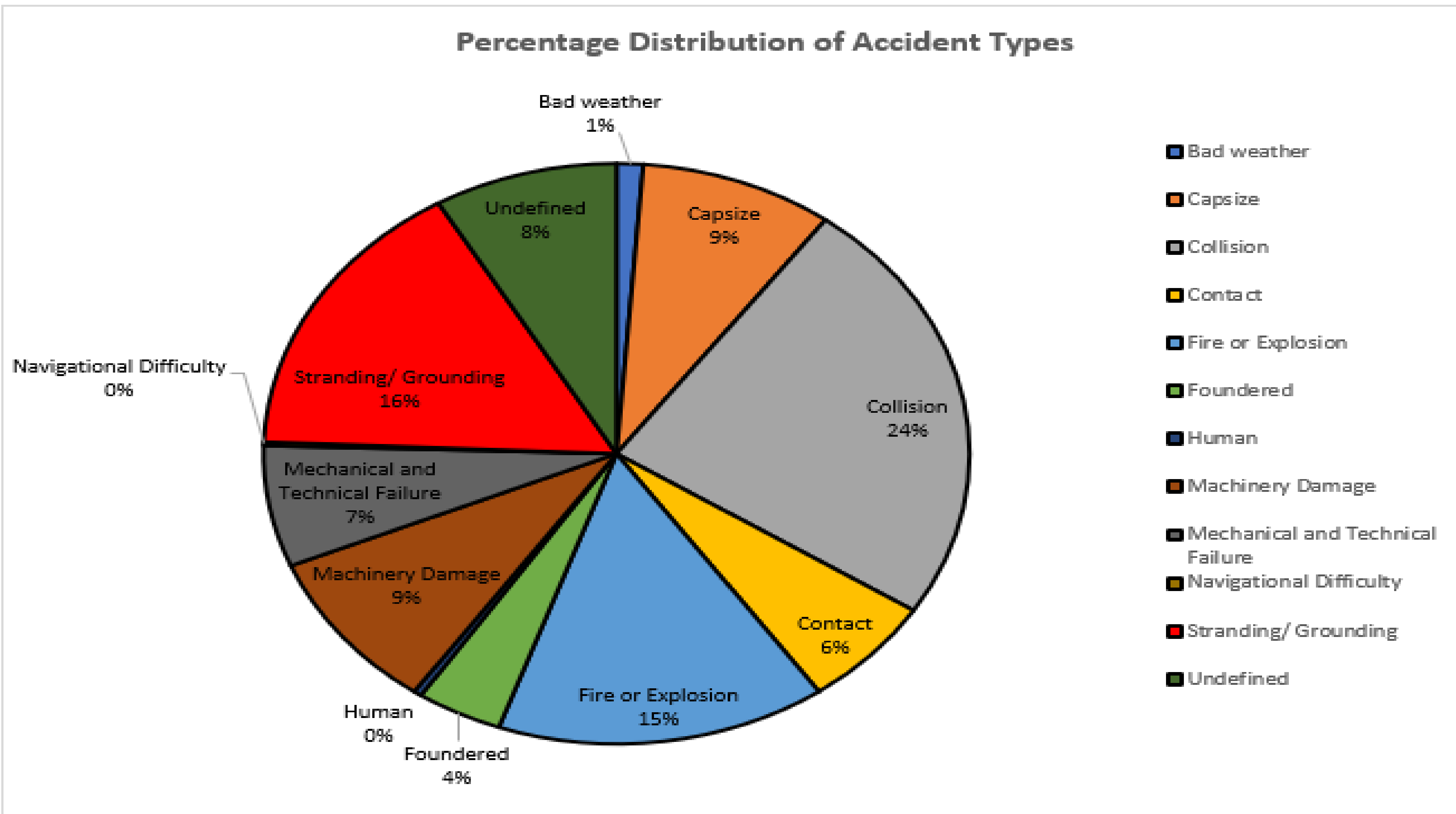
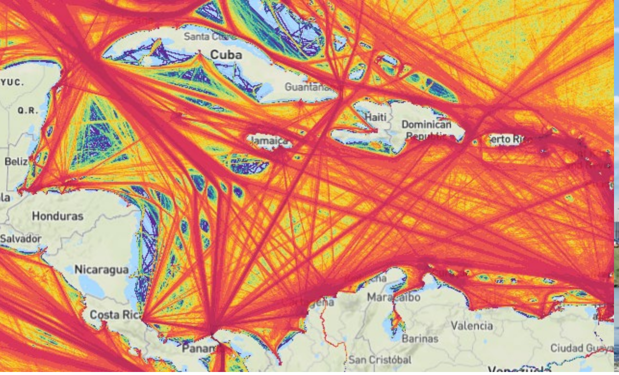
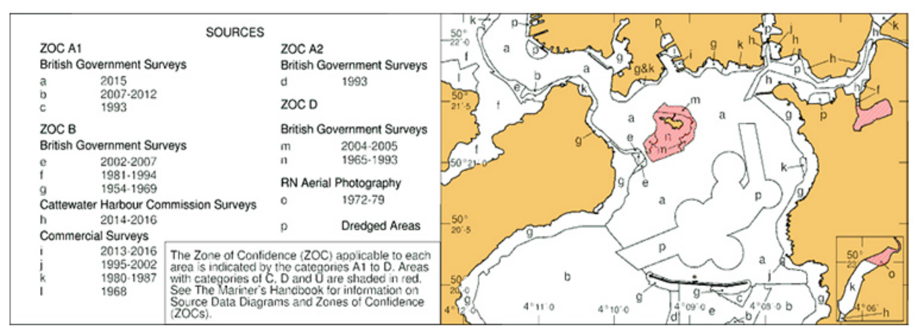
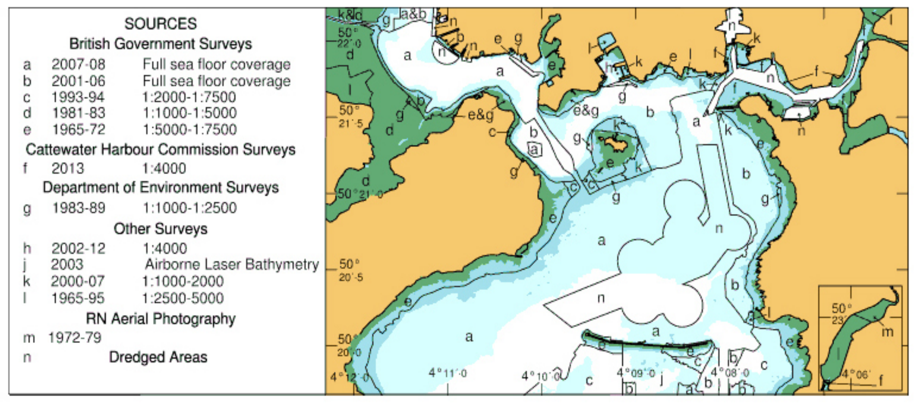
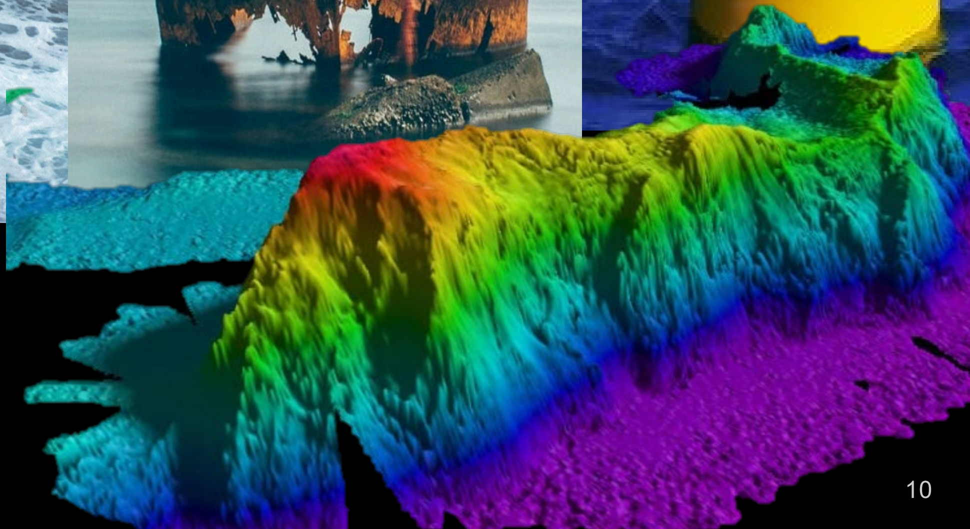
Quantitative Analysis of Maritime Causalities and Incidents









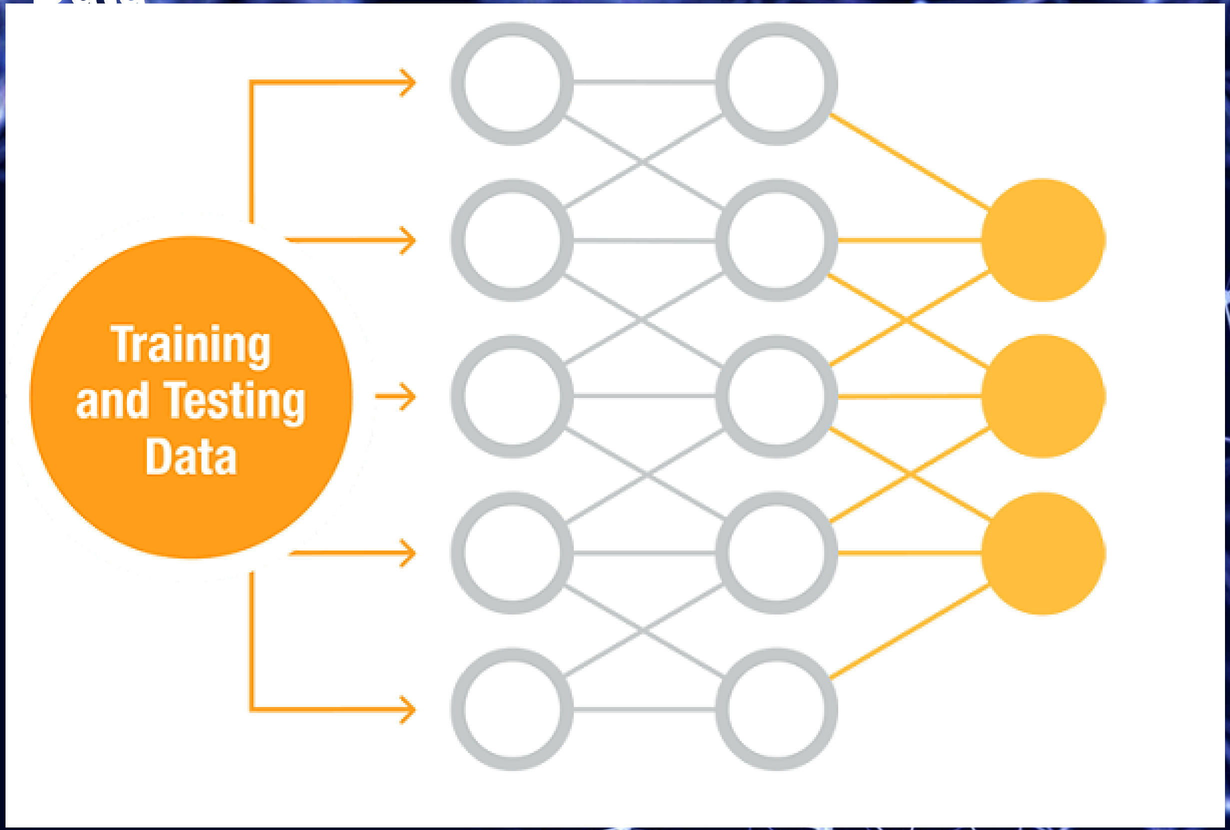


Data Preparation

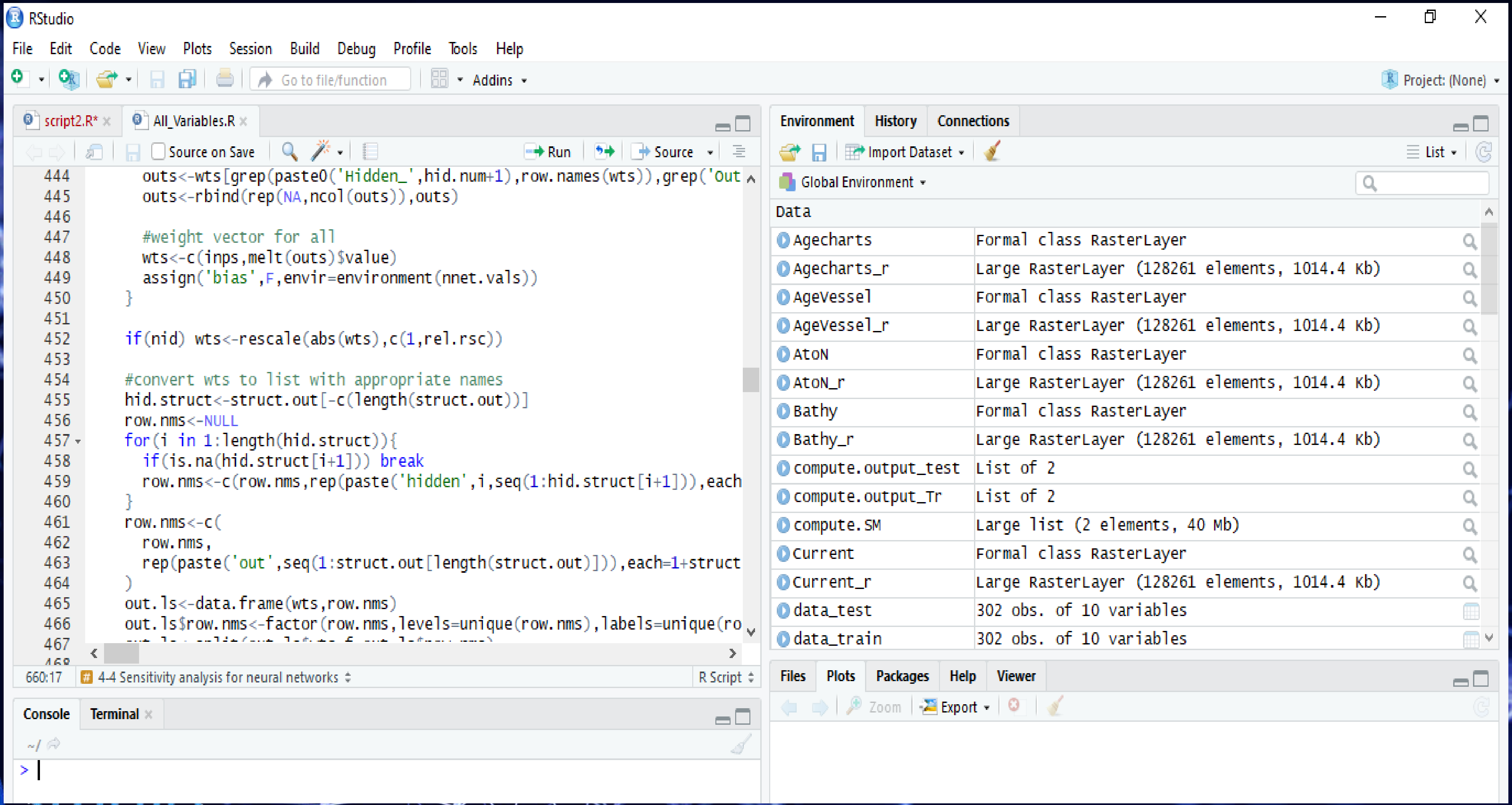
1) Selection of Risk Factors

Data Preparation

2) Production of Testing and Training Data



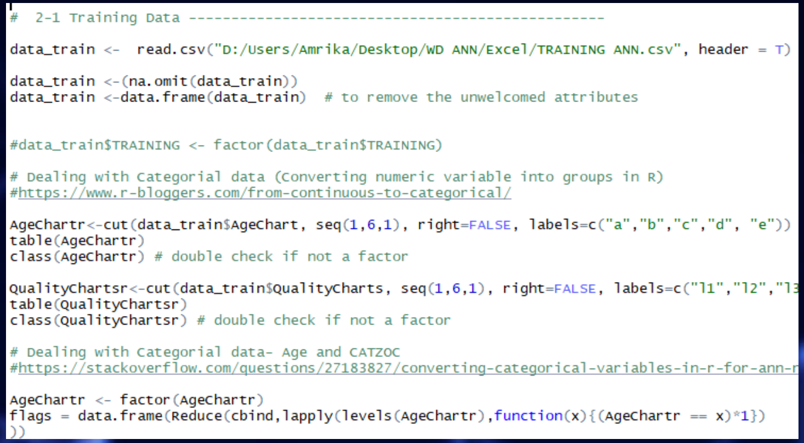
R-Studio Environment



Predictive Model

1) Environment settings, training and validation data processing.

- Loading variables
- Creating data frames
- Scaling the data



```
#  2-1 Training Data ----------------------------------------------

data_train <-  read.csv("D:/Users/Amrika/Desktop/WD ANN/Excel/TRAINING ANN.csv", header = T)

data_train <-(na.omit(data_train))
data_train <-data.frame(data_train)  # to remove the unwelcomed attributes


#data_train$TRAINING <- factor(data_train$TRAINING)

# Dealing with Categorial data (Converting numeric variable into groups in R)
#https://www.r-bloggers.com/from-continuous-to-categorical/

AgeChartr<-cut(data_train$AgeChart, seq(1,6,1), right=FALSE, labels=c("a","b","c","d", "e"))
table(AgeChartr)
class(AgeChartr) # double check if not a factor

QualityChartsr<-cut(data_train$QualityCharts, seq(1,6,1), right=FALSE, labels=c("l1","l2","l3
table(QualityChartsr)
class(QualityChartsr) # double check if not a factor

# Dealing with Categorial data- Age and CATZOC
#https://stackoverflow.com/questions/27183827/converting-categorical-variables-in-r-for-ann-r

AgeChartr <- factor(AgeChartr)
flags = data.frame(Reduce(cbind,lapply(levels(AgeChartr),function(x){(AgeChartr == x)*1})
))
```

Figure 5: Loading variables in R Studio

2) Training the Neural Network

- Plot NN Function Network
- Plot Pairwise NN model of Explanatory variables
- Generalized weight plot of training data frame

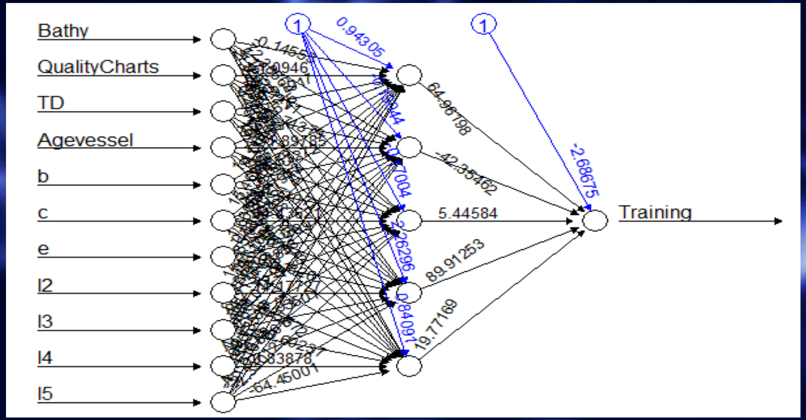


Figure 6: Neural Network Plot in R Studio

Predictive Model

3) Testing of the Neural Network (BP)

- Run NNET function (Back Propagation)
- Plot NN function network
- Plot variables importance using NNET

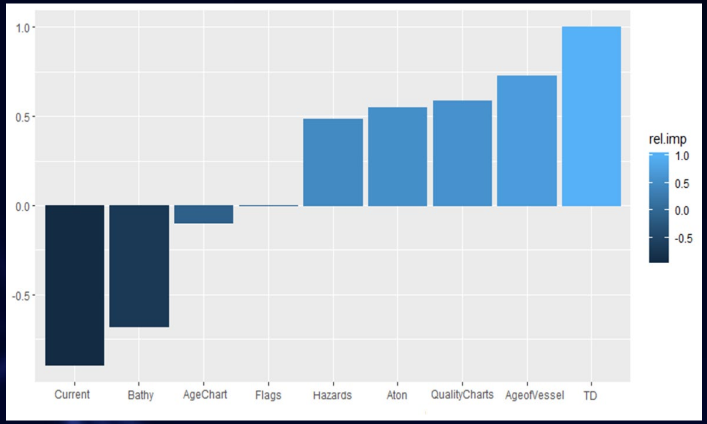


Figure 7: Variable Importance Graph

4) Validation of the Network

- Validation of results with AUC and ROC plot

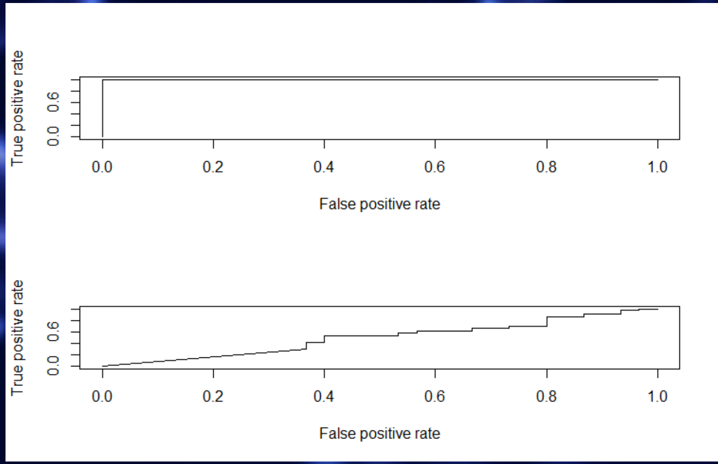


Figure 8: Success rate and Prediction Rate Graph

Predictive Model

5) Prediction Map using Raster Data

- Import and process thematic maps
- Compute prediction to the raster data
- Export final prediction map as raster tif.

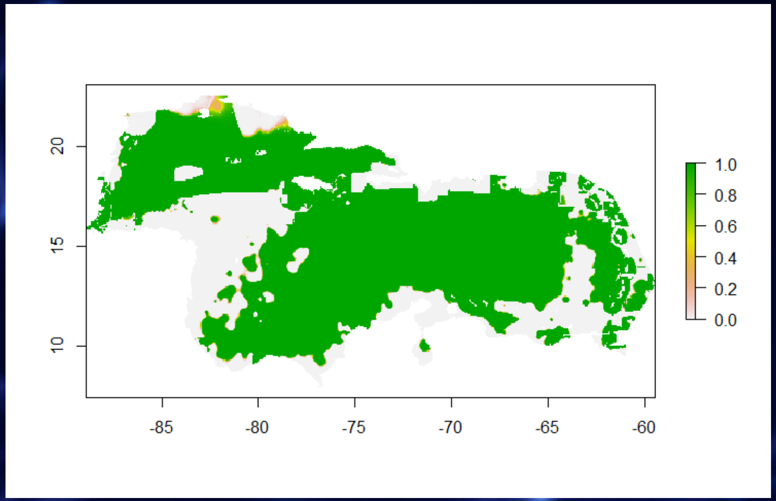


Figure 9: Sample Maritime Accident Prediction Map of the Caribbean Sea

6) Sensitivity Analysis

- Undertaking analysis to determine the significance of the input parameters

Neural Network Plot

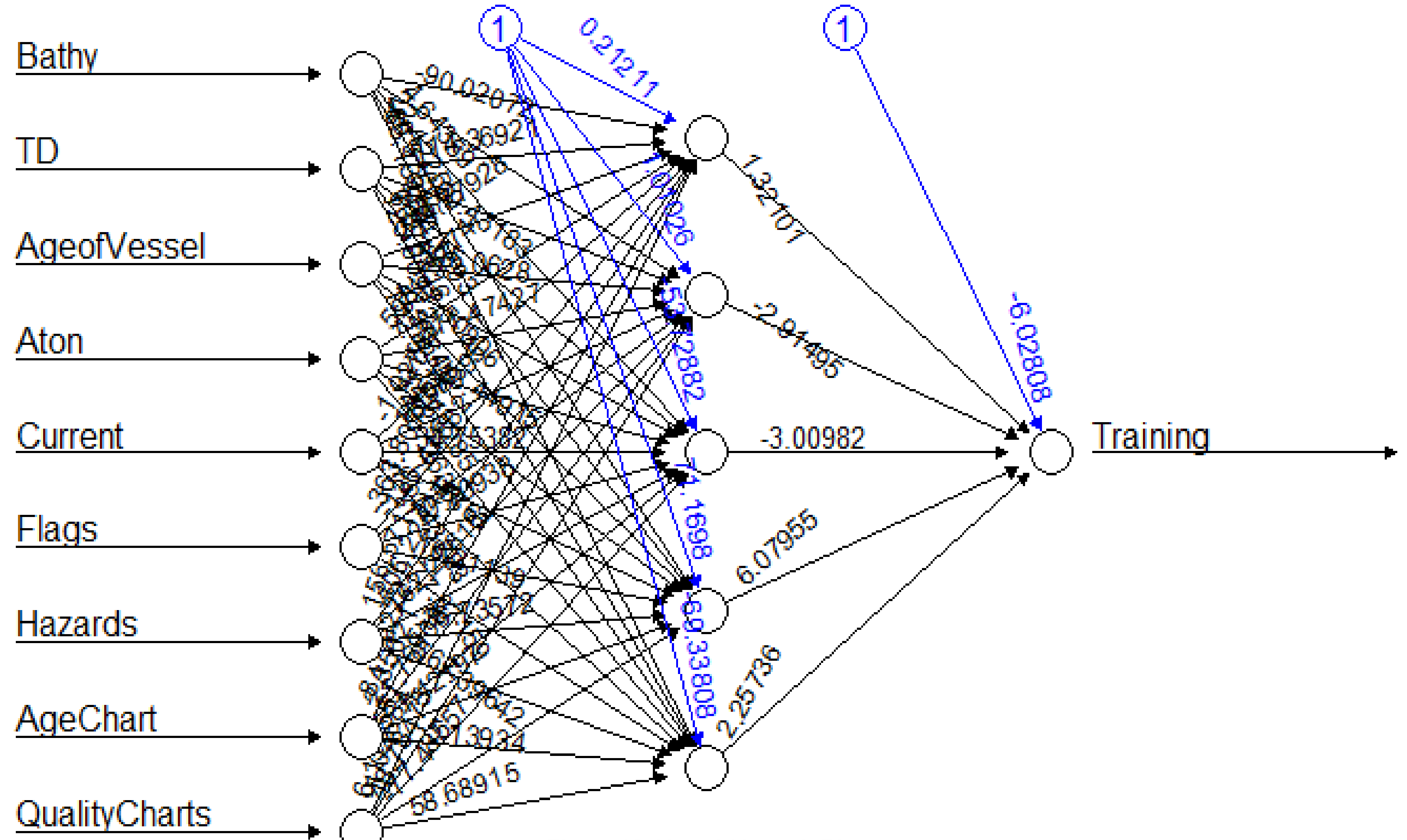


Figure 10: Neural Network Plot

Back Propagation of Neural Network

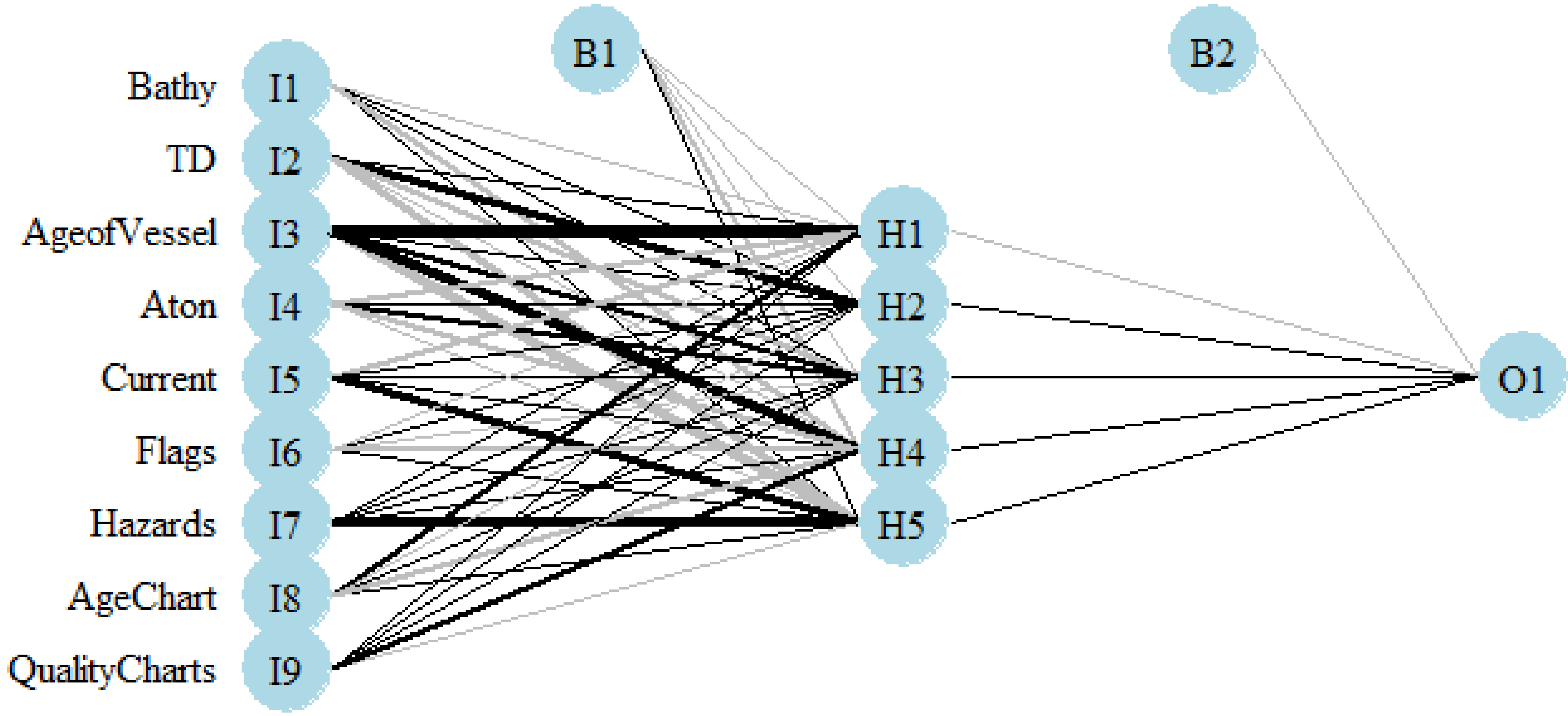


Figure 11: Neural Network Plot (BP)

Variable Importance Graph

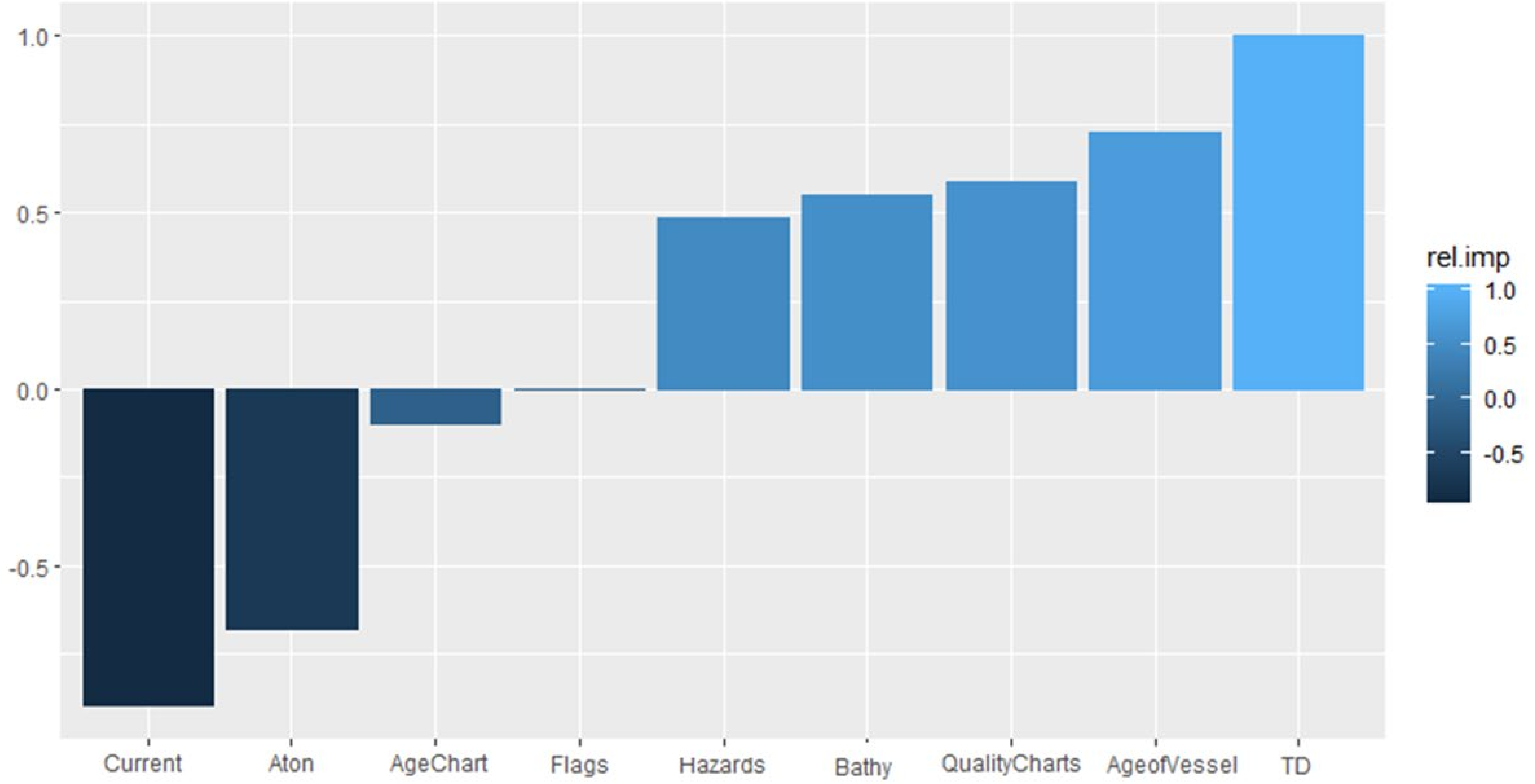


Figure 12: Importance of Variables

Model Accuracy

- ROC Curve- Accuracy of the predictions
- AUC Curve- Accuracy of the classification
- High AUC indicates a better model

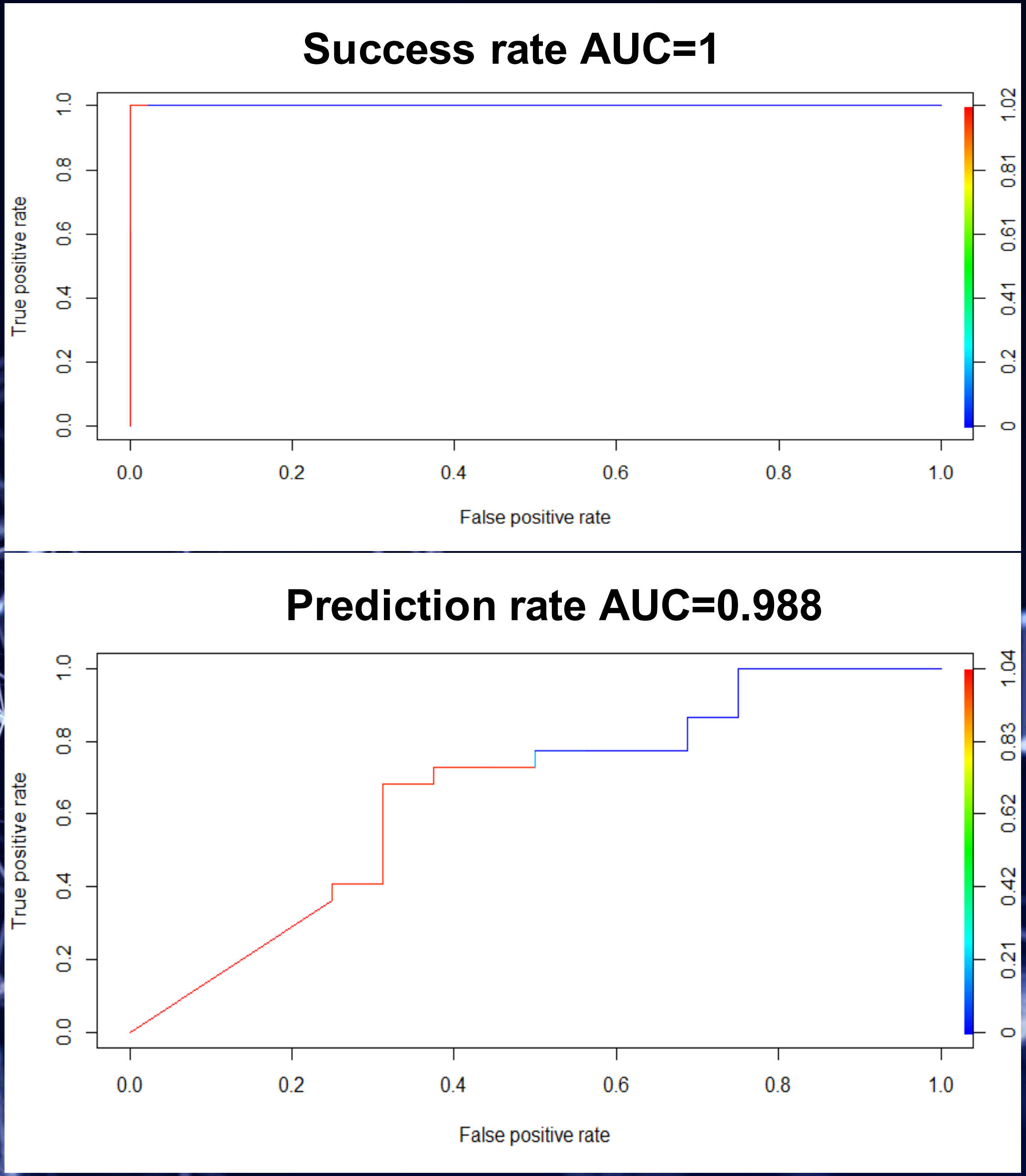


Figure 14: Success Rate and Prediction Rate Response Curves

ANN Prediction Map

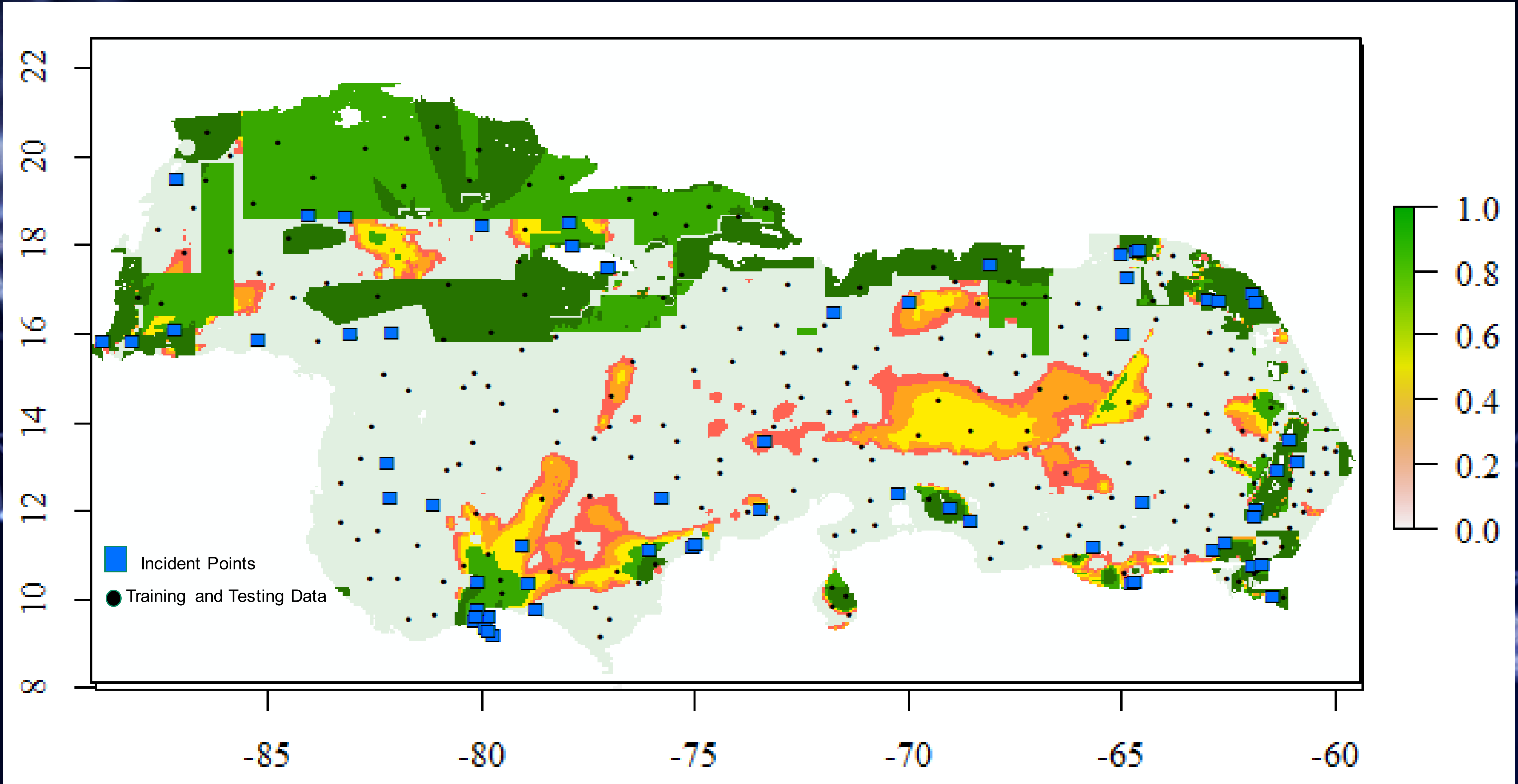


Figure 15: ANN Prediction Map

Summary of Findings

- The Neural Network has the potential for Risk Assessment
- The Sensitivity Analysis and the Variable Importance graphs, identified the significance of each variable.
- Results contribute to decision-making for Mitigation.

Research Plan

On going research:

- Reduction in risk will then need to be evaluated by computing simulations of traffic under different scenarios, which will be used to assess the benefits of implementation to long term reduction in pollution events and loss of life

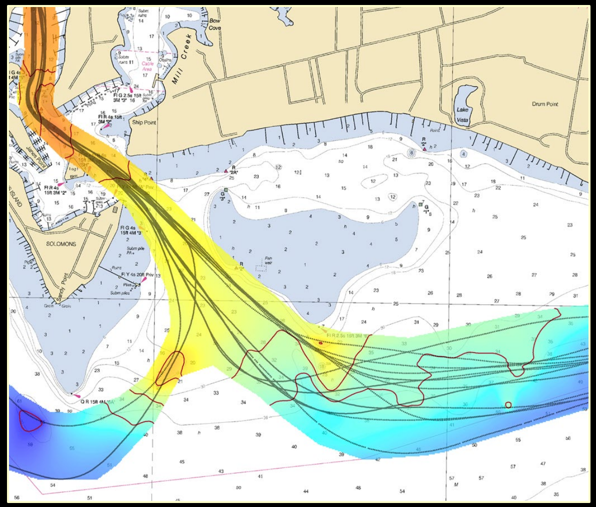


Figure 10: VTMS (Magnus 2016)