



# 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](mailto: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.

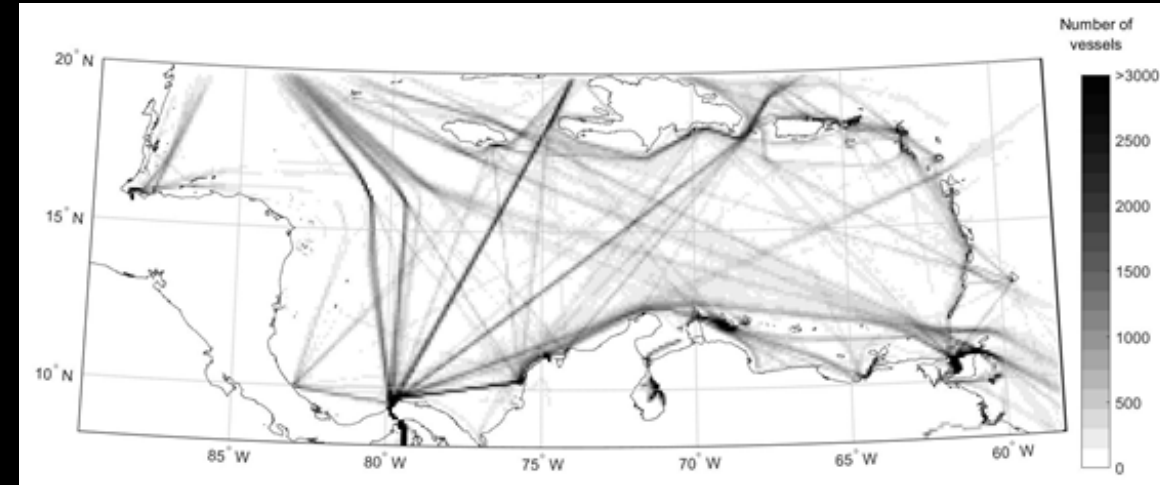


Figure 1 : Vessel Traffic density across the Wider Caribbean Region

# 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 transshipment 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:**

- ➊ 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
- ➋ Apply mitigation measures such as improved charting, AtoN's and traffic management to re-assess risk
- ➌ 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)

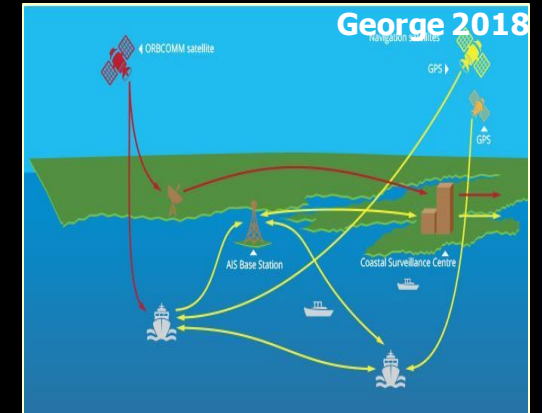


Figure 3 SAIS Communication



Figure 4: Accident Database (IMO 2021)



# Predicting events with Artificial Neural Networks



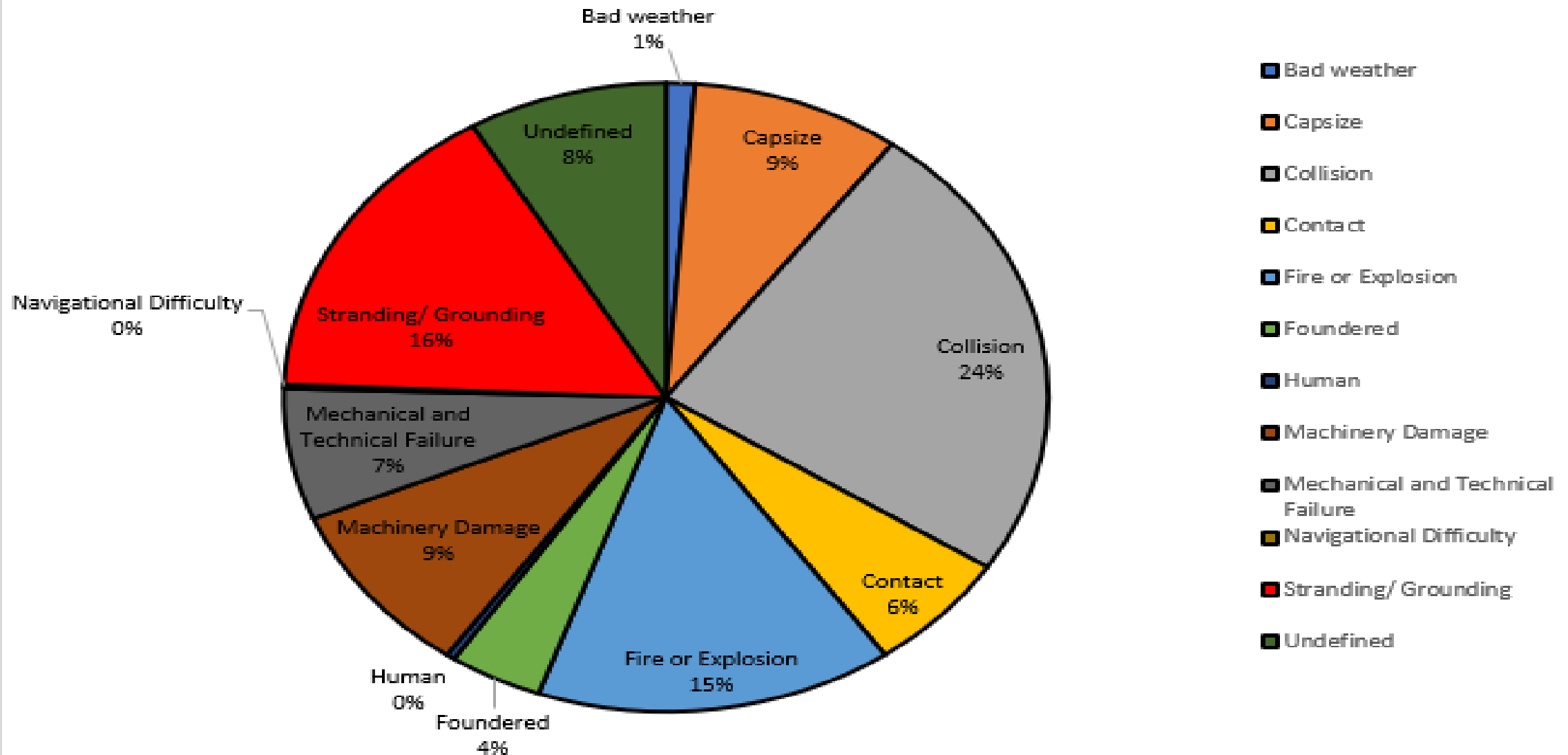
# Global Maritime Accidents (2002-2020)

68

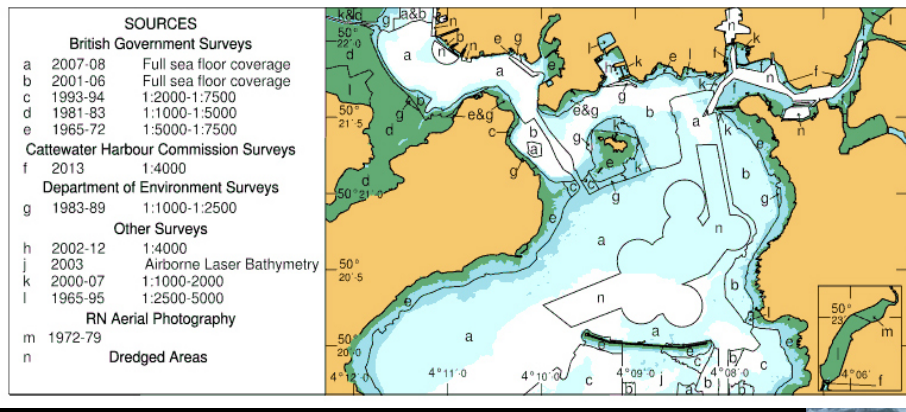
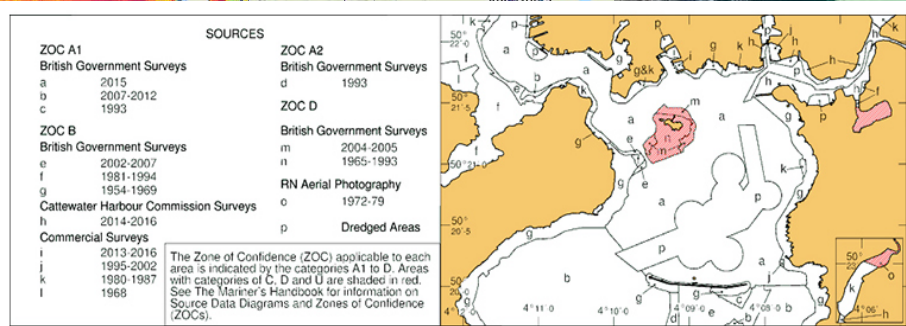
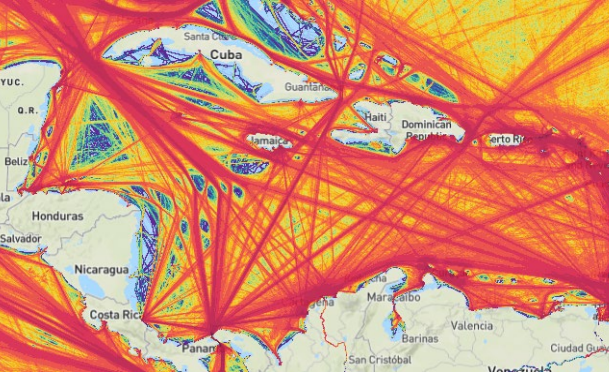


# Quantitative Analysis of Maritime Casualties and Incidents

Percentage Distribution of Accident Types







# Data Preparation

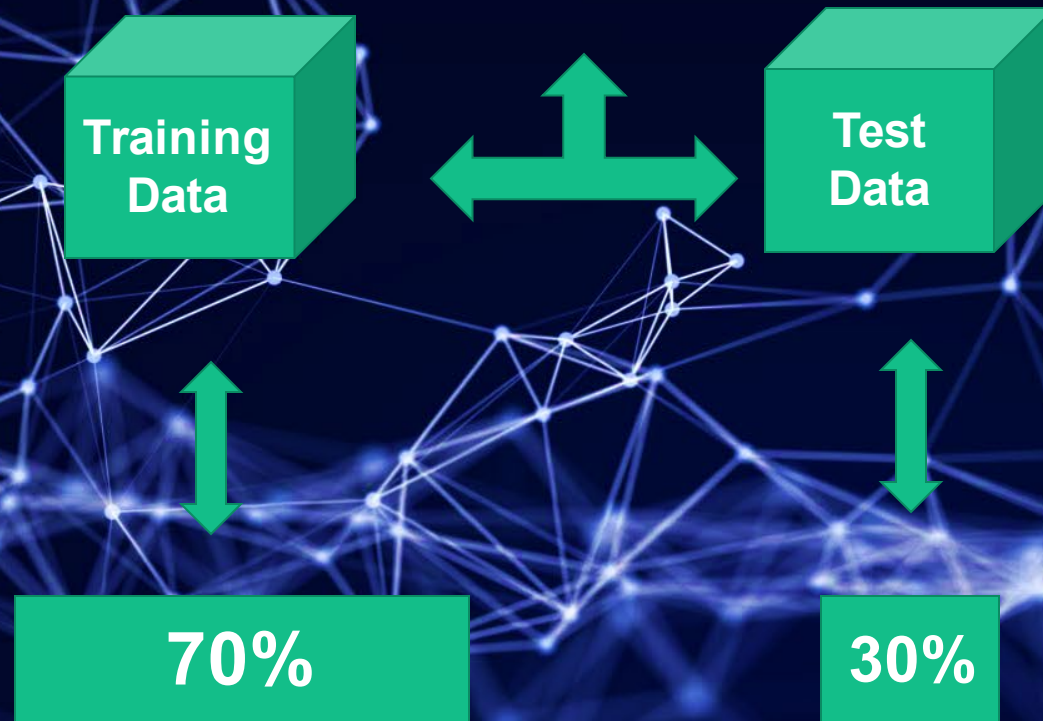
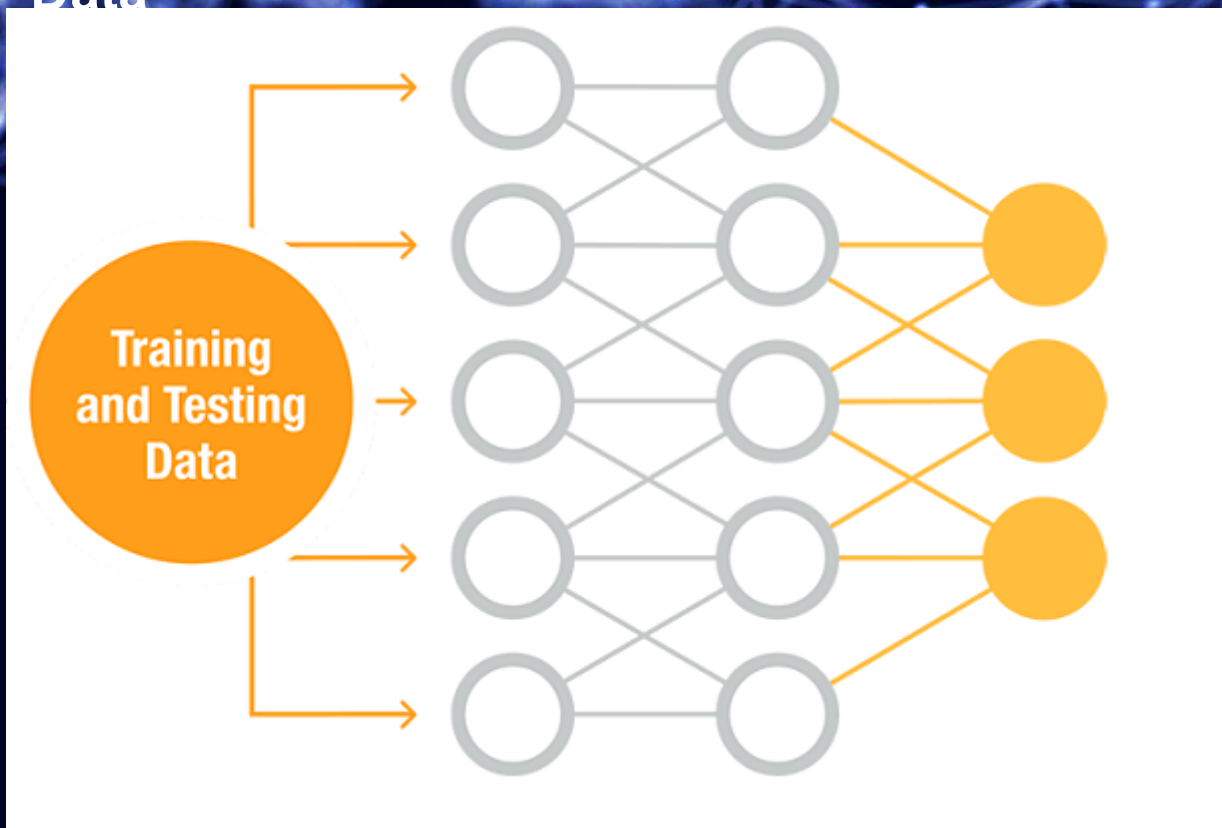
## 1) Selection of Risk Factors





# Data Preparation

## 2) Production of Testing and Training Data



# R-Studio Environment

The screenshot displays the RStudio interface with the following components:

- Source Editor:** Contains R code for a sensitivity analysis. The code includes operations on raster layers, weight assignment, and data frame construction.
- Environment Pane:** Lists objects in the Global Environment, including raster layers and data frames.
- Console:** Shows the R prompt ready for input.

```
444   outs<-wts[grepl(paste0('Hidden_',hid.num+1),row.names(wts)),grepl('out',row.names(wts))]  
445   outs<-rbind(rep(NA,ncol(outs)),outs)  
446  
447   #weight vector for all  
448   wts<-c(inps,melt(outs)$value)  
449   assign('bias',F,envir=environment(nnet.vals))  
450 }  
451  
452 if(nid) wts<-rescale(abs(wts),c(1,rel.rsc))  
453  
454 #convert wts to list with appropriate names  
455 hid.struct<-struct.out[-c(length(struct.out))]  
456 row.nms<-NULL  
457 for(i in 1:length(hid.struct)){  
458   if(is.na(hid.struct[i+1])) break  
459   row.nms<-c(row.nms,rep(paste('hidden',i,seq(1:hid.struct[i+1])),each=length(hid.struct[i+1])))  
460 }  
461 row.nms<-c(  
462   row.nms,  
463   rep(paste('out',seq(1:struct.out[length(struct.out)])),each=1+struct.out[length(struct.out)])  
464 )  
465 out.ls<-data.frame(wts,row.nms)  
466 out.ls$row.nms<-factor(row.nms,levels=unique(row.nms),labels=unique(row.nms))  
467  
468
```

Object	Class	Size
Agecharts	Formal class RasterLayer	
Agecharts_r	Large RasterLayer (128261 elements, 1014.4 kb)	
AgeVessel	Formal class RasterLayer	
AgeVessel_r	Large RasterLayer (128261 elements, 1014.4 kb)	
AtON	Formal class RasterLayer	
AtON_r	Large RasterLayer (128261 elements, 1014.4 kb)	
Bathy	Formal class RasterLayer	
Bathy_r	Large RasterLayer (128261 elements, 1014.4 kb)	
compute.output_test	List of 2	
compute.output_Tr	List of 2	
compute.SM	Large list (2 elements, 40 Mb)	
Current	Formal class RasterLayer	
Current_r	Large RasterLayer (128261 elements, 1014.4 kb)	
data_test	302 obs. of 10 variables	
data_train	302 obs. of 10 variables	







# 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 categorical 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("11","12","13"))  
table(Qualitychartsr)  
class(Qualitychartsr) # double check if not a factor  
  
# Dealing with Categorical 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

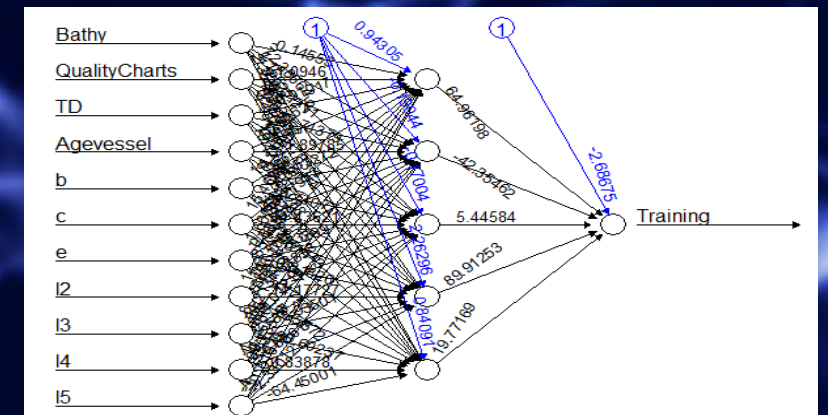


Figure 6: Neural Network Plot in R Studio 13



# Predictive Model

## 3) Testing of the Neural Network (BP)

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

## 4) Validation of the Network

- Validation of results with AUC and ROC plot

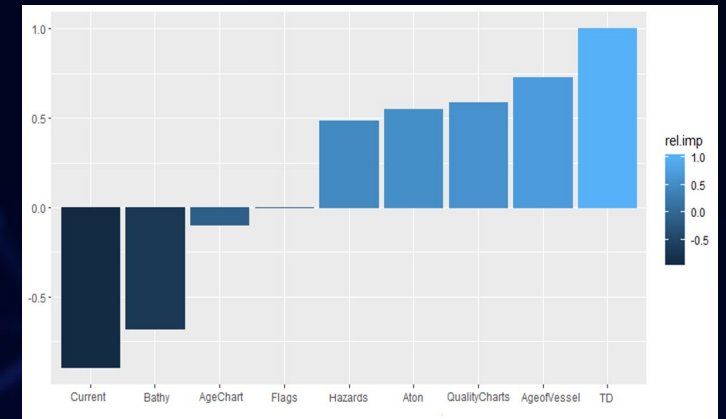


Figure 7: Variable Importance Graph

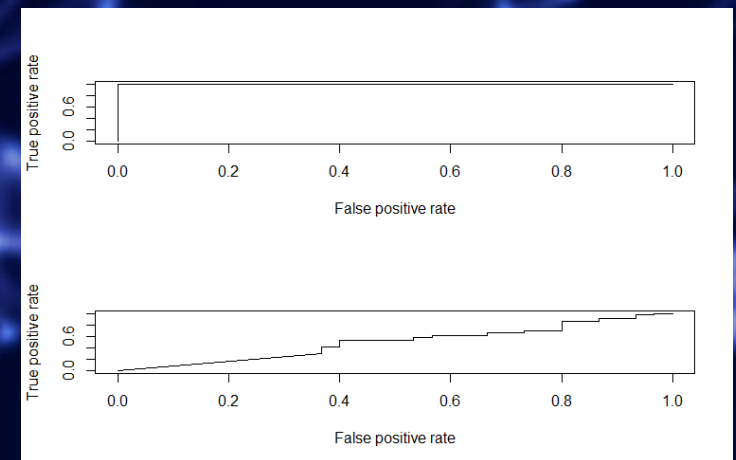


Figure 8: Success rate and Prediction Rate Graph





# 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.

## 6) Sensitivity Analysis

- Undertaking analysis to determine the significance of the input parameters

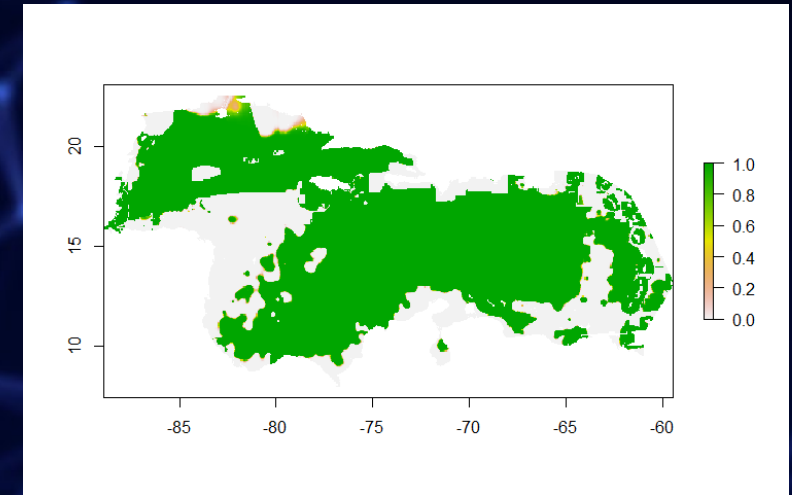


Figure 9: Sample Maritime Accident Prediction Map of the Caribbean Sea



# Neural Network Plot

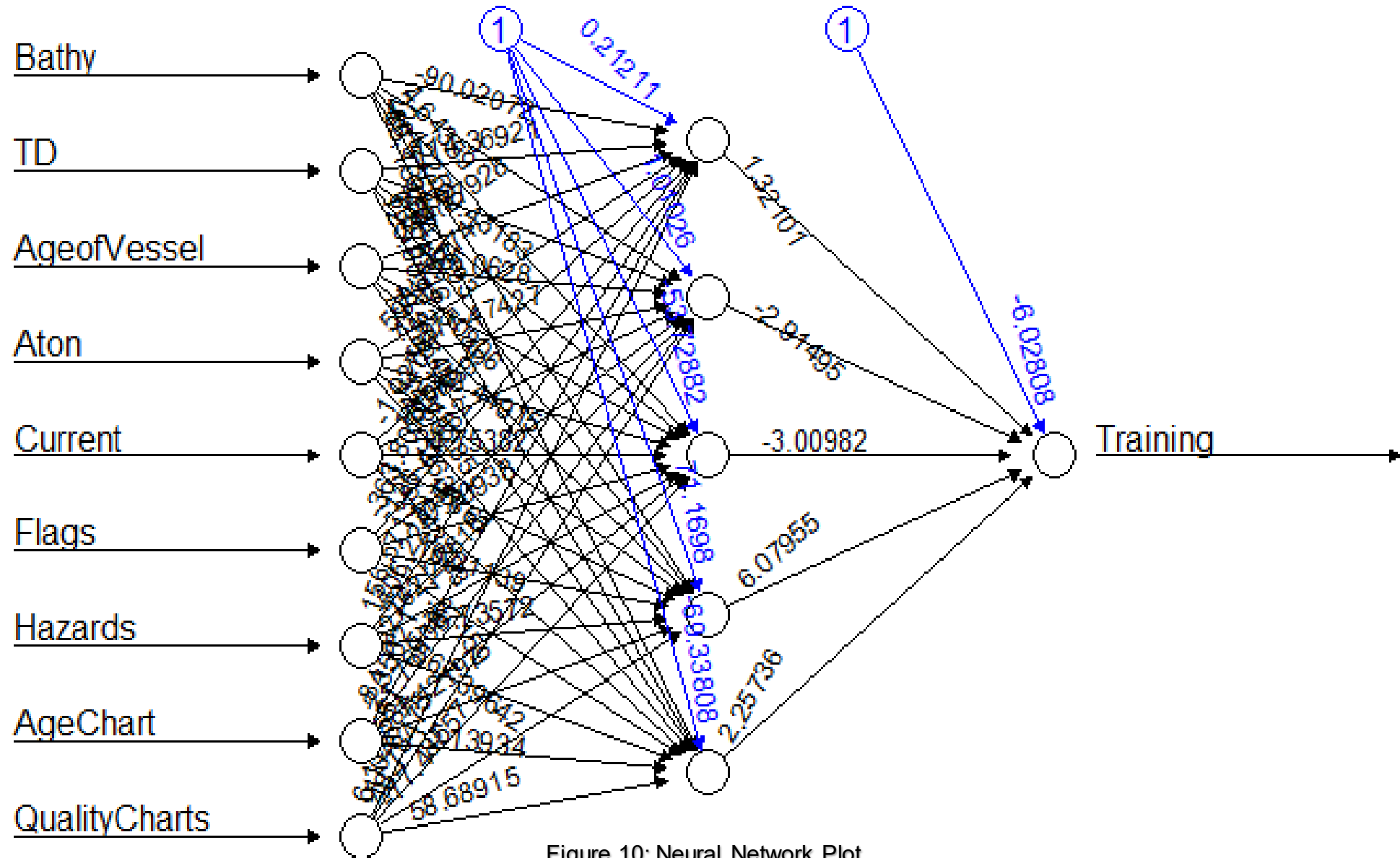


Figure 10: Neural Network Plot

# Back Propagation of Neural Network

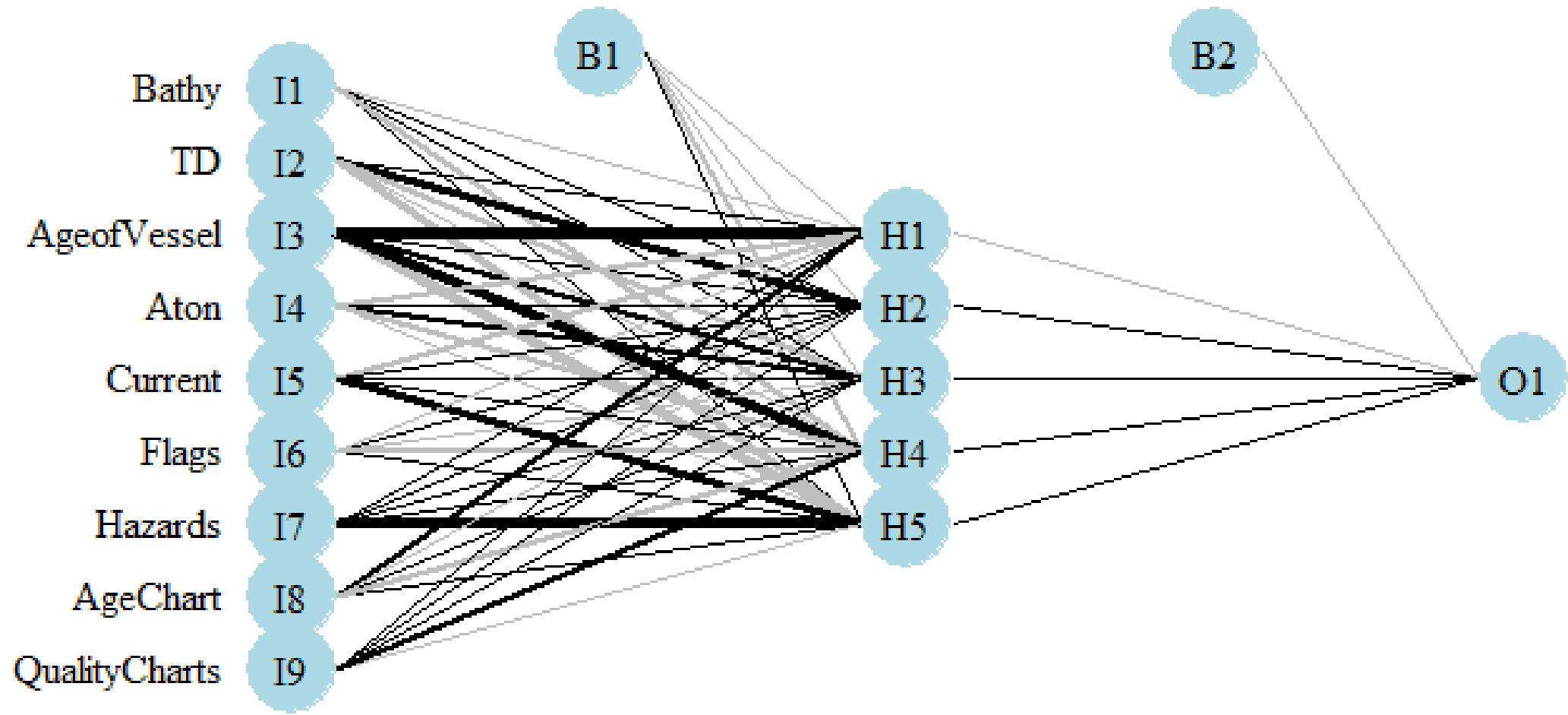


Figure 11: Neural Network Plot (BP)

# Variable Importance Graph

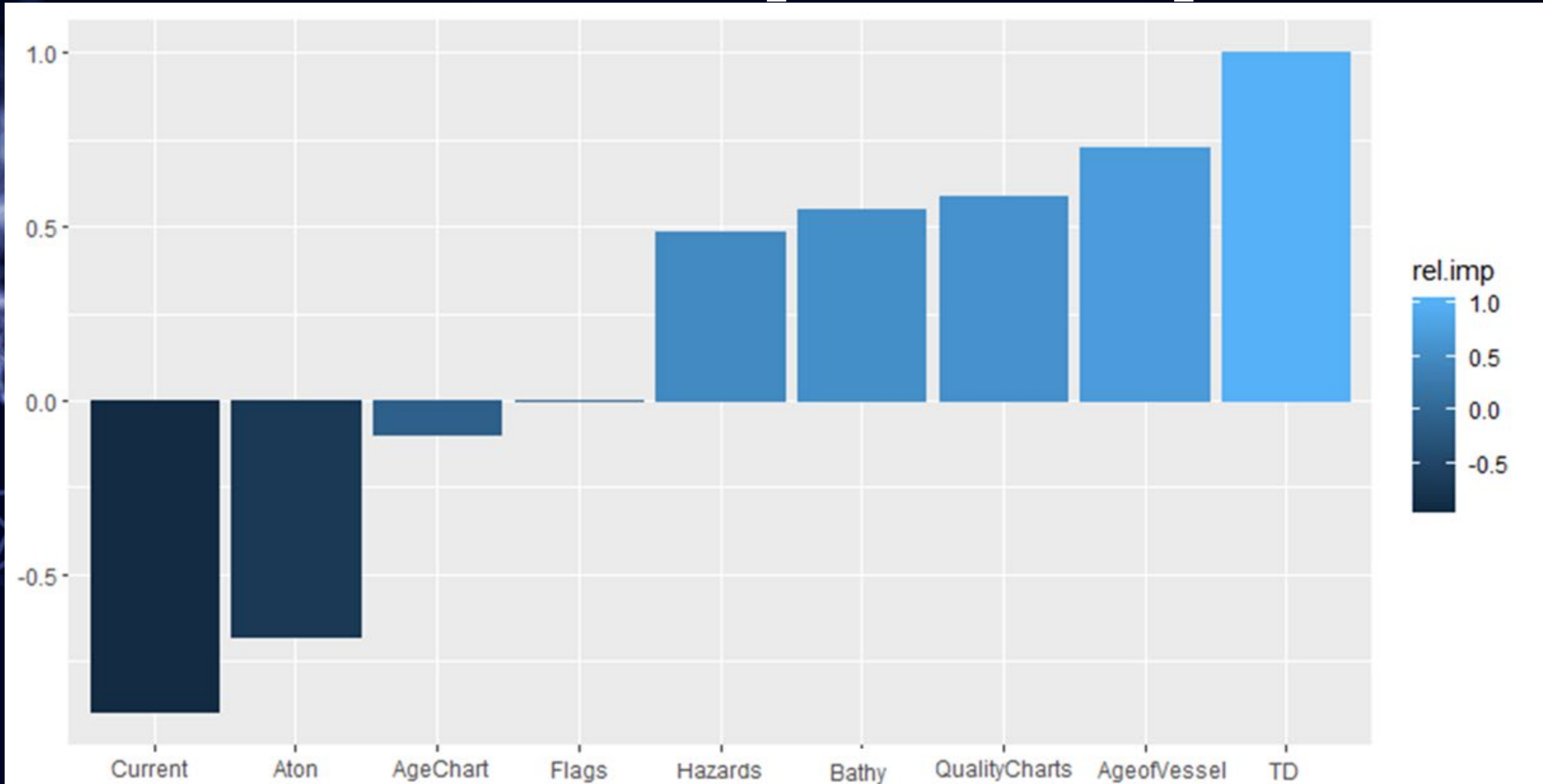


Figure 12: Importance of Variables

# Model Accuracy

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

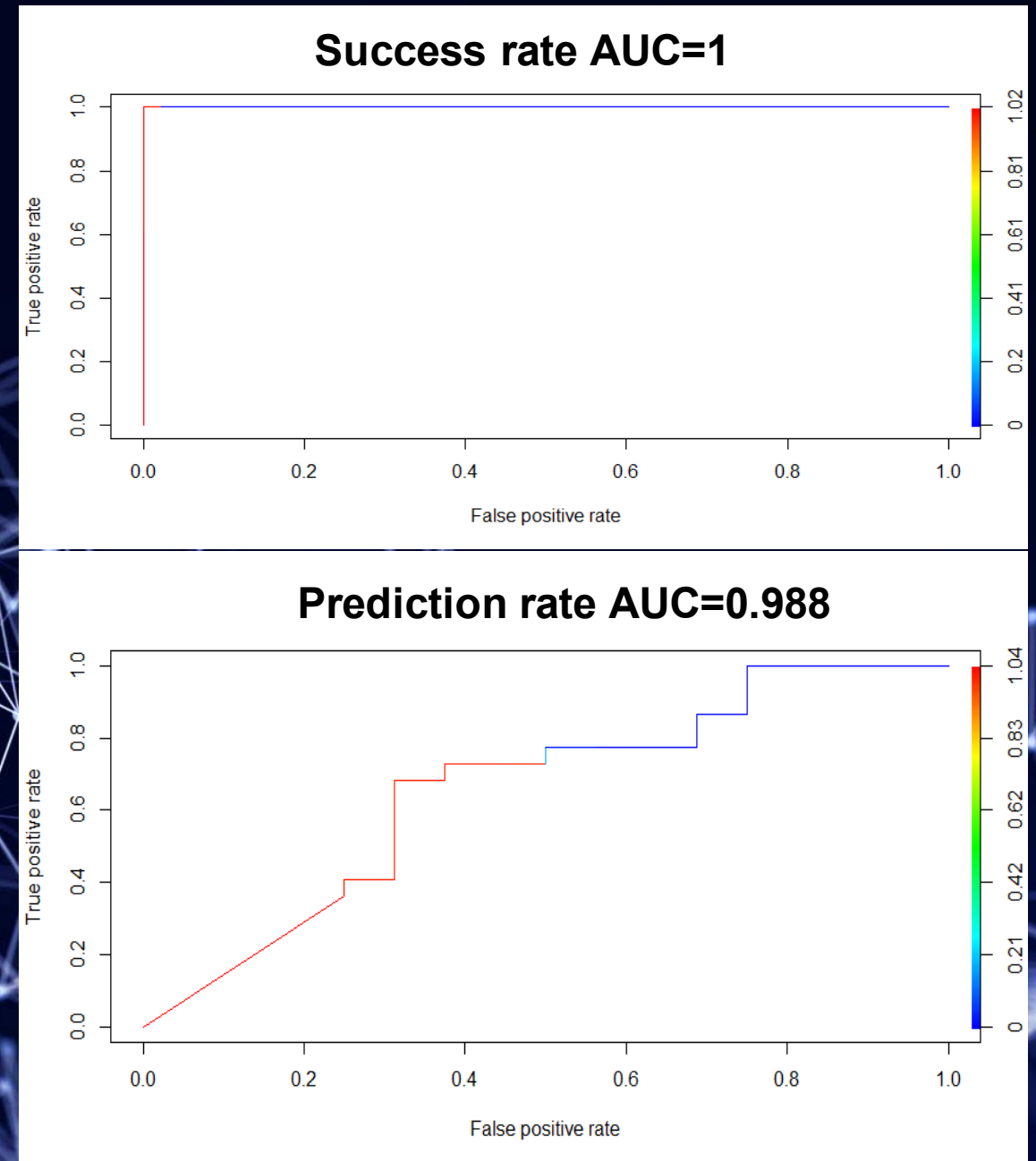


Figure 14: Success Rate and Prediction Rate Response Curves

# ANN Prediction Map

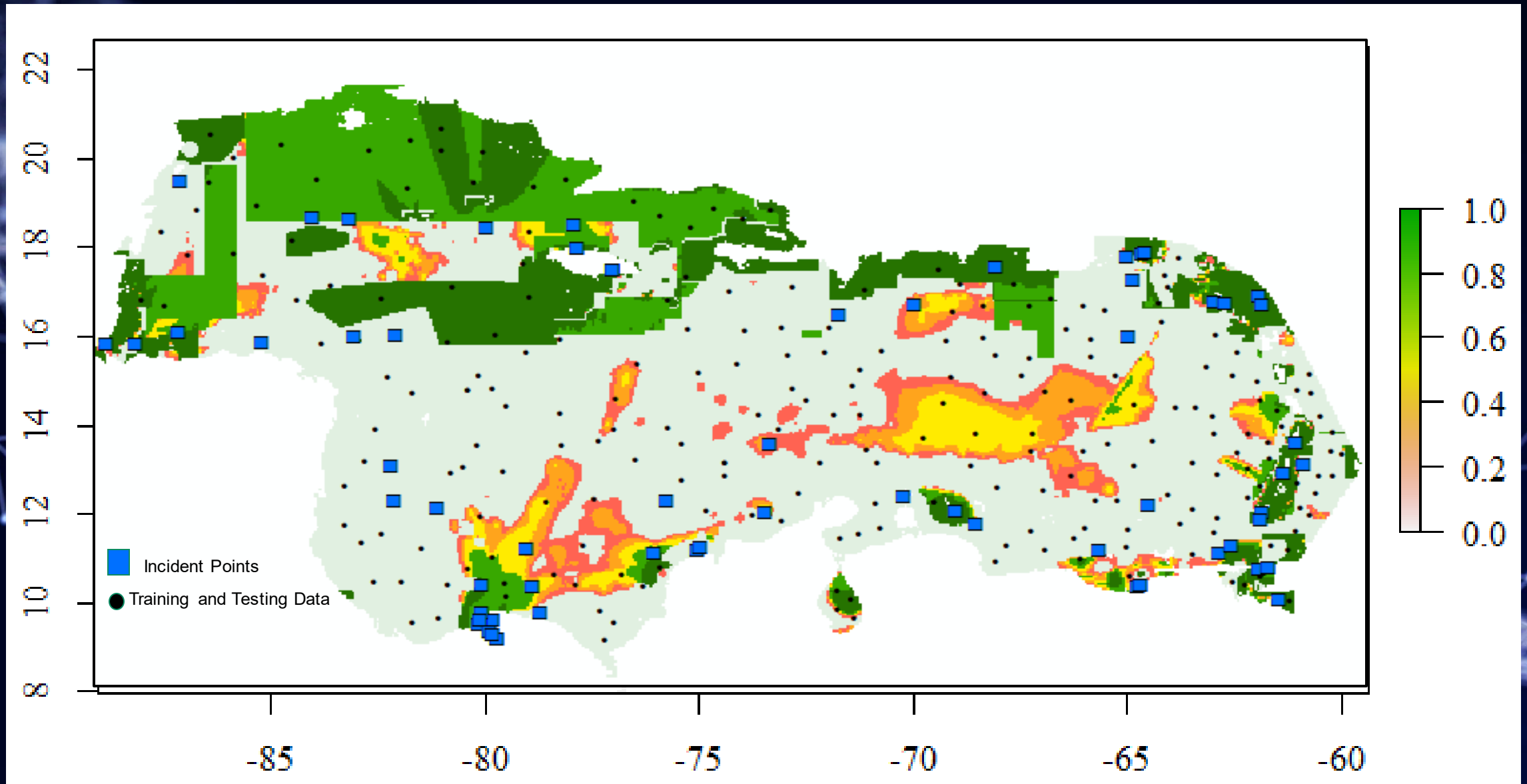


Figure 15: ANN Prediction Map



# 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:

- ➊ 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

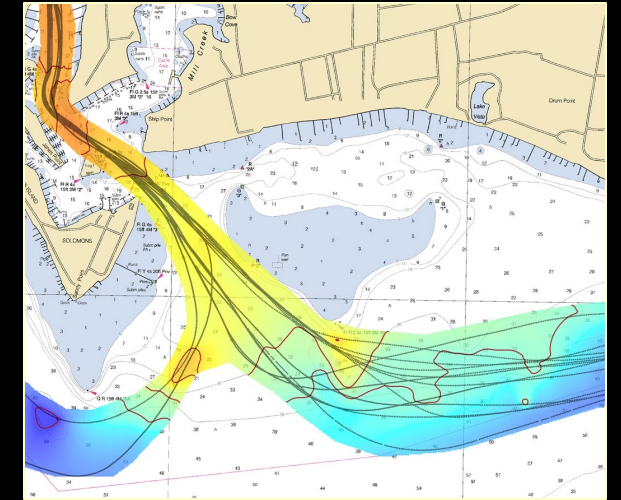


Figure 10: VTMS (Magnus 2016)