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ANALYSIS OF INCREASING THE REQUIRED VMS PING RATE FOR THE CALIFORNIA DRIFT GILLNET FISHERY

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Abstract

To assist the Council with consideration of ping rate alternatives, an analysis of observer data was conducted to characterize the range of DGN vessel speeds while fishing. This analysis uses the 8513 observed sets over the 1990-2014 fishing seasons for which time and location data were available at the start and end of the sets. The objective is to assess the costs and benefits of increasing the DGN VMS ping rate to four times per hour relative to the status quo rate of once per hour. Higher ping rates would presumably provide a higher probability of detecting

prohibited fishing activity. However, our vessel speed analysis calls into question the utility of a higher ping rate for the case of DGN fishing.

Background

The Pacific Fishery Management Council (Council) considered a proposal at its April 2016 meeting to increase the required Vessel Monitoring System (VMS) transmission (ping) rate for Highly Migratory Species (HMS) drift gillnet (DGN) fishing vessels from one to four pings per hour. A further proposal under consideration is to add a continuous transit requirement while traveling through prohibited fishing areas. With a continuous transit requirement, an increased ping rate would presumably allow detection of illegal fishing in closed areas, due to the ability to monitor vessel locations over finer time intervals.

Alternative means to detect DGN fishing activity which would not require increasing the ping rate could include monitoring the speed of DGN vessels between pings at one hour time intervals (the existing requirement), or using other means to detect DGN fishing activity other than high frequency vessel location monitoring. The distance covered between VMS pings at a one hour time interval provides a lower-bound estimate of vessel transit speed which could be compared to the range of drift gillnet fishing speeds to determine whether DGN fishing is occurring. Because DGN fishing involves drifting in the current with an attached net that exceeds one mile in length, vessels engaged in DGN fishing must move at a very low speed. Thus if the vessel movement speed exceeds a few knots, average vessel speed between hourly pings might be used as an indicator that drift gillnet fishing is not occurring. Conversely, slow or zero vessel speed does not provide conclusive evidence of drift gillnet fishing given various other possible explanations for slow movement, which include engine problems or slowing down to engage in other permitted activity such as harpoon fishing.

Data, Methods, and Results

For each set the fishing time was calculated by subtracting the start time from the end time; measuring the distance covered while fishing as the great circle distance [4] from the start location to the end location; and then computing the average speed as the distance covered divided by the fishing time. A list of observer data used in the analysis, including definitions, is provided in Appendix 1; Computer code to carry out the analysis, written in the language R [2], and an R Markdown [3] summary of results are provided in Appendix 2.

Figure 1 is a histogram representing the distribution of DGN fishing speeds. The horizontal axis labels vessel speed ranges included in the figure, and the bar heights represent percentages of observed sets, with the numeric percentages provided inside each bar. The figure documents that over 99% of observed DGN vessel fishing speeds were in the range from 0 to 1.25 knots. The three observations with fishing speeds over 5 knots most likely represent data entry error. Further

analysis shows the median DGN vessel fishing speed was 0.2586 knots and the mean speed was 0.3241 knots, reflecting right skewness in the distribution.

Table 1 and Figure 2 summarize the range of observed DGN vessel fishing speeds as cumulative percentages of observed sets less than each speed shown in the first column (on the horizontal axis of the figure). So, for example, 99.6% of all observed DGN sets showed average speeds below 2 knots, while 99.9% of all observed sets had average speeds below 3.75 knots.

Information provided by DGN fishermen indicates that typical transit speeds range from 7 to 9 knots, although inclement weather may reduce the speed to 3 knots. Some DGN vessels also participate in the albacore troll fishery, which can legally occur inside areas closed to DGN fishing; a typical speed for vessels engaged in albacore troll fishing is 5.5 knots.

Cost Effectiveness Analysis

A further consideration in deciding whether to increase DGN vessel ping rates is the additional benefits of increasing the ping rate compared to the added cost. For the case of DGN fishing, if the ability to meet the regulatory objective would not be improved by increasing the ping rate from one to four per hour, the benefit of increasing the ping rate is unclear. In case no added benefit results from increasing the ping rate, a cost effectiveness analysis as described in the [Regulatory Impact Analysis primer to OMB Circular A-4](#) could be used to compare alternatives in terms of the additional regulatory cost burden due to increasing the ping rate.

Table 2 shows estimated costs of increasing the VMS ping rate from one to four pings per hour based on the range of monthly transmission costs for different vendors provided in [Table 1-8 of the VMS scoping document](#) [1]. The DGN fishing season lasts from mid-August through January each fishing year, for a period of 5.5 months. Assuming the recent participation level of about 20 active DGN fishing vessels will continue, this would increase fleet wide annual operating costs on a range of \$660 to \$14,256 per year. Assuming this constant real dollar cost would continue over a 20 year period and using the 20-year real discount rate of 1.2% specified in [Appendix C to OMB Circular No. A-94](#), the estimated discounted present value of additional future regulatory costs imposed on the DGN fleet due to increasing the ping rate is in the range of \$11,674 to \$252,150. The actual cost would depend upon which of the VMS Vendor options in Table 1-8 were selected for use on DGN vessels.

Alternative Proposal to Increasing Ping Rates or Regulating Vessel Speed

Depending on the ability to control the ping rates of VMS systems, an alternative to increasing ping rates or regulating vessel speed could be to randomize the times when VMS systems ping satellites. If VMS is set up to ping satellites at regular and known intervals (for example, at the beginning of each hour), a vessel could theoretically enter restricted fishing space between pings and return to allowed areas before the next scheduled ping. Although this seems an unlikely scenario for drift gillnet vessels, given the speed of vessel movement while fishing and the time

and effort it takes to set and pull fishing gear, randomizing the frequency of pings could discourage this possibility. For example, if a vessel operator doesn't know if the time between pings will be 20 minutes or 2 hours, they are unlikely to risk entering restricted space. This approach would possibly have the added benefits of not requiring regulation of vessel speed and eliminating the need to increase ping rates, providing cost savings for both vessel owners and fishery managers.

References

- [1] Pacific Fishery Management Council. 2016. April 2016 Council Meeting Agenda Item D.2, Attachment 1: Vessel Movement Monitoring Public Scoping Document.
- [2] R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>
- [3] RStudio. 2013. R Markdown from RStudio. <http://rmarkdown.rstudio.com/>
- [4] Weisstein, E. W. "Great Circle." From MathWorld--A Wolfram Web Resource. <http://mathworld.wolfram.com/GreatCircle.html>

Tables

Table 1. Cumulative distribution of observed DGN vessel fishing speeds.

Cumulative Distribution of DGN Fishing Speeds	
Speed (Knots)	Cumulative Percent
0.25	48.1
0.50	83.6
0.75	94.9
1.00	98.3
1.25	99.1
1.50	99.4
1.75	99.5
2.00	99.6
2.25	99.6
2.50	99.7
2.75	99.7
3.00	99.7
3.25	99.7
3.50	99.8
3.75	99.9
4.00	99.9

Table 2. Estimated Costs to Increasing the VMS Ping Rate.

VMS Vendor	Annual Cost Increase	Net Present Value
McMurdo FMCT/G	1,650	29,184
CLS America Thorium TST A2.0	2,640	46,694
CLS America Thorium LEO A2.0	660	11,674
Faria WatchDog 750VMS	14,256	252,150
Network Innovations - Sailor VMS Gold	8,470	149,811
Network Innovations - Sailor VMS Gold Plus	2,057	36,383
Skymate I 1500	660	11,674

Figures

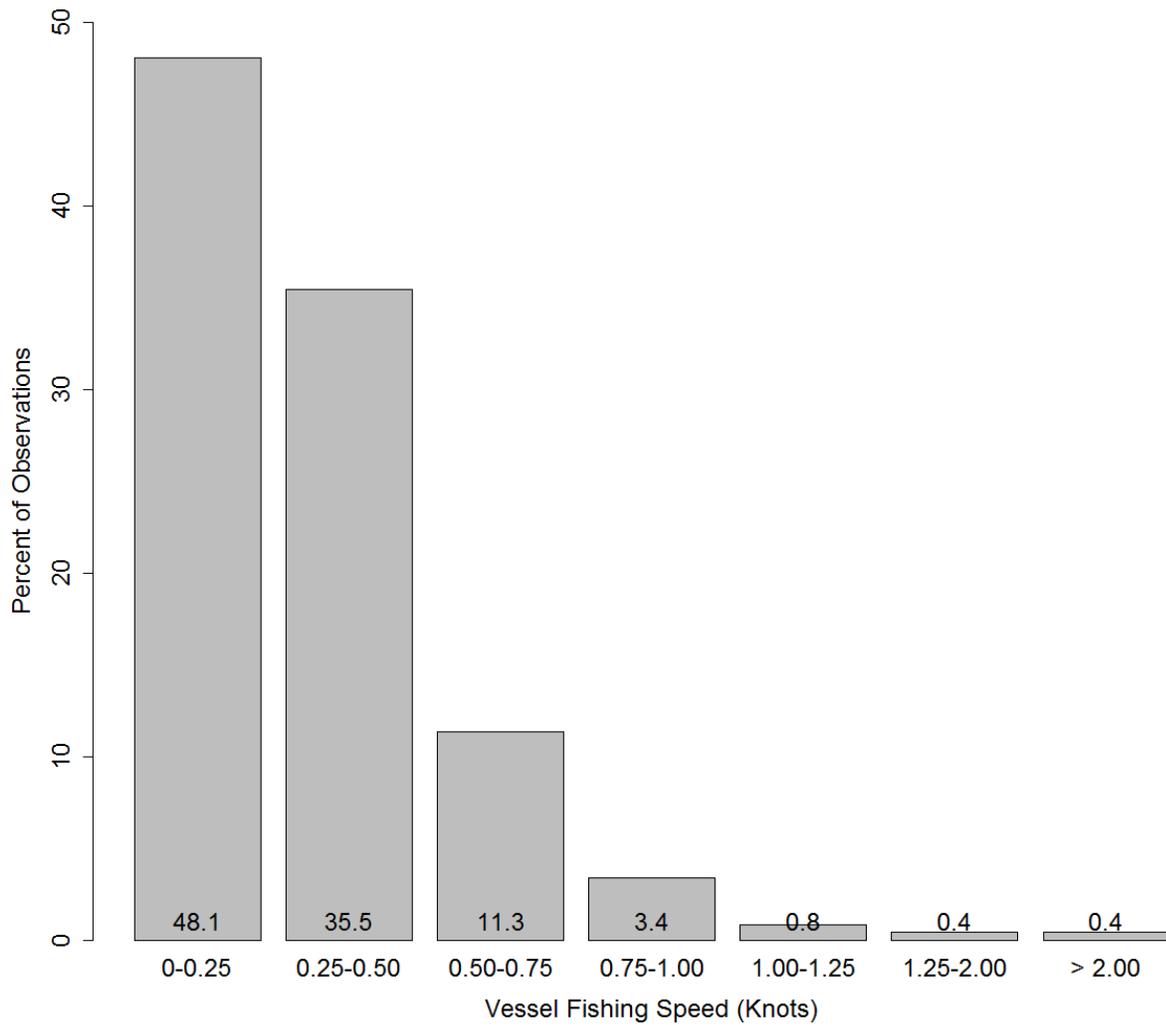


Figure 1. Histogram of observed DGN vessel fishing speeds.

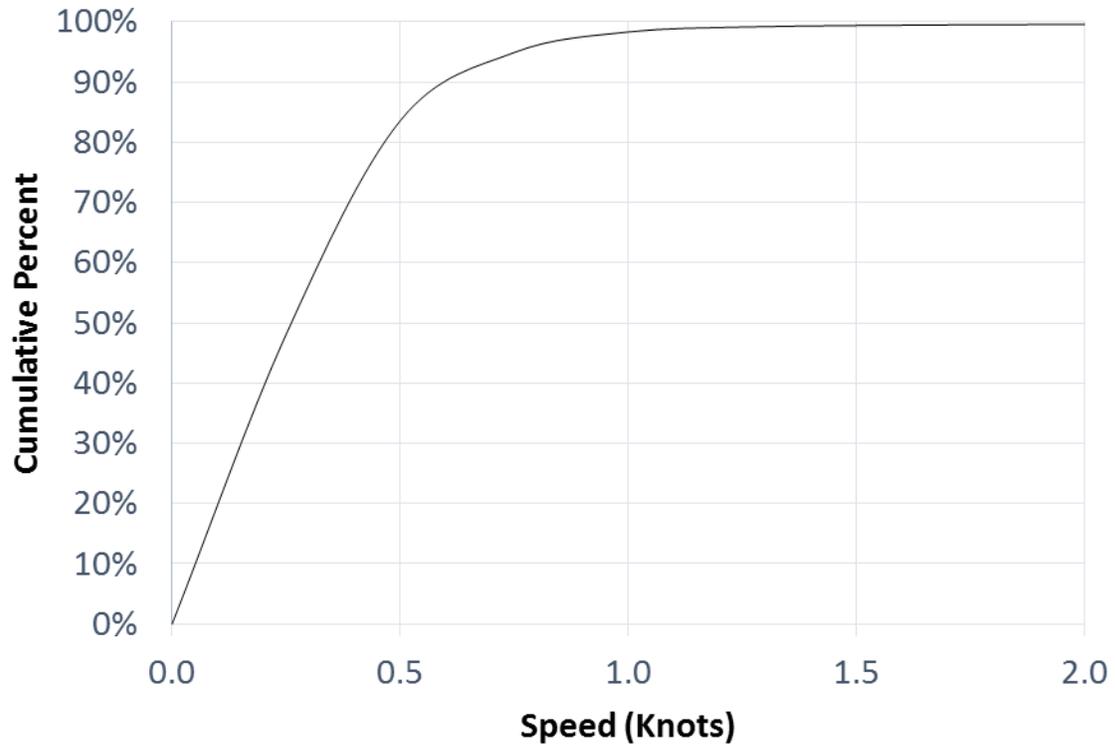


Figure 2. Cumulative distribution of observed DGN vessel fishing speeds.

Appendix 1: Data Field Definitions

- **TripNumber**
- **Set** Set number within trip
- **Season** Year of February 1 - January 31 season
- **Year** Year when set occurred
- **MM** Month of set
- **DD** Day of set
- **LatD1** Degrees north latitude at start of set
- **LatM1** Minutes north latitude at start of set
- **LongD1** Degrees west longitude at start of set
- **LongM1** Minutes west longitude at start of set
- **LatD2** Degrees north latitude at start of pull
- **LatM2** Minutes north latitude at start of pull
- **LongD2** Degrees west longitude at start of pull
- **LongM2** Minutes west longitude at start of pull
- **MM@Set** Month at start of set
- **DD@Set** Day at start of set
- **HH@Set** Hour at start of set
- **NN@Set** Minute at start of set
- **HH@Pul** Hour at end of set
- **NN@Pul** Minute at end of set
- **Soak** Soak time to near hour

Appendix 2: R Code for Data Analysis

Read in the data; omit rows with missing values in fields needed for calculations. 168 records with missing values were dropped, leaving 8,513 records for the analysis.

```
D_all <- read.csv("Set.csv", header=TRUE)
attach(D_all)
# Avoid rows with NAs in fields of interest
NotNA <- !(is.na(HH.Pu1) | is.na(HH.Set) | is.na(NN.Pu1) | is.na(NN.Set) |
is.na(LatD1) | is.na(LatM1) | is.na(LongD1) | is.na(LongM1) | is.na(LatD2) |
is.na(LatM2) | is.na(LongD2)
| is.na(LongM2))
# Only retain observations where data are available to calculate average
speed per set
D <- D_all[NotNA,]
TotSets <- dim(D_all)[1]
rm(D_all, NotNA)
NumKept <- dim(D)[1]
NumDropd <- TotSets - NumKept
NumDropd

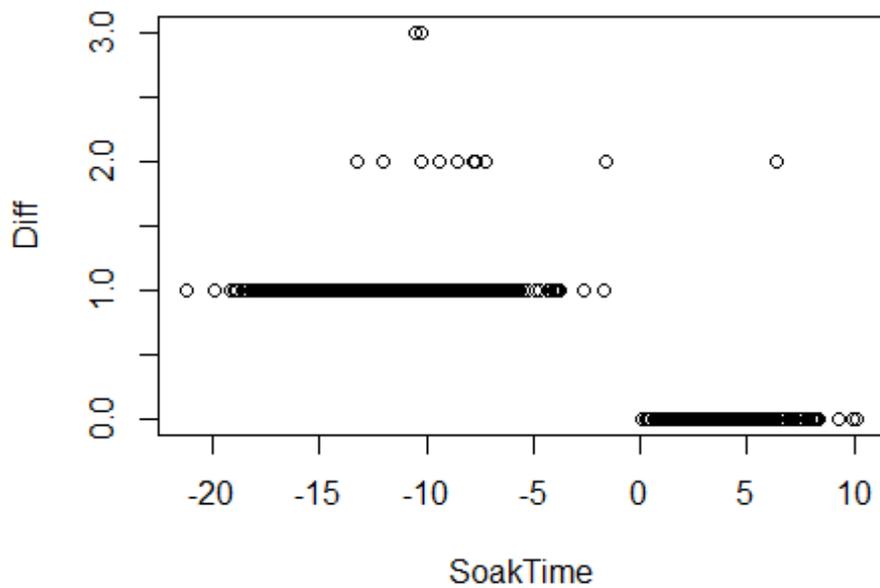
## [1] 168

NumKept

## [1] 8513
```

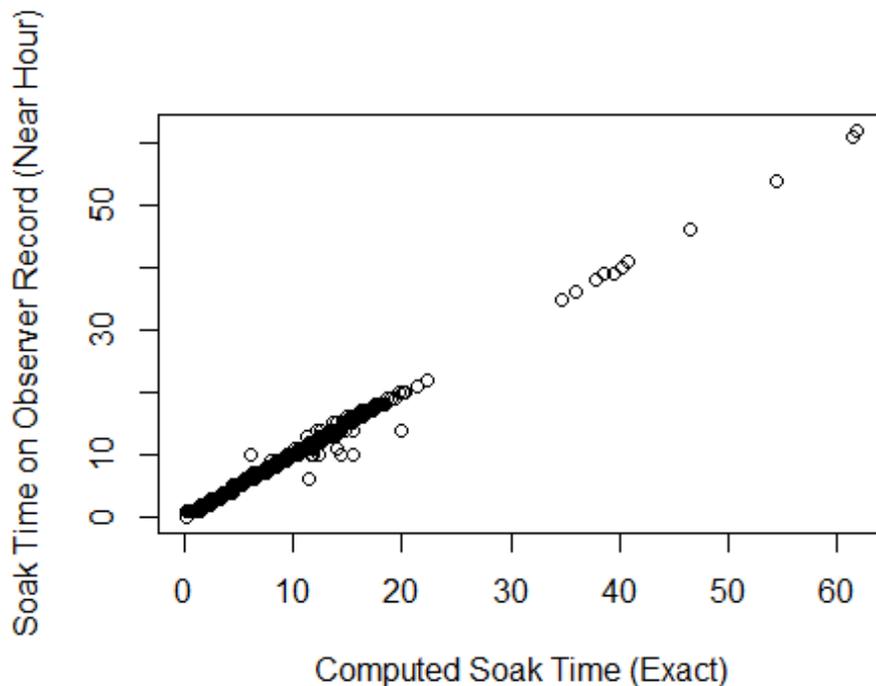
Compute exact fishing time for each set and compare Soak time to near-hour on observer records

```
Start <- D$HH.Set + D$NN.Set/60
End <- D$HH.Pu1 + D$NN.Pu1/60
SoakTime <- End - Start
Diff <- round((D$Soak - SoakTime)/24,0)
plot(SoakTime, Diff)
```



The plot indicates inclusion of trips of greater than 24 hours, which are indicated by $Diff > 0$. Since the set start date is included in the data but not set end date, the SoakTime variable is adjusted by adding in 24 hours times Diff. The plot of the adjusted D\$Soak variable on SoakTime indicates the adjustment worked.

```
SoakTime <- SoakTime + 24*Diff
plot(SoakTime,D$Soak,xlab="Computed Soak Time (Exact)",ylab="Soak Time on
Observer Record (Near Hour)")
```



```
lm.SoakTime <- lm(SoakTime ~ D$Soak - 1)
summary(lm.SoakTime)

##
## Call:
## lm(formula = SoakTime ~ D$Soak - 1)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -3.9081 -0.2197  0.0303  0.2354  6.0187
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## D$Soak  0.9974742    0.0002694    3702  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3126 on 8512 degrees of freedom
## Multiple R-squared:  0.9994, Adjusted R-squared:  0.9994
## F-statistic: 1.371e+07 on 1 and 8512 DF, p-value: < 2.2e-16
```

Compute great circle (Haversine) distances between locations of sets and pulls.

```
# Define Haversine distance function:
```

```
HavrDist <- function(Lat1,Long1,Lat2,Long2,Radius=3443.89849) {
```

```

# Function to compute Haversine ("Great Circle") distance
# between two Lat-Long coordinate pairs
#
# Lat1 = Latitude of first point
# Long1 = Longitude of first point
# Lat2 = Latitude of second point
# Long2 = Longitude of second point
# Radius = radius of the earth in desired units of measurement
#
# Note: North Latitude and east Longitude are positive decimal numbers;
#       south Latitude and west Longitude are negative

#Convert to Radians
Lat1R <- Lat1*pi/180
Long1R <- Long1*pi/180
Lat2R <- Lat2*pi/180
Long2R <- Long2*pi/180

Distance = acos(sin(Lat1R)*sin(Lat2R)+cos(Lat1R)*cos(Lat2R)*cos(Long2R-
Long1R))*Radius

return(Distance)}

Lat1 <- D$LatD1+D$LatM1/60
Long1 <- D$LongD1+D$LongM1/60
Lat2 <- D$LatD2+D$LatM2/60
Long2 <- D$LongD2+D$LongM2/60

Dist <- HavrDist(Lat1,Long1,Lat2,Long2,Radius=3443.89849)

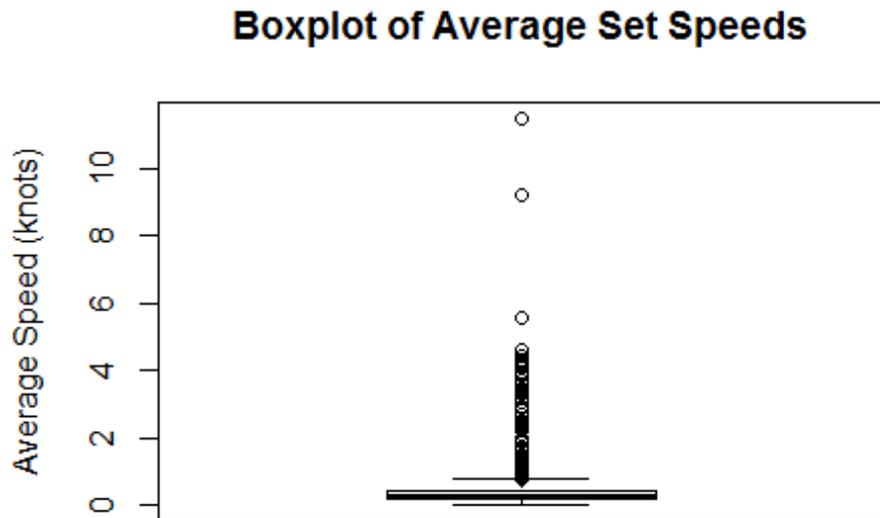
AveSpeed <- Dist/SoakTime
plot(ecdf(AveSpeed),main="C.D.F. of Average Set Speeds",xlab="Set Speed
(knots)",ylab="Cumulative Share of Sets")

```



```
##    9 | 2
##   10 |
##   11 | 5
```

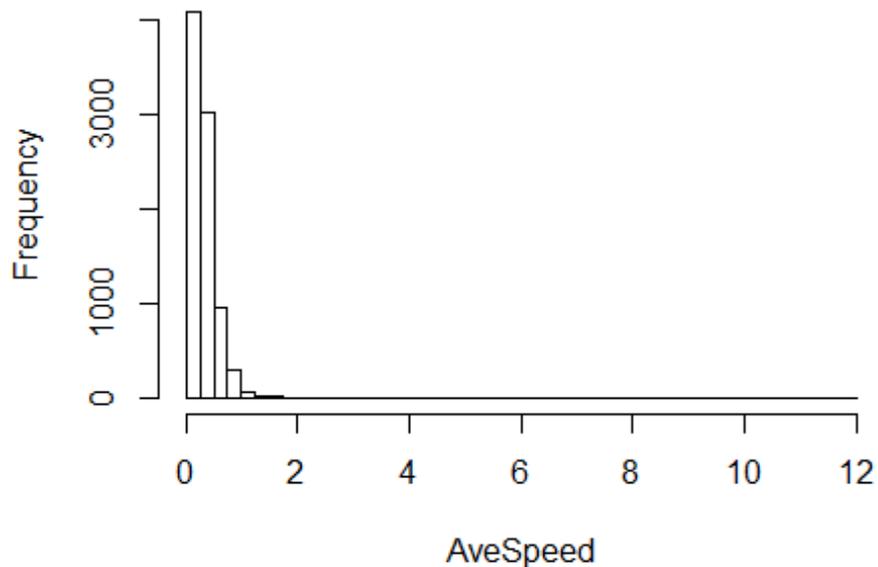
```
boxplot(sort(AveSpeed),main="Boxplot of Average Set Speeds",ylab="Average Speed (knots)")
```



```
# Produce a histogram and frequency distribution of results
```

```
BrkPnts <- (0:48)/4
hist.AveSpeed <- hist(AveSpeed, breaks = BrkPnts,
  freq = TRUE, include.lowest = TRUE, right = TRUE,
  density = NULL, angle = 45, col = NULL, border = NULL,
  main = "Histogram of Average Set Speeds")
```

Histogram of Average Set Speeds



```
hist.AveSpeed$percents <- 25*hist.AveSpeed$density
barheights <- hist.AveSpeed$percents[1:5]
barheights <- c(barheights,sum(hist.AveSpeed$percents[6:8]))
barheights <- c(barheights,100-sum(barheights))
barnames <- c("0-0.25", "0.25-0.50", "0.50-0.75", "0.75-1.00", "1.00-1.25", "1.25-2.00", "> 2.00")
bp <- barplot(barheights,xlab="Vessel Fishing Speed (Knots)",ylim=c(0,50),ylab="Percent of Observations",names.arg=barnames,
              cex.lab=1.5,cex.axis=1.5, cex.names=1.5)
text(bp, 0, round(barheights, 1),cex=1.5,pos=3)
```

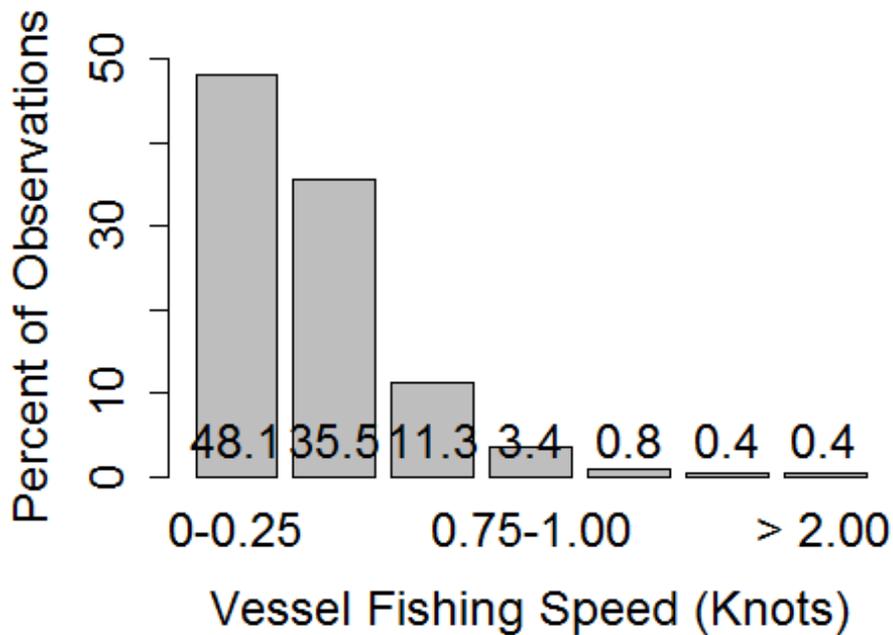


Table of cumulative percentages

```
CumPct <- cumsum(hist.AveSpeed$percents)
CumTbl <- cbind(BrkPnts[2:49], CumPct)
colnames(CumTbl) <- c("Break Points", "Cumulative Percent")
CumTbl
```

```
##      Break Points Cumulative Percent
## [1,]          0.25          48.09115
## [2,]          0.50          83.56631
## [3,]          0.75          94.90191
## [4,]          1.00          98.30847
## [5,]          1.25          99.13074
## [6,]          1.50          99.38917
## [7,]          1.75          99.51838
## [8,]          2.00          99.56537
## [9,]          2.25          99.60061
## [10,]         2.50          99.67109
## [11,]         2.75          99.69458
## [12,]         3.00          99.71808
## [13,]         3.25          99.74157
## [14,]         3.50          99.82380
## [15,]         3.75          99.85904
## [16,]         4.00          99.87079
## [17,]         4.25          99.91777
## [18,]         4.50          99.95301
```

## [19,]	4.75	99.96476
## [20,]	5.00	99.96476
## [21,]	5.25	99.96476
## [22,]	5.50	99.96476
## [23,]	5.75	99.97651
## [24,]	6.00	99.97651
## [25,]	6.25	99.97651
## [26,]	6.50	99.97651
## [27,]	6.75	99.97651
## [28,]	7.00	99.97651
## [29,]	7.25	99.97651
## [30,]	7.50	99.97651
## [31,]	7.75	99.97651
## [32,]	8.00	99.97651
## [33,]	8.25	99.97651
## [34,]	8.50	99.97651
## [35,]	8.75	99.97651
## [36,]	9.00	99.97651
## [37,]	9.25	99.98825
## [38,]	9.50	99.98825
## [39,]	9.75	99.98825
## [40,]	10.00	99.98825
## [41,]	10.25	99.98825
## [42,]	10.50	99.98825
## [43,]	10.75	99.98825
## [44,]	11.00	99.98825
## [45,]	11.25	99.98825
## [46,]	11.50	99.98825
## [47,]	11.75	100.00000
## [48,]	12.00	100.00000

Compute the discounted present value of future costs of increasing the ping rate from one to four times per hour:

```
library(FinCal)
## Warning: package 'FinCal' was built under R version 3.2.3
r <- 1.2/100
n <- 20
# Assume 20 vessels fish each year for 5.5 months using added monthly pinger
# costs from Table 1-8 of VMS scoping doc
# Agenda Item C.2 Attachment 1 April 2016 (reference [1])
PmtVec <- 5.5*20*(c(63,69,38.95,172.8,115.99,38.5,38.95)-
c(48,45,32.95,43.2,38.99,19.8,32.95))
NPV_Cost <- pv.annuity(r, n, -PmtVec, type = 0)
# Double check canned calculation
v <- 1/(1+r)
NPV_Chck <- PmtVec*v*(1-v^n)/(1-v)
cbind(PmtVec, NPV_Cost)
```

```
##      PmtVec  NPV_Cost
## [1,]   1650  29184.04
## [2,]   2640  46694.47
## [3,]    660  11673.62
## [4,]  14256 252150.12
## [5,]   8470 149811.41
## [6,]   2057  36382.77
## [7,]    660  11673.62

NPV_Chck
## [1]  29184.04  46694.47  11673.62 252150.12 149811.41  36382.77  11673.62
```