

Results Section: Antibiotic Resistance Patterns

```
library(staphopia)
library(ggplot2)
library(reshape2)
library(scales)
library(dplyr)

##
## Attaching package: 'dplyr'
## The following objects are masked from 'package:stats':
##   filter, lag
## The following objects are masked from 'package:base':
##   intersect, setdiff, setequal, union
library(gridExtra)

##
## Attaching package: 'gridExtra'
## The following object is masked from 'package:dplyr':
##   combine
library(grid)
produce_all_plots = FALSE
```

In this section we will look into resistance patterns *Staphylococcus aureus*.

Aggregating Data For Public Samples

First we'll get all publicly available *S. aureus* samples.

```
ps <- get_public_samples()
```

MRSA and MSSA

We defined MRSA by the presence of the *mecA*. Samples which did not have evidence for *mecA* were classified as MSSA.

Primer based classification

First we'll use the results from the primer based SCCmec classification to identify samples with full matches to the *mecA* primers. It is important to note these results will only identify SCCmec types containing *mecA* (Example: SCCmec Xi has *mecC* and will not be included in these)

Strict (Full Hits Only)

```
sccmec_primer <- get_sccmec_type(ps$sample_id)
table(sccmec_primer$meca)

##
## FALSE TRUE
## 16206 26743

sccmec_counts <- as.data.frame(colSums(sccmec_primer[,2:11]))
colnames(sccmec_counts) <- c('Total')
sccmec_counts <- data.frame(Type=rownames(sccmec_counts),
                               Total=sccmec_counts$Total)
sccmec_counts

##      Type Total
## 1      I    41
## 2     II   5146
## 3    III   3212
## 4    IV  14016
## 5     V   4301
## 6    VI    28
## 7   VII   4301
## 8  VIII    1
## 9   IX    53
## 10 meca 26743
```

Relaxed (Hamming Distance)

```
sccmec_type_hd <- get_sccmec_type(ps$sample_id,
                                      hamming = TRUE)
table(sccmec_type_hd$meca)

##
##      0    1    2    3    4    5    7    8    9    10   11   12
## 26743  2    1    2    1    2    1   15   128   86    4    1
## 13    15   16   17   18   19   20   21   29   30   42
## 1     12   18   216  4370 10846   460    4    5   30    1
```

Protein Based Classification

```
sccmec_proteins <- get_sccmec_protein_hits(ps$sample_id)
max_score <- group_by(sccmec_proteins,target) %>%
  summarise(maxscore = max(bitscore))
sccmec_proteins <- merge(sccmec_proteins, max_score,
                           by='target')

sccmec_proteins$BSR <- sccmec_proteins$bitscore / sccmec_proteins$maxscore
table(sccmec_proteins[sccmec_proteins$BSR >0.95,]$target)

##
##    blaZ   ccrA1   ccrA2   ccrA3   ccrA4   ccrB1   ccrB2   ccrB3   ccrB4   ccrC1
##    867     773   19521    3279     504     357   19500    1084      31    2279
```

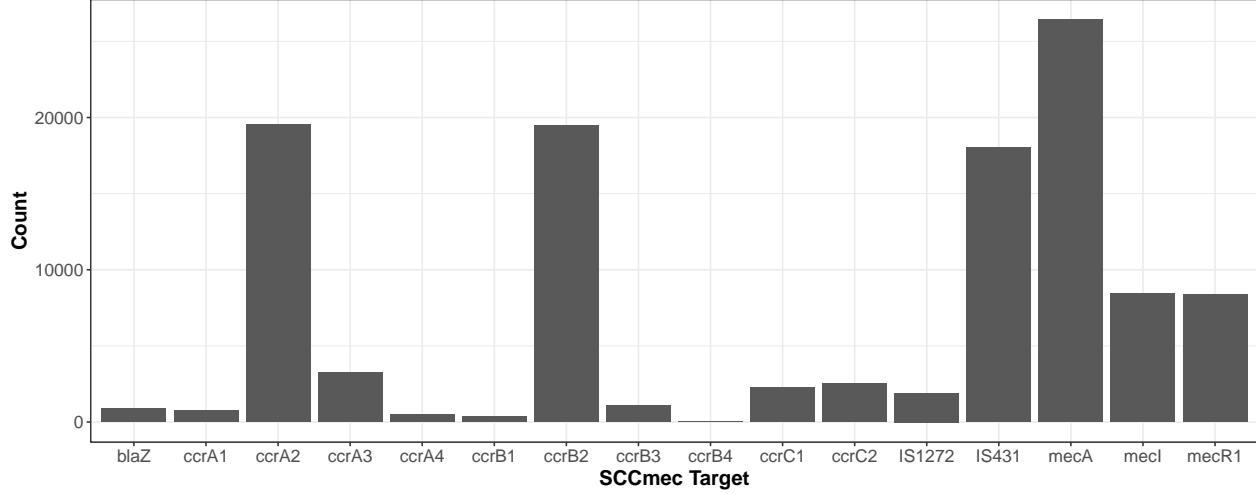
```

##   ccrC2 IS1272  IS431    mecA    mecI  mecR1
##   2534    1909  18021   26430    8434    8360

p <- ggplot(data=sccmec_proteins[sccmec_proteins$BSR > 0.95] ,
             aes(x=target)) +
  ylab("Count") +
  xlab("SCCmec Target") +
  geom_bar() +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14,face="bold"),
        legend.title = element_blank())

```

p

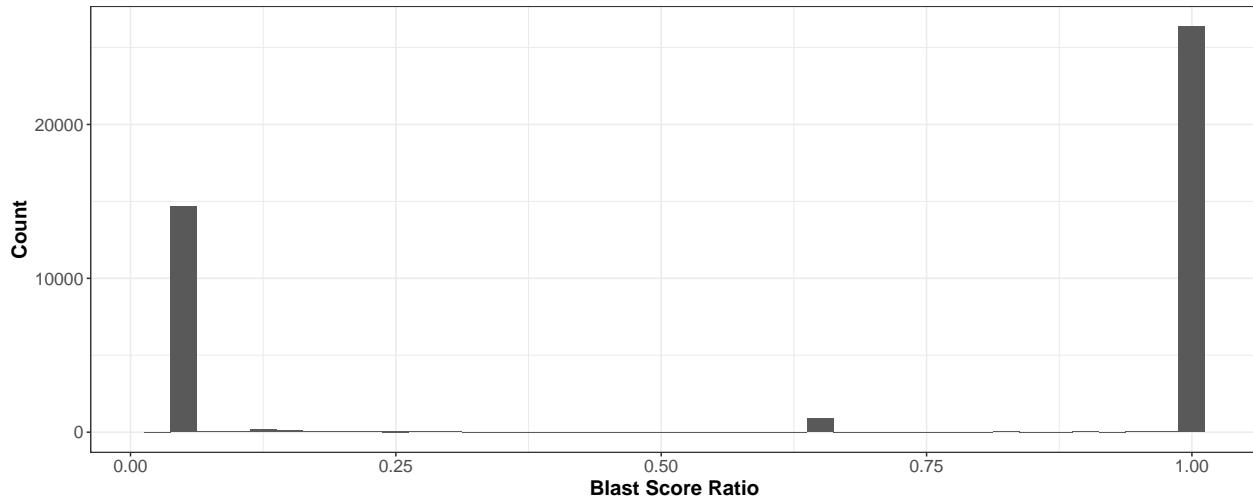


```

a <- sccmec_proteins[sccmec_proteins$target =='mecA',]
sccmec_proteins_mec <- data.frame(sample_id=a$sample_id, BSR=a$BSR)
sccmec_proteins_mec$mec <- ifelse(
  sccmec_proteins_mec$BSR >= 0.95, TRUE, FALSE
)
p <- ggplot(data=sccmec_proteins_mec, aes(x=BSR)) +
  xlab("Blast Score Ratio") +
  ylab("Count") +
  geom_histogram(binwidth = 0.025) +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14,face="bold"),
        legend.title = element_blank())

```

p



```

a <- hist(sccmec_proteins_mec$BSR, plot=FALSE)
meca_bsr <- data.frame(
  region=sapply(1:length(a$counts), function(x){
    paste0(a$breaks[x] , " - ",a$breaks[x+1])
  }),
  count=a$counts
)
meca_bsr

##          region count
## 1      0 - 0.05    21
## 2     0.05 - 0.1 14731
## 3     0.1 - 0.15   243
## 4     0.15 - 0.2   133
## 5     0.2 - 0.25   120
## 6     0.25 - 0.3    60
## 7     0.3 - 0.35    45
## 8     0.35 - 0.4    26
## 9     0.4 - 0.45    26
## 10    0.45 - 0.5    17
## 11    0.5 - 0.55    23
## 12    0.55 - 0.6    24
## 13    0.6 - 0.65    23
## 14    0.65 - 0.7   879
## 15    0.7 - 0.75    18
## 16    0.75 - 0.8    24
## 17    0.8 - 0.85    33
## 18    0.85 - 0.9    13
## 19    0.9 - 0.95    51
## 20    0.95 - 1 26430

```

Ariba based classification

We can use the results from Ariba (via MEGARes) to identify samples with predicted resistance to methicillin. We will do this in two ways, first by only looking at results with a match (strict), and the other being those results that include partial assemblies (relaxed). A reminder, the Ariba results only include samples with paired end reads.

Strict

These results are based on the a match to a SCCmec related cluster.

```
ariba <- get_sccmec_ariba(ps$sample_id, resistance_report = TRUE)
table(ariba$mec)

## 
## FALSE TRUE
## 15342 27120
```

Relaxed

These results allow for partial matches to a SCCmec related cluster.

```
ariba_relaxed <- get_sccmec_ariba(ps$sample_id,
                                     resistance_report = TRUE,
                                     include_all=TRUE)
table(ariba_relaxed$mec)

## 
## FALSE TRUE
## 14621 27841
```

SCCmec Cassette Coverage

```
sccmec_coverage <- get_sccmec_cassette_coverages(ps$sample_id)
```

Group By Most Covered SCCmec Type

```
top_type <- sccmec_coverage %>% group_by(sample_id) %>% slice(
  which.max(total)
)
table(top_type[top_type$total > 0.5,]$cassette)

## 
##     I   IIa   IIe   III   IVa   IVb   IVc   IVe   IVg   IWh   IVi   IVj   IVl   V    VI
##   688 5156    26 2801 5540    98  549   829   206   280   178 6586   250 1188   170
##    VII VIII      X   XI
##    12   452    19  895
length(top_type[top_type$total > 0.5,]$cassette)

## [1] 25923
```

Group By Most Covered *mec* Region

```
top_mec <- sccmec_coverage %>% group_by(sample_id) %>% slice(
  which.max(meca_total)
)
table(top_mec[top_mec$total > 0.5,]$cassette)
```

```

##          I   IIa   IIe   III   IVa   IVb   IVc   IVe   IVg   IVh   IVi   IVj   IVl   IX      V
## 1642    468  2268  1221  2020  1942  1521  1643  1512  1198  1600  1193  1412  1329  844
##       VI    VII  VIII     X    XI
##    772    975  1300   169   894

```

Plot Of Top SCCmec Covered and *mec* Region Covered

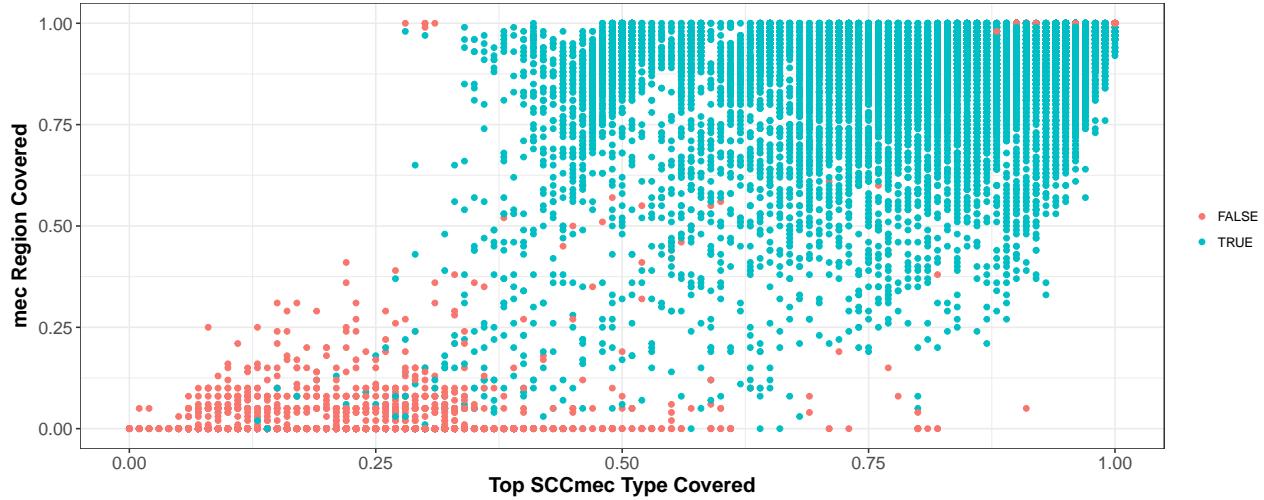
mec Predicted By Primers

```

p <- ggplot(data=merge(top_type, sccmec_primer, by='sample_id'),
             aes(total, meca_total, colour = meca)) +
  ylab("mec Region Covered") +
  xlab("Top SCCmec Type Covered") +
  geom_point() +
  scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14,face="bold"),
        legend.title = element_blank())

```

p



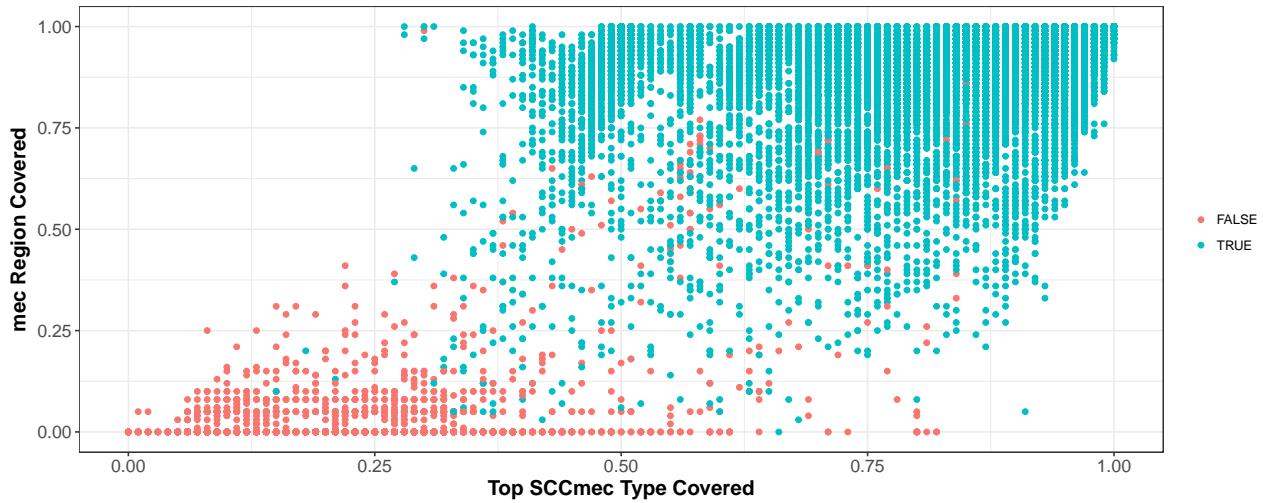
mec Predicted By Ariba (Strict)

```

p <- ggplot(data=merge(top_type, ariba, by='sample_id'),
             aes(total, meca_total, colour = mec)) +
  ylab("mec Region Covered") +
  xlab("Top SCCmec Type Covered") +
  geom_point() +
  scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14,face="bold"),
        legend.title = element_blank())

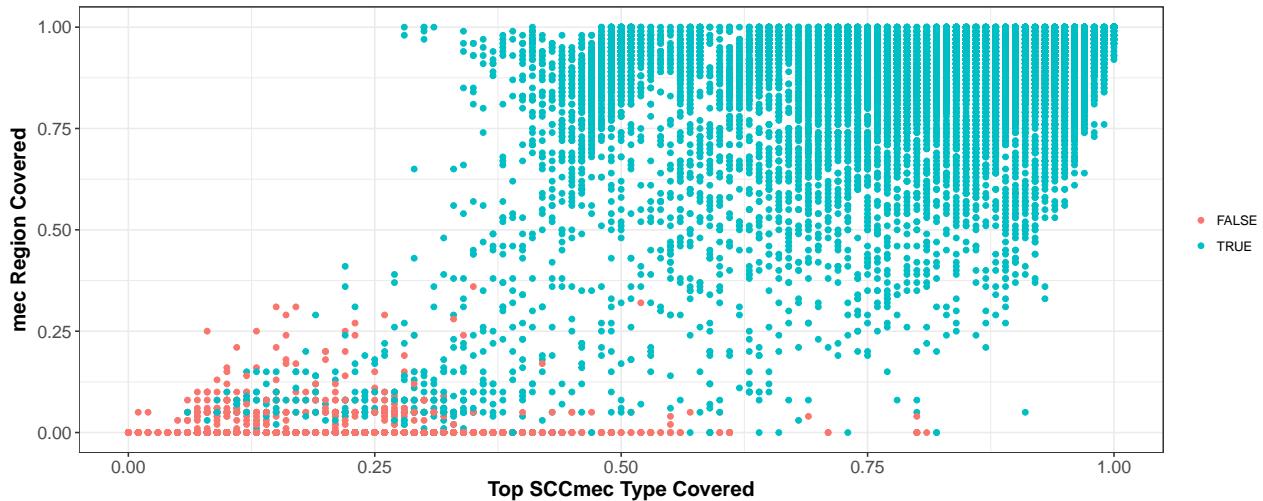
```

p



mec Predicted By Ariba (Relaxed)

```
p <- ggplot(data=merge(top_type, ariba_relaxed, by='sample_id'),
             aes(total, meca_total, colour = mec)) +
  ylab("mec Region Covered") +
  xlab("Top SCCmec Type Covered") +
  geom_point() +
  scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14, face="bold"),
        legend.title = element_blank())
p
```



Plot Of SCCmec Covered and Top *mec* Region Covered

mec Predicted By Primers

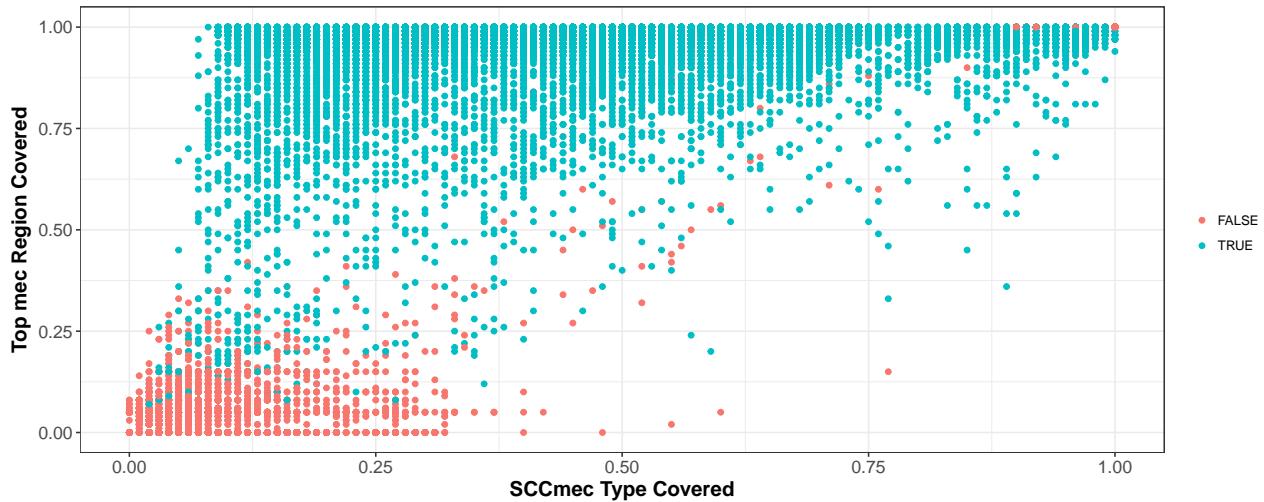
```
p <- ggplot(data=merge(top_mec, sccmec_primer, by='sample_id'),
             aes(total, meca_total, colour = meca)) +
```

```

    ylab("Top mec Region Covered") +
    xlab("SCCmec Type Covered") +
    geom_point() +
    scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
    theme_bw() +
    theme(axis.text=element_text(size=12),
          axis.title=element_text(size=14,face="bold"),
          legend.title = element_blank())

```

p



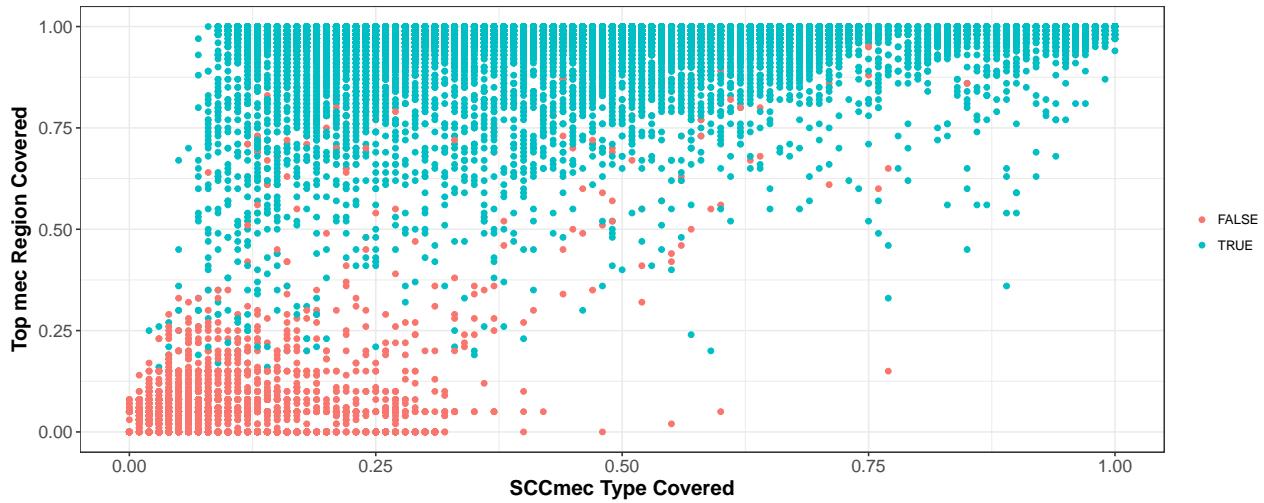
mec Predicted By Ariba (Strict)

```

p <- ggplot(data=merge(top_mec, ariba, by='sample_id'),
             aes(total, meca_total, colour = mec)) +
    ylab("Top mec Region Covered") +
    xlab("SCCmec Type Covered") +
    geom_point() +
    scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
    theme_bw() +
    theme(axis.text=element_text(size=12),
          axis.title=element_text(size=14,face="bold"),
          legend.title = element_blank())

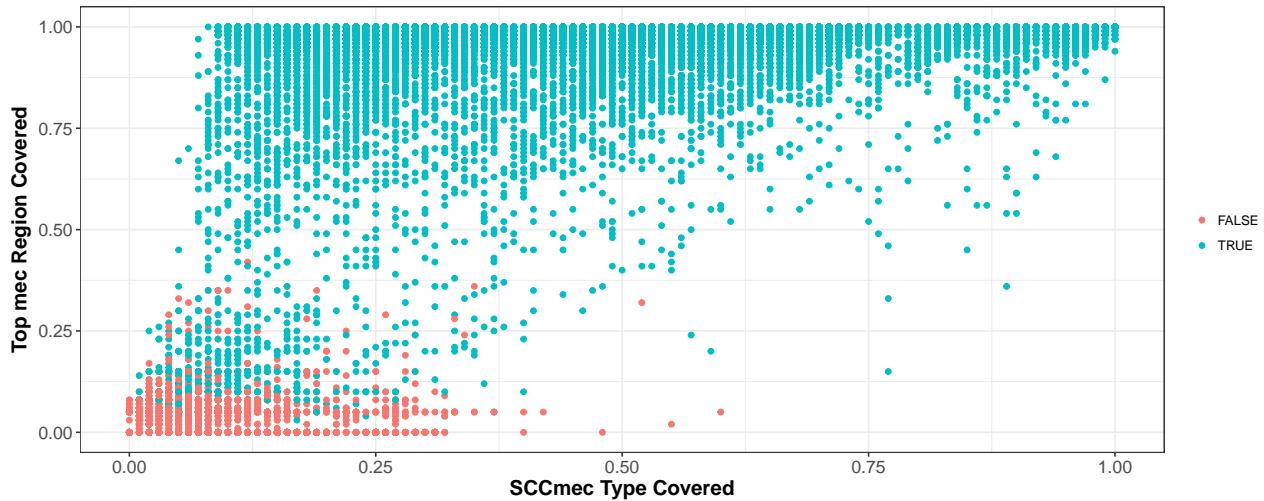
```

p



mec Predicted By Ariba (Relaxed)

```
p <- ggplot(data=merge(top_mec, ariba_relaxed, by='sample_id'),
             aes(total, meca_total, colour = mec)) +
  ylab("Top mec Region Covered") +
  xlab("SCCmec Type Covered") +
  geom_point() +
  scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14, face="bold"),
        legend.title = element_blank())
p
```



Plot of Each SCCmec Type Individually

Function For Plotting

```
plot_by_sccmectype <- function(coverage, column) {
  p <- ggplot(data=coverage,
```

```

        aes(x=total, y=meca_total, colour = mec)) +
    ylab("mec Region Covered") +
    xlab(paste0("SCCmec Type ", column," Covered")) +
    geom_point() +
    scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
    theme_bw() +
    theme(axis.text=element_text(size=12),
          axis.title=element_text(size=14,face="bold"),
          legend.title = element_blank())
  return(p)
}

```

Each SCCmec Type Individually (Colored By Ariba (Strict))

```

if (produce_all_plots) {
  for (column in unique(sccmec_coverage$cassette)) {
    print(plot_by_sccmectype(
      merge(sccmec_coverage[sccmec_coverage$cassette == column,],
            ariba,
            by='sample_id'),
      column
    )))
  }
}

```

Each SCCmec Type Individually (Colored By Ariba (Relaxed))

```

if (produce_all_plots) {
  for (column in unique(sccmec_coverage$cassette)) {
    print(plot_by_sccmectype(
      merge(sccmec_coverage[sccmec_coverage$cassette == column,],
            ariba_relaxed,
            by='sample_id'),
      column
    )))
  }
}

```

Compare *mec* Predictions

```

mec <- merge(
  ps,
  data.frame(
    sample_id=sccmec_proteins_mec$sample_id,
    protein_mec=sccmec_proteins_mec$mec
  ),
  by='sample_id',
  all=TRUE
)
mec[is.na(mec$protein_mec),]$protein_mec <- FALSE
mec <- merge(mec, data.frame(
  sample_id=sccmec_primer$sample_id,

```

```

primer_mec=sccmec_primer$meca
), by='sample_id', all=TRUE)
mec <- merge(mec, data.frame(
  sample_id=ariba$sample_id,
  ariba_mec=ariba$mec
), by='sample_id', all=TRUE)
mec$agreement <- paste0(
  ifelse(mec$protein_mec, 1, 0),
  ifelse(mec$primer_mec, 1, 0),
  ifelse(is.na(mec$ariba_mec), ' ', ifelse(
    mec$ariba_mec, 1, 0
  )))
)
table(mec$agreement)

## 
##   00-    000    001    01-    010    011    101    11-    110    111
##   211  15110   875     12    152   159     10    264     80  26076

```

Notes

- 0: **mec** not predicted
- 1: **mec** predicted
- -: Not tested by Ariba (Single-End reads)

The order of numbering is:

- 1: **mecA** with BSR > 0.95 based on Proteins
- 2: **mecA** with full Primer hit
- 3: **mec** with full match based on Ariba

Example:

- 00- : Single-End, Protein and Primer are False
- 0000 : All approaches agree that **mec** is not predicted
- 1111 : All approaches agree that **mec** is predicted

```

metrics <- merge(
  ps,
  merge(
    get_assembly_stats(ps$sample_id),
    merge(
      get_metadata(ps$sample_id),
      get_sequence_quality(ps$sample_id, stage='cleanup'),
      by='sample_id'
    ),
    by='sample_id'
  ),
  by='sample_id'
)
metrics$year <- sapply(
  metrics$first_public,
  function(x) {
    strsplit(x, "-")[[1]][1]
  }
)

```

```

metrics$rank_name <- ifelse(
  metrics$rank.x == 3,
  'Gold',
  ifelse(
    metrics$rank.x == 2,
    'Silver',
    'Bronze'
  )
)
platform <- metrics[,c('sample_id', 'instrument_model', 'total_contig', 'study_accession', 'rank_name')]
mec_temp <- merge(mec, platform, by='sample_id')

table(mec_temp[mec_temp$agreement == '111',]$study_accession)

## #PRJEB10262 PRJEB10403 PRJEB10686 PRJEB11177 PRJEB11281 PRJEB11627
## 10 1 3 648 6 9
## PRJEB1182 PRJEB12240 PRJEB12333 PRJEB12419 PRJEB12470 PRJEB12513
## 75 8 25 2 97 33
## PRJEB12552 PRJEB12734 PRJEB12950 PRJEB13165 PRJEB13482 PRJEB1411
## 35 1 1 448 693 20
## PRJEB14152 PRJEB14187 PRJEB14251 PRJEB14381 PRJEB14648 PRJEB14723
## 2 3 27 1 25 9
## PRJEB14759 PRJEB14816 PRJEB14975 PRJEB15192 PRJEB15231 PRJEB15409
## 1 63 12 69 92 22
## PRJEB15413 PRJEB15428 PRJEB17079 PRJEB17615 PRJEB18725 PRJEB18732
## 9 10 14 114 9 107
## PRJEB1915 PRJEB19362 PRJEB19432 PRJEB19505 PRJEB19874 PRJEB2076
## 1515 41 5 124 113 211
## PRJEB2096 PRJEB2097 PRJEB21460 PRJEB21660 PRJEB2173 PRJEB22380
## 99 193 2 2 120 43
## PRJEB22689 PRJEB2295 PRJEB2394 PRJEB2478 PRJEB2489 PRJEB2510
## 42 253 108 174 58 149
## PRJEB2561 PRJEB2627 PRJEB2655 PRJEB2686 PRJEB2737 PRJEB2755
## 324 69 977 1048 91 1
## PRJEB2756 PRJEB2812 PRJEB2848 PRJEB2858 PRJEB2870 PRJEB2881
## 1042 163 4 24 444 48
## PRJEB2912 PRJEB2944 PRJEB2998 PRJEB3006 PRJEB3037 PRJEB3068
## 14 316 66 18 98 156
## PRJEB3144 PRJEB3174 PRJEB3201 PRJEB4140 PRJEB4141 PRJEB4438
## 287 2211 510 1686 485 13
## PRJEB4475 PRJEB4506 PRJEB4917 PRJEB4980 PRJEB5042 PRJEB5225
## 50 1 5 13 52 7
## PRJEB5261 PRJEB5707 PRJEB6236 PRJEB6625 PRJEB6993 PRJEB7089
## 221 519 8 128 2 414
## PRJEB7209 PRJEB7654 PRJEB8084 PRJEB8104 PRJEB8247 PRJEB8645
## 7 69 327 1 77 24
## PRJEB8895 PRJEB8896 PRJEB8897 PRJEB8898 PRJEB8899 PRJEB9193
## 1 1 1 1 1 16
## PRJEB9390 PRJEB9575 PRJEB9644 PRJNA157545 PRJNA158759 PRJNA158761
## 974 6 13 18 2 2
## PRJNA158765 PRJNA158769 PRJNA158771 PRJNA158773 PRJNA158775 PRJNA158777
## 2 2 2 2 2 2
## PRJNA158779 PRJNA158781 PRJNA158783 PRJNA158785 PRJNA158787 PRJNA158789

```

```

##          2          2          2          2          2          2
## PRJNA158791 PRJNA158793 PRJNA158795 PRJNA158797 PRJNA158799 PRJNA158801
##          2          2          2          2          2          2
## PRJNA158803 PRJNA160947 PRJNA167119 PRJNA170479 PRJNA171265 PRJNA171266
##          2          3          1         13          2          2
## PRJNA171267 PRJNA171268 PRJNA171269 PRJNA171270 PRJNA171271 PRJNA171272
##          2          2          2          2          2          2
## PRJNA171273 PRJNA171274 PRJNA171276 PRJNA171277 PRJNA171278 PRJNA172413
##          2          2          2          2          1          1
## PRJNA172414 PRJNA172415 PRJNA172419 PRJNA172442 PRJNA173467 PRJNA173468
##          1          1          1          2          2          2
## PRJNA173469 PRJNA173470 PRJNA173471 PRJNA173472 PRJNA173473 PRJNA173474
##          2          2          2          2          2          2
## PRJNA173475 PRJNA173476 PRJNA173477 PRJNA173478 PRJNA173480 PRJNA173481
##          2          2          2          2          2          2
## PRJNA176856 PRJNA177560 PRJNA184888 PRJNA185253 PRJNA185254 PRJNA192952
##          5          1          2          1          1         29
## PRJNA202376 PRJNA203440 PRJNA203445 PRJNA206507 PRJNA214785 PRJNA216155
##          6          3         289         118         29          1
## PRJNA216156 PRJNA216157 PRJNA216158 PRJNA216159 PRJNA216160 PRJNA216161
##          1          1          1          1          1          1
## PRJNA216162 PRJNA216163 PRJNA216164 PRJNA216165 PRJNA216166 PRJNA216167
##          1          1          1          1          1          1
## PRJNA216168 PRJNA216169 PRJNA216170 PRJNA216171 PRJNA216173 PRJNA216174
##          1          1          1          1          1          1
## PRJNA216175 PRJNA216176 PRJNA216177 PRJNA216178 PRJNA216180 PRJNA216181
##          1          1          1          1          1          1
## PRJNA216182 PRJNA216183 PRJNA216184 PRJNA216185 PRJNA216186 PRJNA216187
##          1          1          1          1          1          1
## PRJNA216188 PRJNA216189 PRJNA216190 PRJNA216191 PRJNA216192 PRJNA216193
##          1          1          1          1          1          1
## PRJNA216194 PRJNA216195 PRJNA216196 PRJNA216197 PRJNA216198 PRJNA216199
##          1          1          1          1          1          1
## PRJNA216200 PRJNA216201 PRJNA216202 PRJNA216203 PRJNA216204 PRJNA216205
##          1          1          1          1          1          1
## PRJNA216206 PRJNA216207 PRJNA216208 PRJNA216209 PRJNA216210 PRJNA216211
##          1          1          1          1          1          1
## PRJNA216212 PRJNA216213 PRJNA216214 PRJNA216215 PRJNA216217 PRJNA216218
##          1          1          1          1          1          1
## PRJNA216219 PRJNA216220 PRJNA216221 PRJNA216222 PRJNA216223 PRJNA216224
##          1          1          1          1          1          1
## PRJNA216225 PRJNA216226 PRJNA216227 PRJNA216228 PRJNA216229 PRJNA216230
##          1          1          1          1          1          1
## PRJNA216231 PRJNA216232 PRJNA216233 PRJNA216234 PRJNA216235 PRJNA216236
##          1          1          1          1          1          1
## PRJNA216237 PRJNA216238 PRJNA216239 PRJNA216240 PRJNA216241 PRJNA216242
##          1          1          1          1          1          1
## PRJNA216243 PRJNA216244 PRJNA216245 PRJNA216246 PRJNA216247 PRJNA216248
##          1          1          1          1          1          1
## PRJNA216249 PRJNA216250 PRJNA216251 PRJNA216252 PRJNA216253 PRJNA216254
##          1          1          1          1          1          1
## PRJNA216255 PRJNA216256 PRJNA216257 PRJNA216258 PRJNA216259 PRJNA216260
##          1          1          1          1          1          1
## PRJNA216261 PRJNA216262 PRJNA216263 PRJNA216264 PRJNA216265 PRJNA216266

```

```

##          1          1          1          1          1          1
## PRJNA216268 PRJNA216269 PRJNA216270 PRJNA216271 PRJNA216272 PRJNA216273
##          1          1          1          1          1          1
## PRJNA216274 PRJNA216275 PRJNA216276 PRJNA216277 PRJNA216278 PRJNA216279
##          1          1          1          1          1          1
## PRJNA216280 PRJNA216281 PRJNA216282 PRJNA216283 PRJNA216284 PRJNA216285
##          1          1          1          1          1          1
## PRJNA216286 PRJNA216287 PRJNA216288 PRJNA216289 PRJNA216290 PRJNA216291
##          1          1          1          1          1          1
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##          1          1          1          1          1          1
## PRJNA228514 PRJNA228515 PRJNA228516 PRJNA228517 PRJNA228518 PRJNA228519
##          1          1          1          1          1          1
## PRJNA228520 PRJNA228521 PRJNA228522 PRJNA228523 PRJNA228524 PRJNA228525
##          1          1          1          1          1          1
## PRJNA228526 PRJNA228528 PRJNA228529 PRJNA228530 PRJNA228531 PRJNA228532
##          1          1          1          1          1          1
## PRJNA228533 PRJNA228534 PRJNA228535 PRJNA228536 PRJNA228537 PRJNA228538
##          1          1          1          1          1          1
## PRJNA228539 PRJNA228540 PRJNA228541 PRJNA228542 PRJNA228543 PRJNA228544

```

```

##          1          1          1          1          1          1
## PRJNA228545 PRJNA228546 PRJNA228547 PRJNA228548 PRJNA228549 PRJNA228550
##          1          1          1          1          1          1
## PRJNA228551 PRJNA228552 PRJNA228553 PRJNA228554 PRJNA228555 PRJNA228556
##          1          1          1          1          1          1
## PRJNA228557 PRJNA228558 PRJNA228559 PRJNA228560 PRJNA228561 PRJNA228562
##          1          1          1          1          1          1
## PRJNA228563 PRJNA228564 PRJNA228565 PRJNA228566 PRJNA228567 PRJNA228568
##          1          1          1          1          1          1
## PRJNA228569 PRJNA228570 PRJNA228571 PRJNA228572 PRJNA228573 PRJNA228574
##          1          1          1          1          1          1
## PRJNA228575 PRJNA228576 PRJNA228582 PRJNA228585 PRJNA228586 PRJNA228589
##          1          1          1          1          1          1
## PRJNA228591 PRJNA228600 PRJNA228601 PRJNA228602 PRJNA228603 PRJNA228604
##          1          1          1          1          1          1
## PRJNA228606 PRJNA228607 PRJNA228608 PRJNA228609 PRJNA228610 PRJNA228611
##          1          1          1          1          1          1
## PRJNA228612 PRJNA228613 PRJNA228614 PRJNA228615 PRJNA228616 PRJNA228617
##          1          1          1          1          1          1
## PRJNA228618 PRJNA228619 PRJNA228620 PRJNA228621 PRJNA228622 PRJNA228623
##          1          1          1          1          1          1
## PRJNA228627 PRJNA228630 PRJNA228631 PRJNA228632 PRJNA228633 PRJNA228634
##          1          1          1          1          1          1
## PRJNA228635 PRJNA228644 PRJNA228648 PRJNA228649 PRJNA228651 PRJNA228652
##          1          1          1          1          1          1
## PRJNA228653 PRJNA228654 PRJNA228655 PRJNA228656 PRJNA228660 PRJNA228661
##          1          1          1          1          1          1
## PRJNA228662 PRJNA228663 PRJNA228665 PRJNA228666 PRJNA228669 PRJNA228672
##          1          1          1          1          1          1
## PRJNA228673 PRJNA228674 PRJNA228675 PRJNA228678 PRJNA228679 PRJNA228681
##          1          1          1          1          1          1
## PRJNA228682 PRJNA228683 PRJNA228685 PRJNA228686 PRJNA228688 PRJNA228690
##          1          1          1          1          1          1
## PRJNA228691 PRJNA228692 PRJNA228693 PRJNA228696 PRJNA228697 PRJNA228698
##          1          1          1          1          1          1
## PRJNA228699 PRJNA228700 PRJNA228701 PRJNA228705 PRJNA228706 PRJNA228707
##          1          1          1          1          1          1
## PRJNA228708 PRJNA228709 PRJNA228711 PRJNA228712 PRJNA228714 PRJNA228715
##          1          1          1          1          1          1
## PRJNA228716 PRJNA228717 PRJNA228718 PRJNA228719 PRJNA228720 PRJNA228721
##          1          1          1          1          1          1
## PRJNA228722 PRJNA228723 PRJNA228724 PRJNA228725 PRJNA228727 PRJNA228730
##          1          1          1          1          1          1
## PRJNA228731 PRJNA228733 PRJNA228734 PRJNA228735 PRJNA228736 PRJNA228738
##          1          1          1          1          1          1
## PRJNA228739 PRJNA228740 PRJNA228742 PRJNA228743 PRJNA228744 PRJNA228747
##          1          1          1          1          1          1
## PRJNA228748 PRJNA228749 PRJNA228751 PRJNA228752 PRJNA228753 PRJNA228755
##          1          1          1          1          1          1
## PRJNA228756 PRJNA228757 PRJNA228758 PRJNA228759 PRJNA228761 PRJNA228763
##          1          1          1          1          1          1
## PRJNA228764 PRJNA228765 PRJNA228767 PRJNA228768 PRJNA228769 PRJNA228772
##          1          1          1          1          1          1
## PRJNA228773 PRJNA228774 PRJNA228775 PRJNA228776 PRJNA228777 PRJNA228778

```

```

##          1          1          1          1          1          1
## PRJNA228779 PRJNA228780 PRJNA228782 PRJNA228783 PRJNA228784 PRJNA228785
##          1          1          1          1          1          1
## PRJNA228786 PRJNA228787 PRJNA228788 PRJNA228789 PRJNA228790 PRJNA228791
##          1          1          1          1          1          1
## PRJNA228792 PRJNA228793 PRJNA228794 PRJNA228795 PRJNA228796 PRJNA228797
##          1          1          1          1          1          1
## PRJNA228798 PRJNA228799 PRJNA228800 PRJNA228801 PRJNA228802 PRJNA228803
##          1          1          1          1          1          1
## PRJNA228804 PRJNA228805 PRJNA228806 PRJNA228807 PRJNA228808 PRJNA228809
##          1          1          1          1          1          1
## PRJNA228810 PRJNA228811 PRJNA228812 PRJNA228813 PRJNA228814 PRJNA228815
##          1          1          1          1          1          1
## PRJNA228816 PRJNA228817 PRJNA228818 PRJNA228819 PRJNA228820 PRJNA228821
##          1          1          1          1          1          1
## PRJNA228822 PRJNA228823 PRJNA228824 PRJNA228825 PRJNA228826 PRJNA228827
##          1          1          1          1          1          1
## PRJNA228828 PRJNA228829 PRJNA228830 PRJNA228831 PRJNA228832 PRJNA228833
##          1          1          1          1          1          1
## PRJNA228834 PRJNA228835 PRJNA228836 PRJNA228837 PRJNA228838 PRJNA228839
##          1          1          1          1          1          1
## PRJNA228840 PRJNA228841 PRJNA228842 PRJNA228843 PRJNA228844 PRJNA22886
##          1          1          1          1          1          1
## PRJNA231221 PRJNA232112 PRJNA239000 PRJNA239001 PRJNA244946 PRJNA248678
##          31         39        136         49          6          3
## PRJNA248693 PRJNA251379 PRJNA252378 PRJNA252728 PRJNA259799 PRJNA259800
##          28         32         15         17          1          1
## PRJNA259801 PRJNA267549 PRJNA270998 PRJNA274898 PRJNA275322 PRJNA277213
##          1         38         67         49         94          6
## PRJNA278295 PRJNA278886 PRJNA286158 PRJNA289526 PRJNA289579 PRJNA290232
##          39          6          6         21          1          5
## PRJNA290378 PRJNA293093 PRJNA295808 PRJNA303010 PRJNA304269 PRJNA306753
##          152          1         53          1         20         10
## PRJNA311554 PRJNA312437 PRJNA324190 PRJNA325350 PRJNA330833 PRJNA335349
##          77          9        307         22         20          3
## PRJNA341781 PRJNA342178 PRJNA345163 PRJNA356758 PRJNA357274 PRJNA368710
##          122          10          4         63          3         13
## PRJNA369475 PRJNA374337 PRJNA378150 PRJNA40073 PRJNA412599 PRJNA414029
##          20         173          1          3          8          1
## PRJNA60651 PRJNA60653 PRJNA60655 PRJNA60657 PRJNA60659 PRJNA60661
##          1          1          1          1          1          1
## PRJNA60663 PRJNA60665 PRJNA60667 PRJNA60669 PRJNA60671 PRJNA60673
##          1          1          1          1          1          1
## PRJNA60675 PRJNA60677 PRJNA60679 PRJNA60681 PRJNA60683 PRJNA60685
##          1          1          1          1          1          1
## PRJNA60687 PRJNA60691 PRJNA60693 PRJNA60695 PRJNA60697 PRJNA60699
##          1          1          1          1          1          1
## PRJNA60701 PRJNA60703 PRJNA60705 PRJNA70811 PRJNA82607 PRJNA82609
##          1          1          1          9          1          1
## PRJNA88545 PRJNA88547 PRJNA88549 PRJNA88551 PRJNA88557 PRJNA88559
##          2          2          1          1          2          2
## PRJNA88561 PRJNA88563 PRJNA88565 PRJNA88567 PRJNA88569 PRJNA88571
##          2          2          2          2          2          2
## PRJNA88573 PRJNA88575 PRJNA88577 PRJNA88579 PRJNA88581 PRJNA88583

```

```

##      4      2      2      2      2      2      2
## PRJNA88585 PRJNA88587 PRJNA88589 PRJNA88591 PRJNA88595 PRJNA88597
##      2      2      2      2      2      2      2
## PRJNA88599 PRJNA88601 PRJNA88603 PRJNA88605 PRJNA88607 PRJNA88609
##      2      2      2      2      2      2      2
## PRJNA88611 PRJNA88615 PRJNA88617 PRJNA88619 PRJNA88621 PRJNA88623
##      2      2      2      2      2      2      2
## PRJNA88625 PRJNA88635 PRJNA88663 PRJNA88665 PRJNA88667 PRJNA88669
##      1      2      4      4      4      4      4
## PRJNA88671 PRJNA88673 PRJNA88675 PRJNA88677 PRJNA88679 PRJNA88681
##      4      4      4      4      4      4      4
## PRJNA88683 PRJNA88685 PRJNA88687 PRJNA88689 PRJNA88691 PRJNA88693
##      4      4      4      4      4      4      4
## PRJNA88695 PRJNA88697 PRJNA88699 PRJNA88701 PRJNA88703 PRJNA88705
##      4      4      4      4      4      4      4
## PRJNA88707 PRJNA88709 PRJNA88711 PRJNA88713 PRJNA88715 PRJNA88717
##      3      4      4      4      3      4
## PRJNA88719 PRJNA88721 PRJNA88723 PRJNA88725 PRJNA88727 PRJNA88729
##      4      4      4      2      2      2      2
## PRJNA88731 PRJNA88733 PRJNA88735 PRJNA88737 PRJNA88739 PRJNA88741
##      2      2      2      2      2      2      2
## PRJNA88743 PRJNA88745 PRJNA88747 PRJNA88749 PRJNA88751 PRJNA88753
##      2      2      2      2      2      2      2
## PRJNA88755 PRJNA88757 PRJNA88759 PRJNA88761 PRJNA88763 PRJNA88765
##      2      2      2      2      2      2      2
## PRJNA88767 PRJNA88769 PRJNA88771 PRJNA88773 PRJNA88775 PRJNA88777
##      2      2      2      2      2      2      2
## PRJNA88779 PRJNA88781 PRJNA88783 PRJNA88785 PRJNA88787 PRJNA88789
##      2      2      2      2      2      2      2
## PRJNA88791 PRJNA88793 PRJNA88795 PRJNA88901 PRJNA88903 PRJNA88905
##      2      2      2      2      2      2      2
## PRJNA88907 PRJNA88909 PRJNA88911 PRJNA88913 PRJNA88915 PRJNA88917
##      2      2      2      2      2      2      2
## PRJNA88919 PRJNA88921 PRJNA88923 PRJNA88927 PRJNA88929 PRJNA88931
##      2      2      2      2      2      2      2
## PRJNA88933 PRJNA88935 PRJNA88937 PRJNA88939 PRJNA88941 PRJNA88943
##      2      2      2      2      2      2      2
## PRJNA88945 PRJNA88949 PRJNA88951 PRJNA88953 PRJNA88955 PRJNA88957
##      2      2      2      2      2      2      2
## PRJNA88959 PRJNA88961 PRJNA88963 PRJNA88965 PRJNA88969 PRJNA88971
##      2      2      2      2      2      2      2
## PRJNA88975 PRJNA88977 PRJNA88979 PRJNA88981 PRJNA88983 PRJNA88985
##      2      2      2      2      2      2      2
## PRJNA88987 SRP001289 SRP004906 SRP013098
##      2      2      6      1

summary(mec_temp[mec_temp$agreement == '001',]$total_contig)

##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## 27.0     45.0     58.0    140.9    93.0    5285.0

colnames(metrics)

## [1] "sample_id"                      "name.x"
## [3] "is_public.x"                    "is_published.x"

```

```

## [5] "st"                                "rank.x"
## [7] "total_contig"                      "total_contig_length"
## [9] "min_contig_length"                 "median_contig_length"
## [11] "mean_contig_length"                "max_contig_length"
## [13] "n50_contig_length"                 "l50_contig_count"
## [15] "ng50_contig_length"                "lg50_contig_count"
## [17] "contigs_greater_1k"               "contigs_greater_10k"
## [19] "contigs_greater_100k"              "contigs_greater_1m"
## [21] "percent_contigs_greater_1k"       "percent_contigs_greater_10k"
## [23] "percent_contigs_greater_100k"     "percent_contigs_greater_1m"
## [25] "contig_percent_a"                  "contig_percent_t"
## [27] "contig_percent_g"                  "contig_percent_c"
## [29] "contig_percent_n"                  "contig_non_acgtm"
## [31] "num_contig_non_acgtm"              "biosample_center_name"
## [33] "biosample_first_public"            "biosample_scientific_name"
## [35] "biosample_tax_id"                 "broker_name"
## [37] "cell_line"                         "center_link"
## [39] "center_name"                       "checklist"
## [41] "collected_by"                     "collection_date"
## [43] "contains_ena_metadata"             "coordinates"
## [45] "country"                           "description"
## [47] "environment_biome"                "environment_feature"
## [49] "environment_material"              "environmental_sample"
## [51] "experiment_accession"              "experiment_alias"
## [53] "experiment_title"                  "first_public"
## [55] "germline"                          "host"
## [57] "host_body_site"                   "host_sex"
## [59] "host_status"                       "host_tax_id"
## [61] "instrument_model"                  "instrument_platform"
## [63] "investigation_type"                "is_paired"
## [65] "is_public.y"                      "is_published.y"
## [67] "isolate"                           "isolation_source"
## [69] "library_layout"                    "library_selection"
## [71] "library_strategy"                  "location"
## [73] "project_name"                     "region"
## [75] "sample_accession"                  "sample_alias"
## [77] "scientific_name"                   "secondary_sample_accession"
## [79] "secondary_study_accession"         "sequencing_method"
## [81] "serotype"                          "serovar"
## [83] "sex"                               "strain"
## [85] "study_accession"                   "study_alias"
## [87] "study_title"                       "sub_species"
## [89] "submission_accession"              "submitted_host_sex"
## [91] "submitted_sex"                     "tax_id"
## [93] "tissue_type"                       "name.y"
## [95] "rank.y"                            "total_bp"
## [97] "coverage"                          "read_total"
## [99] "read_min"                          "read_mean"
## [101] "read_std"                         "read_median"
## [103] "read_max"                         "read_25th"
## [105] "read_75th"                        "qual_mean"
## [107] "qual_std"                         "qual_median"
## [109] "qual_25th"                        "qual_75th"
## [111] "year"                             "rank_name"

```

```

mec <- merge(mec, data.frame(
  sample_id=top_type$sample_id,
  total=top_type$total
), by='sample_id')
mec <- merge(mec, data.frame(
  sample_id=top_type$sample_id,
  mec_total=top_type$meca_total
), by='sample_id')
table(mec[mec$total >= 0.5,]$primer_mec)

##
## FALSE TRUE
## 965 25497
table(mec[mec$total >= 0.5,]$protein_mec)

##
## FALSE TRUE
## 1138 25324
table(mec[mec$total >= 0.5,]$ariba_mec)

##
## FALSE TRUE
## 198 25987
table(mec[mec$total >= 0.5,]$ariba_relaxed_mec)

## < table of extent 0 >

SCCmec cassettes with 50% coverage but 0% in mec region.
table(mec[mec$total >= 0.5 & mec$mec_total == 0,]$ariba_mec)

##
## FALSE TRUE
## 53 2

```

mecA Presence By ST

```

meca_groups <- merge(
  data.frame(
    sample_id=ps$sample_id,
    st=ps$st,
    rank=ps$rank
  ),
  ariba,
  by='sample_id'
)
meca_groups$status <- ifelse(
  meca_groups$mec == TRUE, 'MRSA', 'MSSA'
)
meca_by_st <- plyr::count(meca_groups, c('st', 'status'))
head(meca_by_st)

##   st status freq
## 1  0    MRSA  225

```

```

## 2 0 MSSA 372
## 3 1 MRSA 244
## 4 1 MSSA 549
## 5 3 MSSA 29
## 6 5 MRSA 3323

```

Get the Top 10 STs

```

top_st <- get_top_sequence_types()
top_st

```

```

##      st count percent overall
## 1    22  7189   16.74   16.74
## 2     8  6184   14.40   31.14
## 3     5  4664   10.86   42.00
## 4   239  3123    7.27   49.27
## 5   398  2326    5.42   54.68
## 6    30  1872    4.36   59.04
## 7    45  1663    3.87   62.91
## 8    15  1172    2.73   65.64
## 9    36   857    2.00   67.64
## 10   105   857    2.00   69.63

```

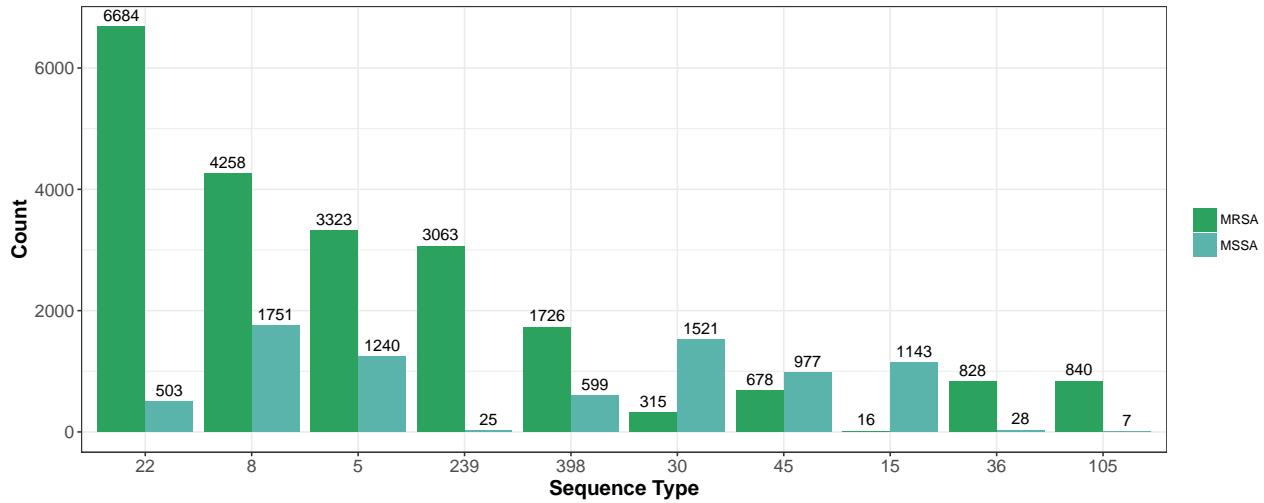
MRSA/MSSA Distribution For Top 10 Sequence Types

Now we are ready to plot out the distribution of MRSA and MSSA predictions by sequence type.

```

top_st_meca <- merge(top_st, meca_by_st, by='st')
p <- ggplot(data=top_st_meca, aes(x=reorder(st, -count), y=freq,
                                    fill = status)) +
  xlab("Sequence Type") +
  ylab("Count") +
  geom_bar(stat="identity", position = "dodge") +
  geom_text(aes(label=freq), vjust = -0.5,
            position = position_dodge(.9)) +
  scale_fill_manual(values=c("#2ca25f", "#5ab4ac")) +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14, face="bold"),
        legend.title = element_blank())
p

```

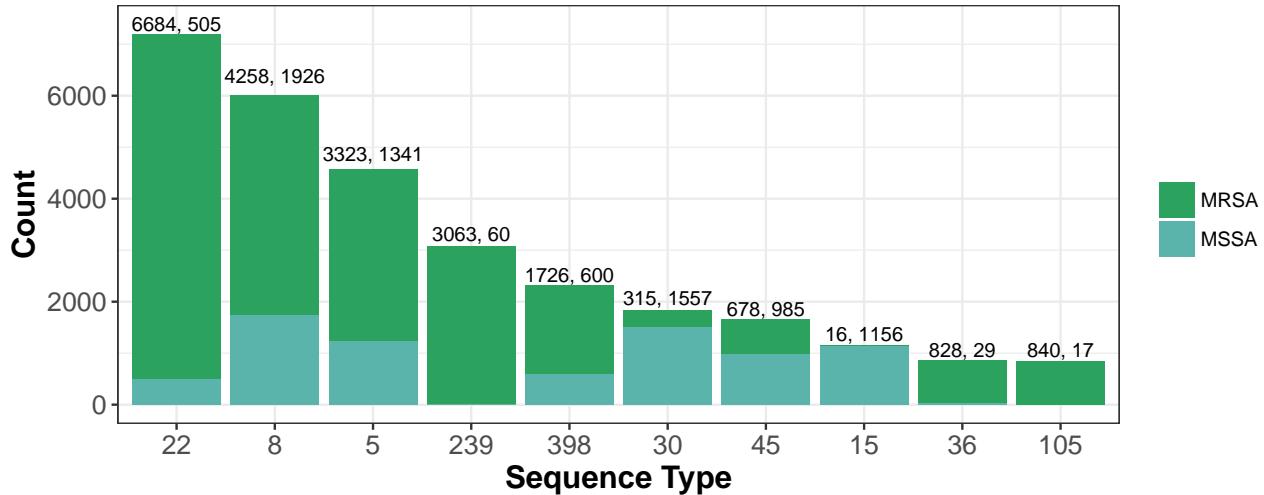


MRSA/MSSA Distribution For Top 10 Sequence Types

Now we are ready to plot out the distribution of MRSA and MSSA predictions by sequence type.

```
top_st_meca <- merge(top_st, meca_by_st, by='st')
counts <- top_st_meca[top_st_meca$status == 'MRSA',]
counts$label <- paste0(counts$freq, ", ", counts$count - counts$freq)
counts <- counts[,c('st', 'count', 'label')]
p <- ggplot(data=top_st_meca, aes(x=reorder(st, -count), y=freq,
                                    fill = status, label=freq)) +
  xlab("Sequence Type") +
  ylab("Count") +
  geom_bar(stat="identity", position = "stack") +
  geom_text(size=3, aes(as.character(st), count + 200, label = label, fill = NULL), data = counts) +
  scale_fill_manual(values=c("#2ca02c", "#5ab4ac")) +
  theme_bw() +
  theme(axis.text=element_text(size=12),
        axis.title=element_text(size=14, face="bold"),
        legend.title = element_blank())

## Warning: Ignoring unknown aesthetics: fill
p
```



Resistance Patterns Based on Ariba and MegaRes

Resistance Classes With A Match

```
resistance_report <- get_resistance_results(ps$sample_id,
                                             resistance_report=TRUE)
df <- as.data.frame(colSums(
  resistance_report[,2:ncol(resistance_report)])
))
colnames(df) <- c('total')
resistance_report_counts <- data.frame(
  class=rownames(df),
  total=df$total
)
resistance_report_counts[resistance_report_counts$total > 0,]

##          class total
## 1      Aminocoumarins    46
## 2      Aminoglycosides 17968
## 4      Betalactams 37758
## 5      Betalactams (mec) 27120
## 8      Fluoroquinolones    69
## 9      Fosfomycin 24205
## 10     Fusidic Acid    346
## 11     Glycopeptides  5777
## 12     Lipopeptides    44
## 13      MLS 22322
## 14 Multi-Drug Resistance 13653
## 16      Phenicol    852
## 17      Rifampin     46
## 18      Sulfonamides    36
## 19      Tetracyclines  8638
## 21      Trimethoprim   6605
```

Resistance Classes Without A Match

```

data.frame(class=as.character(
  resistance_report_counts[resistance_report_counts$total == 0,]$class
))

##                                     class
## 1             Bacitracin
## 2      Cationic Antimicrobial Peptides
## 3          Elfamycins
## 4 Mycobacterium Tuberculosis-Specific Drug
## 5           Thiostrepton
## 6          Tunicamycin

cluster_report <- get_resistance_results(ps$sample_id,
                                         cluster_report=TRUE)

df <- as.data.frame(colSums(
  cluster_report[,2:ncol(cluster_report)])
)

colnames(df) <- c('total')
cluster_report_counts <- data.frame(
  cluster=rownames(df),
  total=df$total
)
cluster_report_counts[cluster_report_counts$total > 0,]

##                                     cluster total
## 4   AAC6_PRIME_14;Aminoglycosides  6660
## 5   AAC6_PRIME_15;Aminoglycosides     2
## 9   AAC6_PRIME_31;Aminoglycosides    10
## 23  ADEAI;Multi-drug resistance     1
## 26  ADEC;Multi-drug resistance    10
## 38  ANT3_DPRIME_10;Aminoglycosides 9850
## 42  ANT4_PRIME_1;Aminoglycosides  7302
## 43    ANT6;Aminoglycosides        978
## 44    ANT6_2;Aminoglycosides       79
## 46    ANT6_6;Aminoglycosides      620
## 47    ANT9_1;Aminoglycosides       76
## 48    APH3_-;Aminoglycosides       1
## 51  APH3_PRIME_7;Aminoglycosides 8363
## 66      BLAZ;betalactams        868
## 67      BLAZ_1;betalactams     33652
## 70      BRP;Glycopeptides       5773
## 72          CAT;Phenicol        225
## 74          CAT_-1;Phenicol      392
## 76          CATA_2;Phenicol      124
## 80          CFRA;Phenicol        6
## 81      CLS_1;Lipopeptides       10
## 94      DFRC;Trimethoprim     1851
## 95      DFRD;Trimethoprim        8
## 96      DFRF;Trimethoprim       10
## 97      DFRG;Trimethoprim     4301
## 98      DFRK;Trimethoprim      510
## 107  EMEA;Multi-drug resistance    34
## 111  EMRE_1;Multi-drug resistance     1
## 115      ERM_-1;MLS            317

```

```

## 116          ERM-_2;MLS    454
## 118          ERM_7;MLS     1
## 119          ERMA;MLS 10133
## 120          ERMA_1;MLS   22
## 121          ERMA_2;MLS   3
## 122          ERMC;MLS 7944
## 129          FEXA;Phenicol 144
## 137          FOLP_2;Sulfonamides 2
## 139          FOLP_23;Sulfonamides 34
## 143          FOSA;Fosfomycin 17
## 146          FOSB;Fosfomycin 24172
## 147          FOSB_1;Fosfomycin 54
## 148          FUSB;Fusidic acid 346
## 160          GYRA_25;Fluoroquinolones 34
## 161          GYRA_28;Fluoroquinolones 2
## 166          GYRA_6;Fluoroquinolones 23
## 174          LIAFSR;Lipopeptides 10
## 175          LIAFSR_1;Lipopeptides 34
## 178          LNUA;MLS 240
## 179          LNUB;MLS 190
## 181          LSA;MLS 34
## 182          LSA_1;MLS 187
## 183          LSA_3;MLS 1
## 206          MEC-;betalactams 26175
## 207          MECA;betalactams 8056
## 208          MECI;betalactams 4460
## 210          MEPB;Multi-drug resistance 10839
## 221          MPHc;MLS 5178
## 225          MSRA_1;MLS 5167
## 226          MSRC;MLS 10
## 234          NORA_1;Fluoroquinolones 23
## 243          OXA_14;betalactams 1
## 256          PARC_12;Fluoroquinolones 2
## 257          PARC_13;Fluoroquinolones 34
## 258          PARC_14;Fluoroquinolones 10
## 266          PARE;Aminocoumarins 10
## 267          PARE_1;Aminocoumarins 34
## 275          PARE_9;Aminocoumarins 2
## 276          PBP1A;betalactams 2
## 277          PBP1B;betalactams 2
## 278          PBP2;betalactams 878
## 281          PBP2X;betalactams 2
## 292          QACAB;Multi-drug resistance 3482
## 308          RPOB_4;Rifampin 2
## 309          RPOB_5;Rifampin 10
## 310          RPOB_6;Rifampin 34
## 314          SAT_1;Aminoglycosides 6260
## 321          SPD;Aminoglycosides 165
## 324          TEM;betalactams 51
## 333          TETK;Tetracyclines 5739
## 335          TETL_1;Tetracyclines 484
## 337          TETM;Tetracyclines 2213
## 338          TETM_1;Tetracyclines 3638
## 339          TETO;Tetracyclines 8

```

```

## 343      TETS;Tetracyclines      5
## 344      TETT;Tetracyclines     65
## 358      VANA_5;Glycopeptides   1
## 362      VANHA_4;Glycopeptides   1
## 363      VANRA;Glycopeptides    1
## 374      VANXA_1;Glycopeptides   3
## 379      VANYA;Glycopeptides    3
## 381      VANZA;Glycopeptides    2
## 382          VATA;MLS           2
## 383          VATB;MLS           3
## 384          VGA;MLS          175
## 385          VGA_1;MLS         77
## 386          VGAB;MLS           3
## 387          VGBA;MLS           2

```

Resistance Clusters Without A Match

```

data.frame(class=as.character(
  cluster_report_counts[cluster_report_counts$total == 0,]$cluster
))

```

```

##
## 1          AAC2_PRIME_3;Aminoglycosides
## 2          AAC3_12;Aminoglycosides
## 3          AAC3_3;Aminoglycosides
## 4          AAC6_PRIME_16;Aminoglycosides
## 5          AAC6_PRIME_29;Aminoglycosides
## 6          AAC6_PRIME_30;Aminoglycosides
## 7          AAC6_PRIME_8;Aminoglycosides
## 8          ABEM;Multi-drug resistance
## 9          ABES;Multi-drug resistance
## 10         ACRB;Multi-drug resistance
## 11         ACRD;Aminoglycosides
## 12         ACRE;Aminoglycosides
## 13         ACRF;Aminoglycosides
## 14         ACRR;Multi-drug resistance
## 15         ACRR_1;Multi-drug resistance
## 16         ACRS;Aminoglycosides
## 17         ACT;betalactams
## 18         ADC;betalactams
## 19         ADEA;Multi-drug resistance
## 20         ADEB;Multi-drug resistance
## 21         ADEB_1;Multi-drug resistance
## 22         ADEF+;Multi-drug resistance
## 23         ADEG;Multi-drug resistance
## 24         ADEH;Multi-drug resistance
## 25         ADEK;Multi-drug resistance
## 26         ADEN;Multi-drug resistance
## 27         ADER;Multi-drug resistance
## 28         ADES;Multi-drug resistance
## 29         AMPH;betalactams
## 30         AMPH_1;betalactams
## 31         ANT2_DPRIME;Aminoglycosides
## 32         ANT3_DPRIME;Aminoglycosides

```

```

## 33          ANT3_DPRIME_6;Aminoglycosides
## 34          ANT3_DPRIME_7;Aminoglycosides
## 35          ANT3_DPRIME_8;Aminoglycosides
## 36          ANT6_5;Aminoglycosides
## 37          APH3_DPRIME_1;Aminoglycosides
## 38          APH3_PRIME_11;Aminoglycosides
## 39          APH4_1;Aminoglycosides
## 40          APH6_4;Aminoglycosides
## 41          ARMA;Aminoglycosides
## 42          ARNA_1;Cationic antimicrobial peptides
## 43          ARR_6;Rifampin
## 44          ASMA;Multi-drug resistance
## 45          ASMA_1;Multi-drug resistance
## 46          BACA;Bacitracin
## 47          BAER;Multi-drug resistance
## 48          BAES;Multi-drug resistance
## 49          BLAA;betalactams
## 50          BLAA_1;betalactams
## 51          BLAA_2;betalactams
## 52          BLAEC;betalactams
## 53          BLT;Multi-drug resistance
## 54          BMR;Multi-drug resistance
## 55          BRP_1;Glycopeptides
## 56          CAT-;Phenicol
## 57          CATA_1;Phenicol
## 58          CATA_3;Phenicol
## 59          CATB;Phenicol
## 60          CEOB;Multi-drug resistance
## 61          cme;Multi-drug resistance
## 62          cme_2;Multi-drug resistance
## 63          cme_3;Multi-drug resistance
## 64          CMER+;Multi-drug resistance
## 65          CML;Phenicol
## 66          CMXAB;Phenicol
## 67          CPXA-;Multi-drug resistance
## 68          CPXA_-1;Multi-drug resistance
## 69          CRP;Multi-drug resistance
## 70          CTX_1;betalactams
## 71          CTX_5;betalactams
## 72          CTX_7;betalactams
## 73          DHFR+;Trimethoprim
## 74          DHFR_1;Trimethoprim
## 75          DHFR_6;Trimethoprim
## 76          DHFR_7;Trimethoprim
## 77          EMBA;Mycobacterium tuberculosis-specific Drug
## 78          EMBB+;Mycobacterium tuberculosis-specific Drug
## 79          EMBC;Mycobacterium tuberculosis-specific Drug
## 80          EMBR;Mycobacterium tuberculosis-specific Drug
## 81          EMRA;Multi-drug resistance
## 82          EMRB;Multi-drug resistance
## 83          EMRD;Multi-drug resistance
## 84          EMRK;Multi-drug resistance
## 85          EMRR;Multi-drug resistance
## 86          EMRY;Multi-drug resistance

```

```

## 87 ERM37;MLS
## 88 ERMD;MLS
## 89 ERMT;MLS
## 90 ERMX;MLS
## 91 ETHA;Mycobacterium tuberculosis-specific Drug
## 92 EVGA;Multi-drug resistance
## 93 EVGS;Multi-drug resistance
## 94 FLOR;Phenicol
## 95 FOLP_1;Sulfonamides
## 96 FOLP_12;Sulfonamides
## 97 FOLP_13;Sulfonamides
## 98 FOLP_14;Sulfonamides
## 99 FOLP_16;Sulfonamides
## 100 FOLP_17;Sulfonamides
## 101 FOLP_22;Sulfonamides
## 102 FOLP_3;Sulfonamides
## 103 FOLP_5;Sulfonamides
## 104 FOLP_8;Sulfonamides
## 105 FOSA_1;Fosfomycin
## 106 FOSA_8;Fosfomycin
## 107 GADX;Multi-drug resistance
## 108 GIDB;Aminoglycosides
## 109 GOLS;Multi-drug resistance
## 110 GYRA_11;Fluoroquinolones
## 111 GYRA_12;Fluoroquinolones
## 112 GYRA_14;Fluoroquinolones
## 113 GYRA_15;Fluoroquinolones
## 114 GYRA_17;Fluoroquinolones
## 115 GYRA_2;Fluoroquinolones
## 116 GYRA_20;Fluoroquinolones
## 117 GYRA_24;Fluoroquinolones
## 118 GYRA_29;Fluoroquinolones
## 119 GYRA_3;Fluoroquinolones
## 120 GYRA_31;Fluoroquinolones
## 121 GYRA_4;Fluoroquinolones
## 122 GYRB_1;Fluoroquinolones
## 123 HNS;Multi-drug resistance
## 124 INHA;Mycobacterium tuberculosis-specific Drug
## 125 INIA;Mycobacterium tuberculosis-specific Drug
## 126 INIC;Mycobacterium tuberculosis-specific Drug
## 127 KASA;Mycobacterium tuberculosis-specific Drug
## 128 KPC;betalactams
## 129 LIAFSR_2;Lipopeptides
## 130 LMRA+;Multi-drug resistance
## 131 LNUC;MLS
## 132 MACA;Multi-drug resistance
## 133 MACB;MLS
## 134 MARA;Multi-drug resistance
## 135 MARR;Multi-drug resistance
## 136 MDFA;Multi-drug resistance
## 137 MDSA;Multi-drug resistance
## 138 MDSB;Multi-drug resistance
## 139 MDSC;Multi-drug resistance
## 140 MDTA;Multi-drug resistance

```

```

## 141 MDTB;Multi-drug resistance
## 142 MDTC;Multi-drug resistance
## 143 MDTC_1;Multi-drug resistance
## 144 MDTC_2;Multi-drug resistance
## 145 MDTD;Multi-drug resistance
## 146 MDTE;Multi-drug resistance
## 147 MDTG;Multi-drug resistance
## 148 MDTH;Multi-drug resistance
## 149 MDTK;Multi-drug resistance
## 150 MDTL;Multi-drug resistance
## 151 MDTN;Multi-drug resistance
## 152 MDTO;Multi-drug resistance
## 153 MDTP;Multi-drug resistance
## 154 MEFA;MLS
## 155 MEXE_1;Multi-drug resistance
## 156 MEXF;Multi-drug resistance
## 157 MEXK;Multi-drug resistance
## 158 MEXP;Multi-drug resistance
## 159 MEXT;Multi-drug resistance
## 160 MEXV;Multi-drug resistance
## 161 MFPA;Fluoroquinolones
## 162 MIR+;betalactams
## 163 MPHA;MLS
## 164 MPHOB;MLS
## 165 MPHE_1;MLS
## 166 MPRF+;Multi-drug resistance
## 167 MSR;Multi-drug resistance
## 168 MTRA;Multi-drug resistance
## 169 MTRC;Multi-drug resistance
## 170 MTRD;Multi-drug resistance
## 171 MTRE;Multi-drug resistance
## 172 MTRR;Multi-drug resistance
## 173 NDH;Mycobacterium tuberculosis-specific Drug
## 174 NDM;betalactams
## 175 OMP36+;betalactams
## 176 OMPD;betalactams
## 177 OMPF_1;Multi-drug resistance
## 178 OMPF_2;Multi-drug resistance
## 179 OMPF_3;Multi-drug resistance
## 180 OQXA;Multi-drug resistance
## 181 OQXB;Multi-drug resistance
## 182 OXA;betalactams
## 183 OXA_17;betalactams
## 184 OXA_19;betalactams
## 185 OXA_24;betalactams
## 186 OXA_3;betalactams
## 187 OXA_34;betalactams
## 188 OXA_4;betalactams
## 189 OXA_41;betalactams
## 190 OXA_5;betalactams
## 191 OXA_6;betalactams
## 192 OXA_7;betalactams
## 193 OXY_1;betalactams
## 194 PARC_1;Fluoroquinolones

```

```

## 195 PARC_2;Fluoroquinolones
## 196 PARC_3;Fluoroquinolones
## 197 PARC_4;Fluoroquinolones
## 198 PARC_5;Fluoroquinolones
## 199 PARC_6;Fluoroquinolones
## 200 PARC_8;Fluoroquinolones
## 201 PARC_9;Fluoroquinolones
## 202 PARE+_1;Aminocoumarins
## 203 PARE_10;Aminocoumarins
## 204 PARE_11;Aminocoumarins
## 205 PARE_12;Aminocoumarins
## 206 PARE_13;Aminocoumarins
## 207 PARE_2;Aminocoumarins
## 208 PARE+_2;Fluoroquinolones
## 209 PBP2_1;betalactams
## 210 PBP2B;betalactams
## 211 PBP4B;betalactams
## 212 PHOP+;Multi-drug resistance
## 213 PHOQ;Multi-drug resistance
## 214 pmrA;Cationic antimicrobial peptides
## 215 PMRB_1;Cationic antimicrobial peptides
## 216 PMRC;Cationic antimicrobial peptides
## 217 PMRC_1;Cationic antimicrobial peptides
## 218 PMRF;Cationic antimicrobial peptides
## 219 PNCA;Mycobacterium tuberculosis-specific Drug
## 220 POR-;Multi-drug resistance
## 221 QNRB;Fluoroquinolones
## 222 RAMA;Multi-drug resistance
## 223 RAMR;Multi-drug resistance
## 224 RAMR_1;Multi-drug resistance
## 225 ROBA;Multi-drug resistance
## 226 ROSB+;Cationic antimicrobial peptides
## 227 RPOB;Rifampin
## 228 RPOB_1;Rifampin
## 229 RPOB_12;Rifampin
## 230 RPOB_13;Rifampin
## 231 RPOB_16;Rifampin
## 232 RPOB_17;Rifampin
## 233 RPOB_18;Rifampin
## 234 RPOB_19;Rifampin
## 235 RPOB_2;Rifampin
## 236 RPOB_7;Rifampin
## 237 RPOB_8;Rifampin
## 238 RPSSL;Aminoglycosides
## 239 SAT_2;Aminoglycosides
## 240 SDIA;Multi-drug resistance
## 241 SHV;betalactams
## 242 SHV+;betalactams
## 243 SOXS;Multi-drug resistance
## 244 SOXS_2;Multi-drug resistance
## 245 SULI+;Sulfonamides
## 246 SULII;Sulfonamides
## 247 TET32;Tetracyclines
## 248 TET33;Tetracyclines

```

```

## 249          TETA_1;Tetracyclines
## 250          TETB_1;Tetracyclines
## 251          TETC;Tetracyclines
## 252          TETD;Tetracyclines
## 253          TETD_1;Tetracyclines
## 254          TETJ;Tetracyclines
## 255          TETL;Tetracyclines
## 256          TETL_2;Tetracyclines
## 257          TETR_1;Tetracyclines
## 258          TETR_3;Tetracyclines
## 259          TETR_7;Tetracyclines
## 260          TETW;Tetracyclines
## 261          TLYA;Aminoglycosides
## 262          TMRB;Tunicamycin
## 263          TOLC;Multi-drug resistance
## 264          TSNR;Thiostrepton
## 265          TUFAB_1;Elfamycins
## 266          TUFAB_12;Elfamycins
## 267          TUFAB_3;Elfamycins
## 268          TUFAB_4;Elfamycins
## 269          TUFAB_5;Elfamycins
## 270          TUFAB_6;Elfamycins
## 271          TUFAB_7;Elfamycins
## 272          TUFAB_8;Elfamycins
## 273          VANB;Glycopeptides
## 274          VANC;Glycopeptides
## 275          VANC_1;Glycopeptides
## 276          VANRB;Glycopeptides
## 277          VANRC_1;Glycopeptides
## 278          VANRC_2;Glycopeptides
## 279          VANSA;Glycopeptides
## 280          VANSB_1;Glycopeptides
## 281          VANSC;Glycopeptides
## 282          VANSC_2;Glycopeptides
## 283          VANTC;Glycopeptides
## 284          VANTC_1;Glycopeptides
## 285          VANWB;Glycopeptides
## 286          VANXA_4;Glycopeptides
## 287          VANXB;Glycopeptides
## 288          VANXYC;Glycopeptides
## 289          VANXYC_1;Glycopeptides
## 290          VANYA_1;Glycopeptides
## 291          YKKC;Multi-drug resistance
## 292          YKKD;Multi-drug resistance

```

Group

```

resistance_groups <- merge(
  data.frame(sample_id=ps$sample_id, st=ps$st, rank=ps$rank),
  resistance_report,
  by='sample_id'
)

```

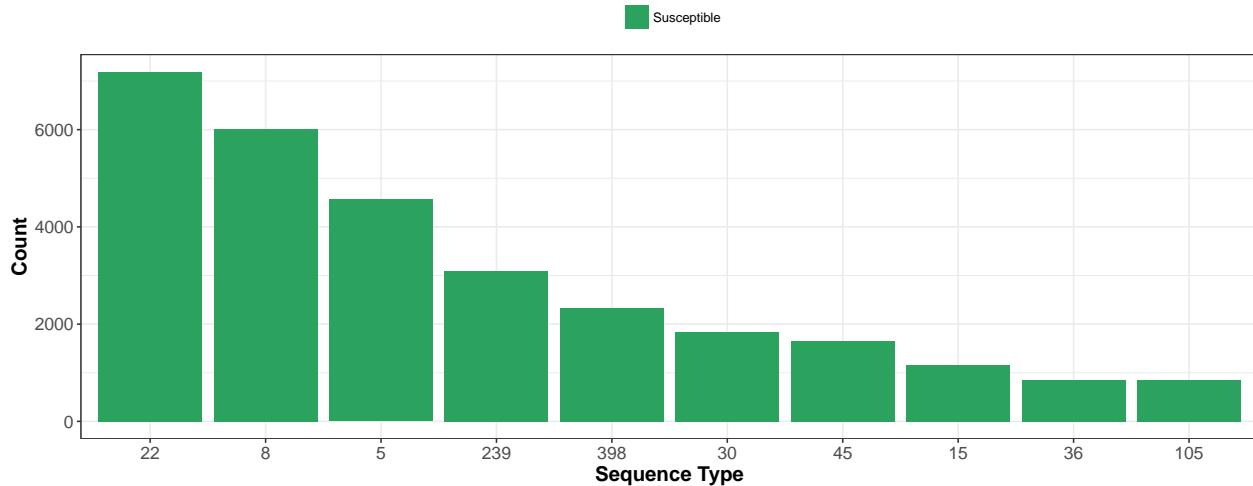
By ST

Function For Plotting

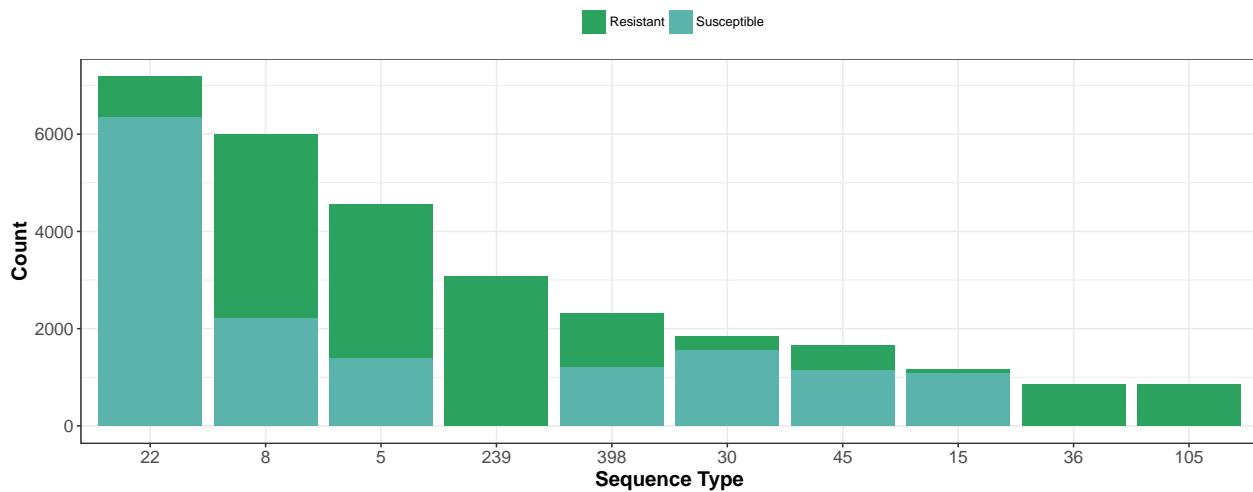
```
plot_by_st <- function(group, top_st, column) {  
  by_st <- plyr::count(  
    group,  
    c('st',  
      ifelse(  
        length(strsplit(column, ' '))[[1]] >= 2,  
        paste0("``", column, "``"),  
        column  
      )  
    )  
  )  
  by_st$status <- ifelse(  
    by_st[,make.names(column)] == TRUE, 'Resistant', 'Susceptible'  
  )  
  top_st_resistance <- merge(top_st, by_st, by='st')  
  p <- ggplot(data=top_st_resistance, aes(x=reorder(st, -count),  
                                             y=freq, fill = status)) +  
    xlab("Sequence Type") +  
    ylab(paste0("Count")) +  
    geom_bar(stat="identity", position = "stack") +  
    scale_fill_manual(values=c("#2ca25f", "#5ab4ac"),  
                      name = column) +  
    theme_bw() +  
    theme(axis.text=element_text(size=12),  
          axis.title=element_text(size=14, face="bold"),  
          legend.position="top",  
          legend.title=element_blank())  
  return(p)  
}
```

Resistance Classes With A Match By Top 10 Sequence Types

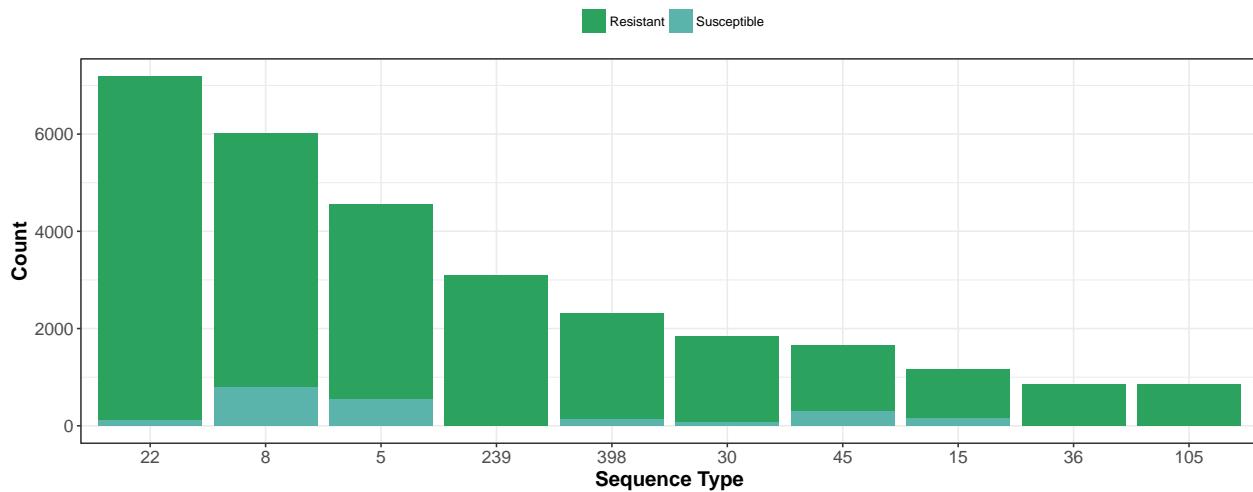
```
top_st <- get_top_sequence_types()  
for (column in sort(as.character(  
  resistance_report_counts[resistance_report_counts$total > 0,]$class  
))) {  
  p <- plot_by_st(resistance_groups, top_st, column)  
  print(column)  
  print(p)  
}  
  
## [1] "Aminocoumarins"
```



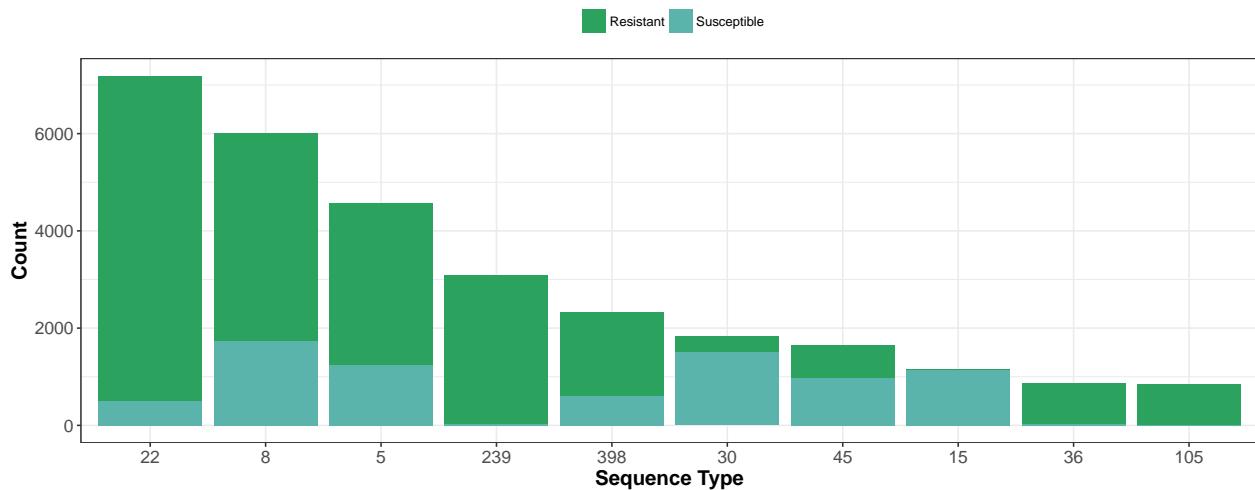
```
## [1] "Aminoglycosides"
```



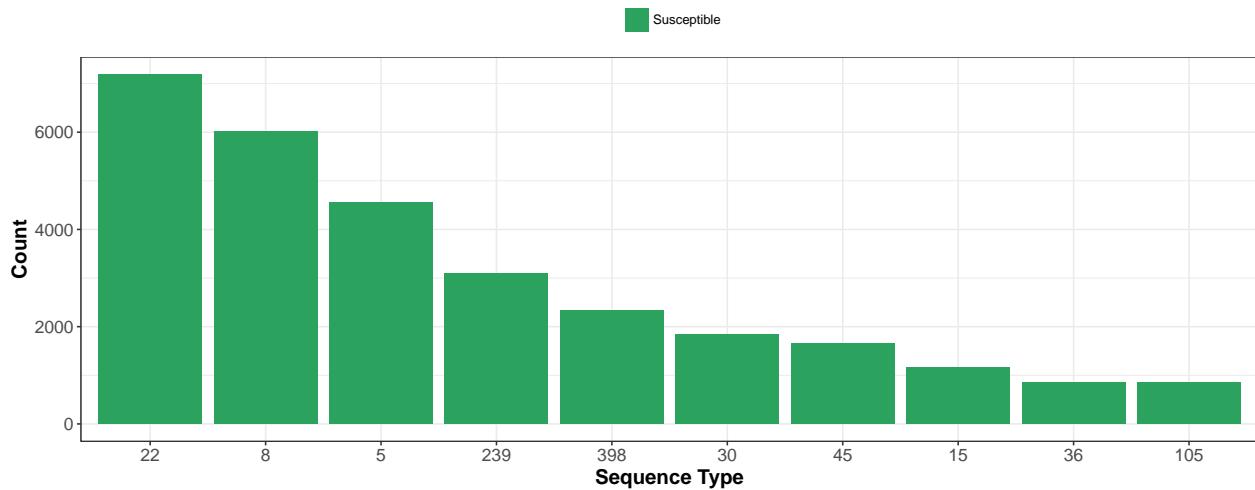
```
## [1] "Betalactams"
```



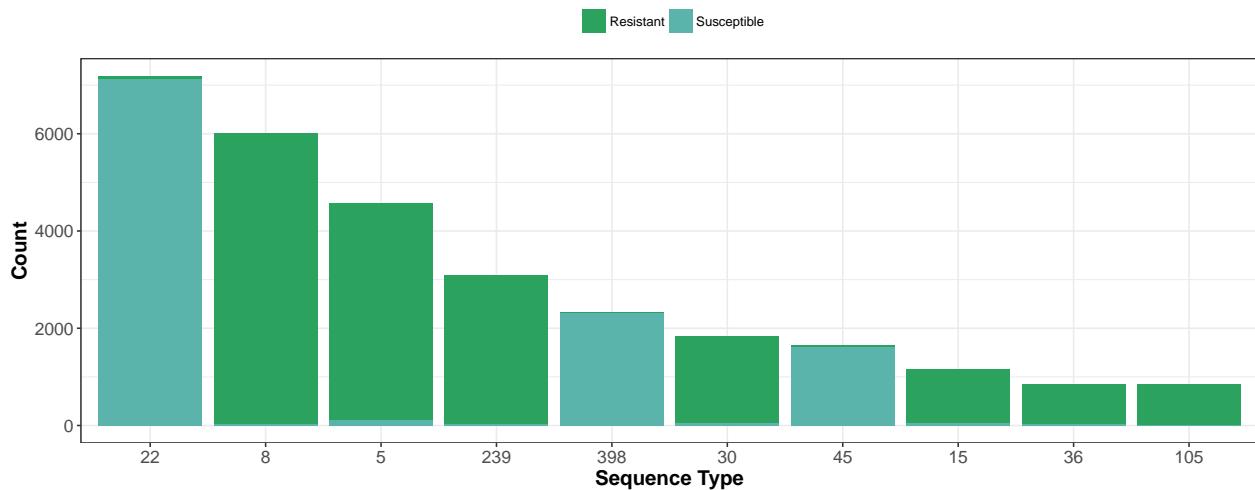
```
## [1] "Betalactams (mec)"
```



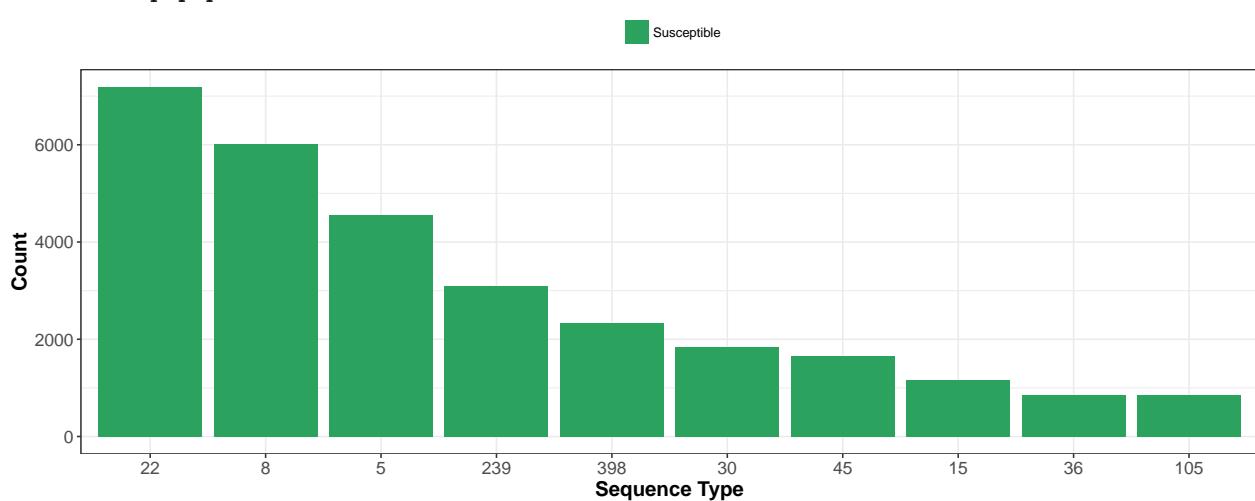
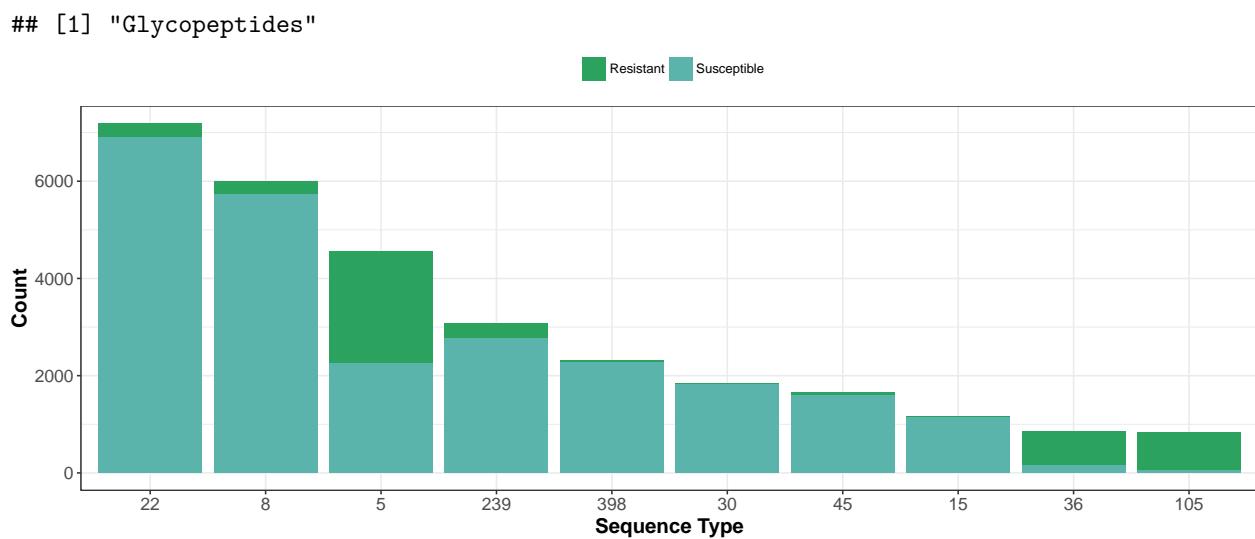
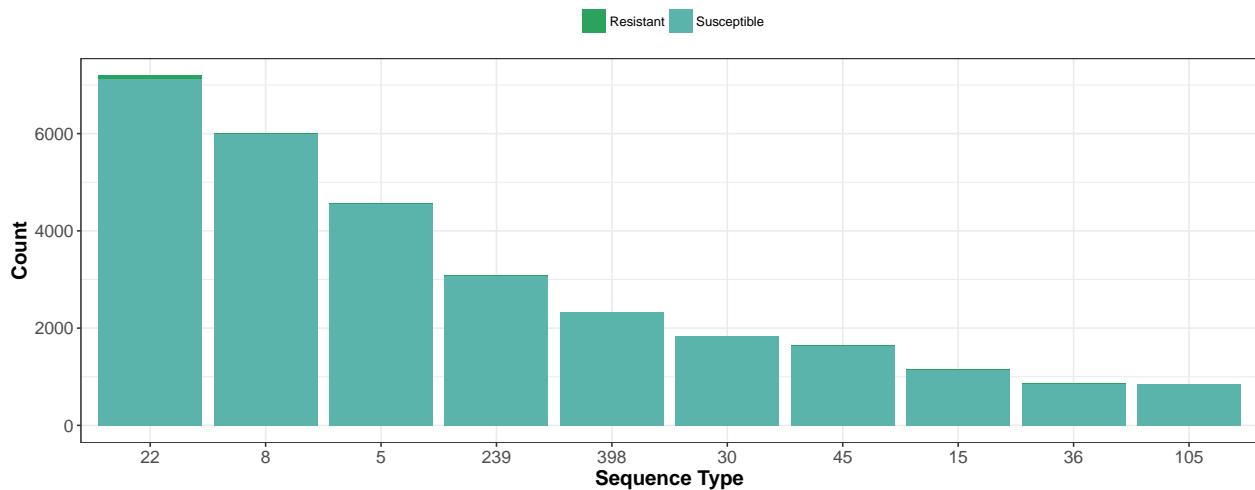
```
## [1] "Fluoroquinolones"
```

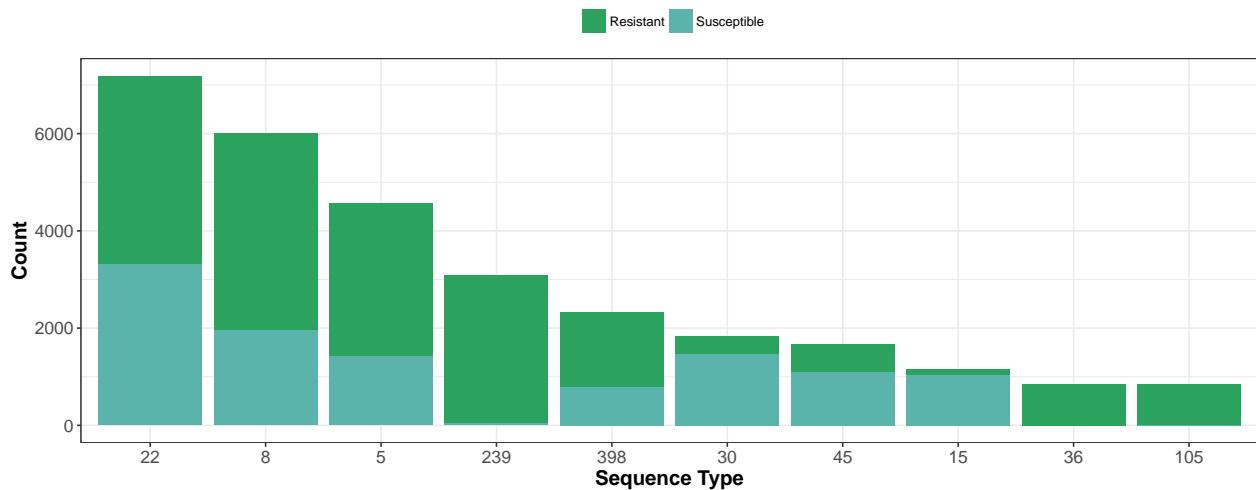


```
## [1] "Fosfomycin"
```

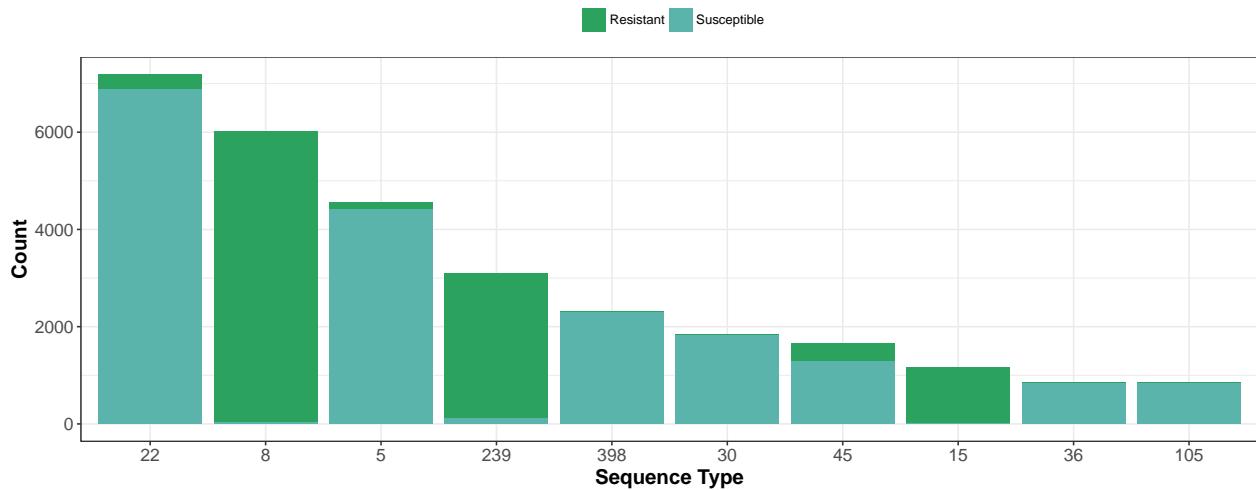


```
## [1] "Fusidic Acid"
```

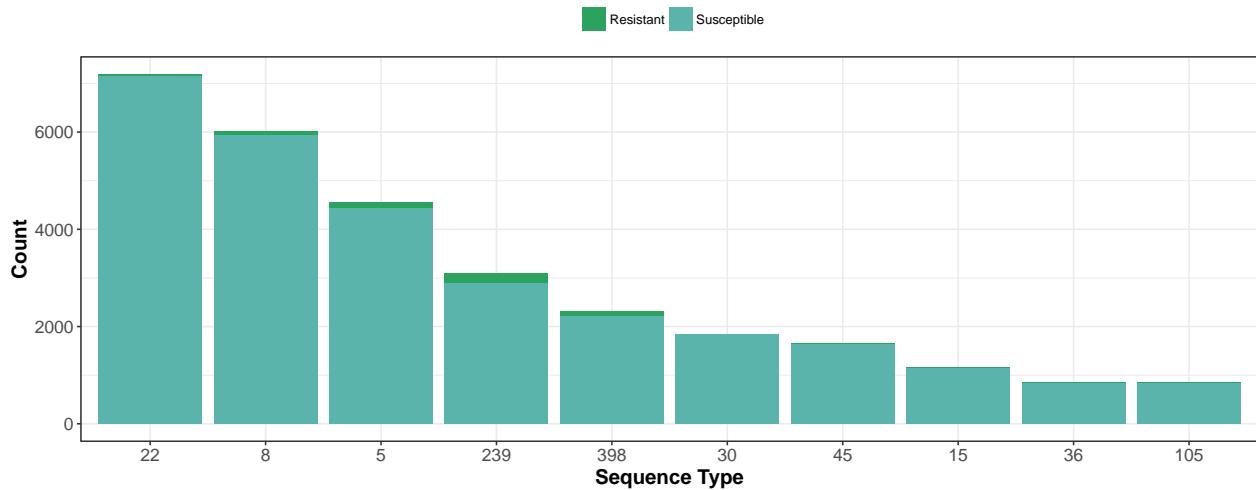




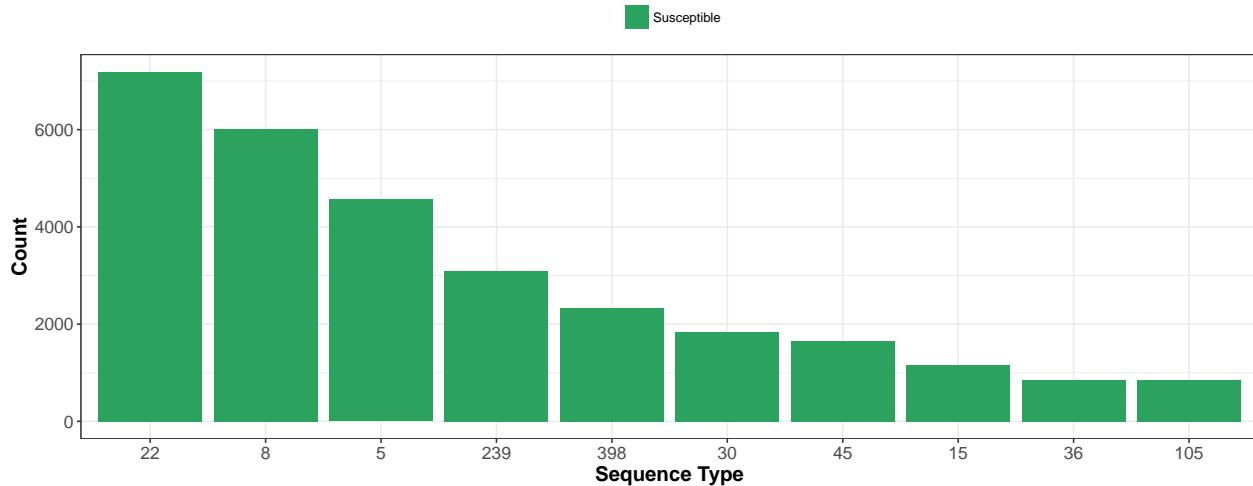
```
## [1] "Multi-Drug Resistance"
```



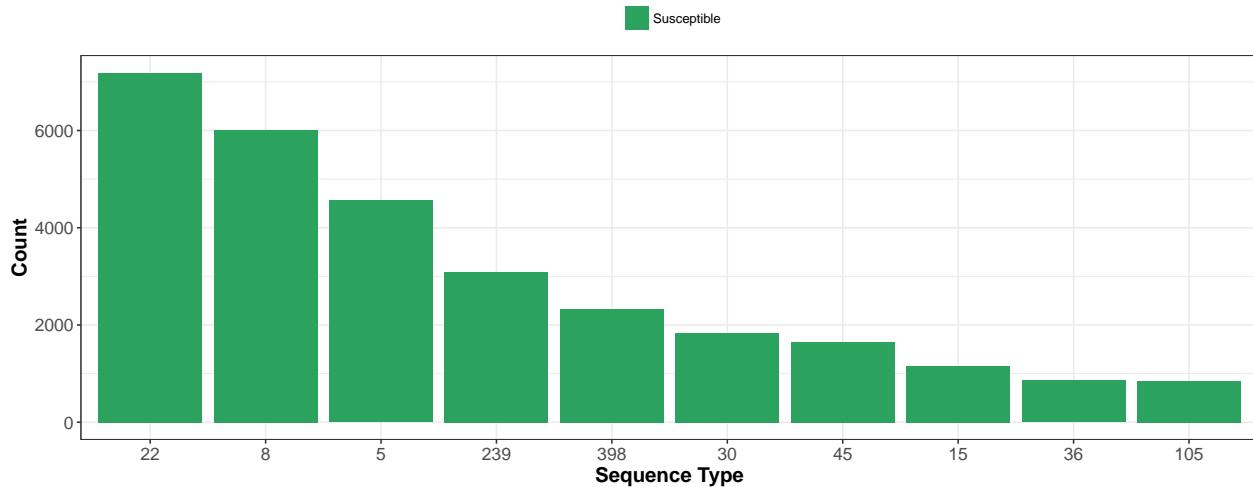
```
## [1] "Phenicol"
```



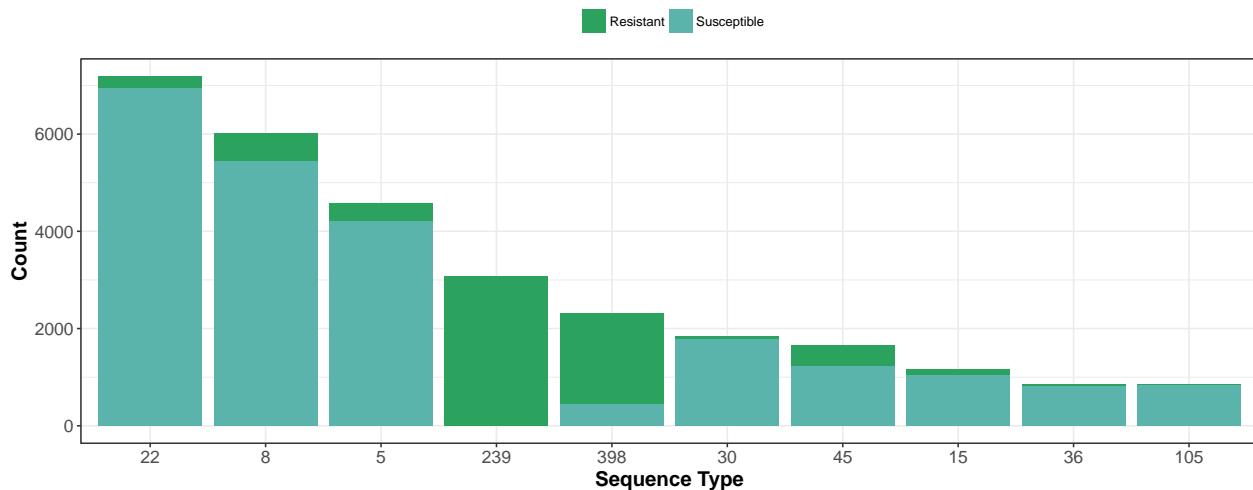
```
## [1] "Rifampin"
```



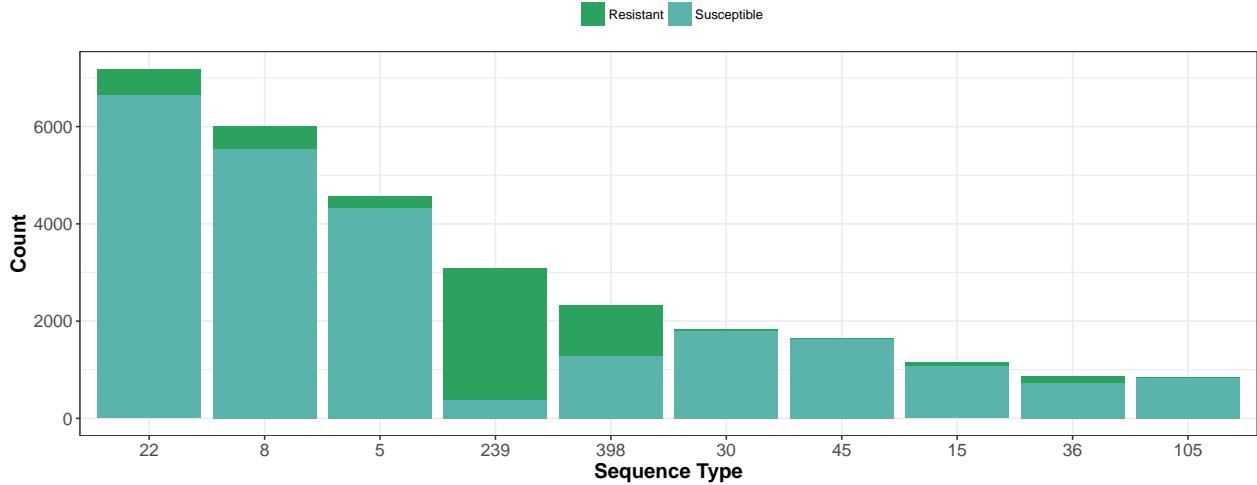
```
## [1] "Sulfonamides"
```



```
## [1] "Tetracyclines"
```



```
## [1] "Trimethoprim"
```



```

grid_arrange_shared <- function(..., ncol = length(list(...)), nrow = 1, position = c("bottom", "right")){
  plots <- list(...)
  position <- match.arg(position)
  g <- ggplotGrob(plots[[1]] + theme(legend.position = position))$grobs
  legend <- g[[which(sapply(g, function(x) x$name) == "guide-box")]]
  lheight <- sum(legend$height)
  lwidth <- sum(legend$width)
  gl <- lapply(plots, function(x) x + theme(legend.position="none"))
  gl[[1]] <-arrangeGrob(gl[[1]], top = textGrob(
    "A", x = unit(0, "npc"), y = unit(1, "npc"), just=c("left","top"),
    gp=gpar(col="black", fontsize=18, fontface="bold"))
  )
  gl[[2]] <-arrangeGrob(gl[[2]], top = textGrob(
    "B", x = unit(0, "npc"), y = unit(1, "npc"), just=c("left","top"),
    gp=gpar(col="black", fontsize=18, fontface="bold"))
  )
  gl[[3]] <-arrangeGrob(gl[[3]], top = textGrob(
    "C", x = unit(0, "npc"), y = unit(1, "npc"), just=c("left","top"),
    gp=gpar(col="black", fontsize=18, fontface="bold"))
  )
  gl[[4]] <-arrangeGrob(gl[[4]], top = textGrob(
    "D", x = unit(0, "npc"), y = unit(1, "npc"), just=c("left","top"),
    gp=gpar(col="black", fontsize=18, fontface="bold"))
  )
  gl <- c(gl, ncol = ncol, nrow = nrow)

  combined <- switch(position,
    "bottom" = arrangeGrob(do.call(arrangeGrob, gl),
      legend,
      ncol = 1,
      heights = unit.c(unit(1, "npc") - lheight, lheight)),
    "right" = arrangeGrob(do.call(arrangeGrob, gl),
      legend,
      ncol = 2,
      widths = unit.c(unit(1, "npc") - lwidth, lwidth)))
}

grid.newpage()

```

```

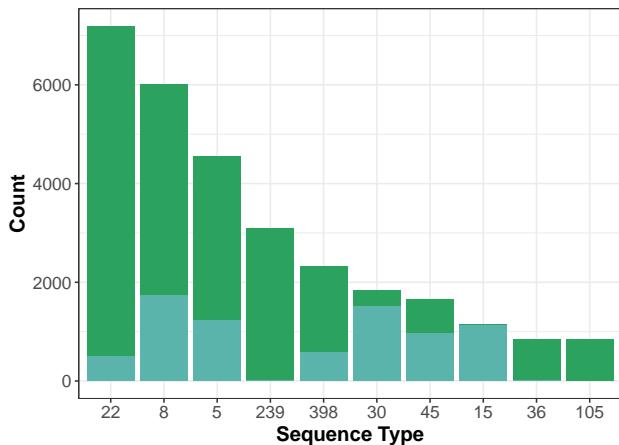
grid.draw(combined)

# return gtable invisibly
invisible(combined)
}

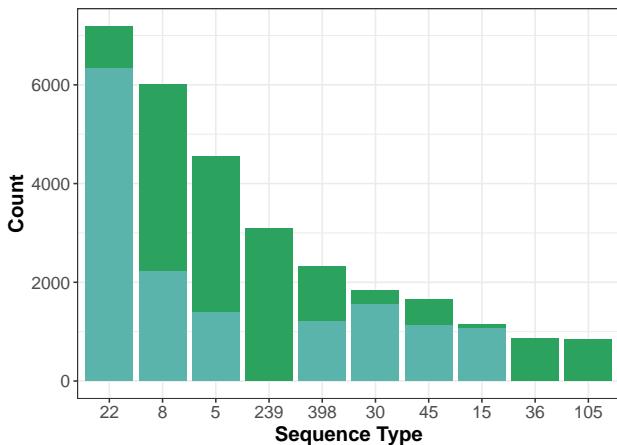
top_st <- get_top_sequence_types()
p1 <- plot_by_st(resistance_groups, top_st, 'Betalactams (mec)')
p2 <- plot_by_st(resistance_groups, top_st, 'Aminoglycosides')
p3 <- plot_by_st(resistance_groups, top_st, 'Fosfomycin')
p4 <- plot_by_st(resistance_groups, top_st, 'MLS')
grid_arrange_shared(p1,p2,p3,p4, nrow=2, ncol=2)

```

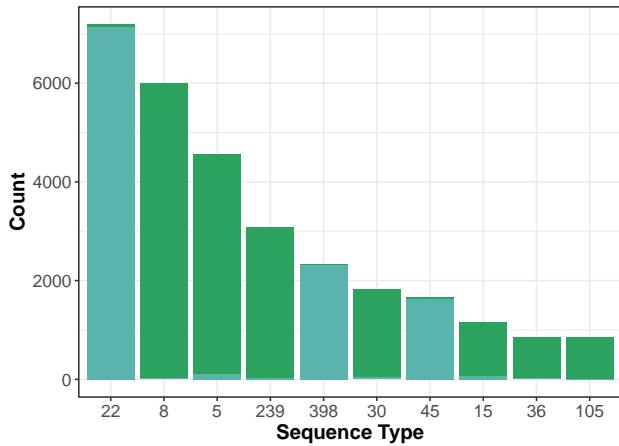
A



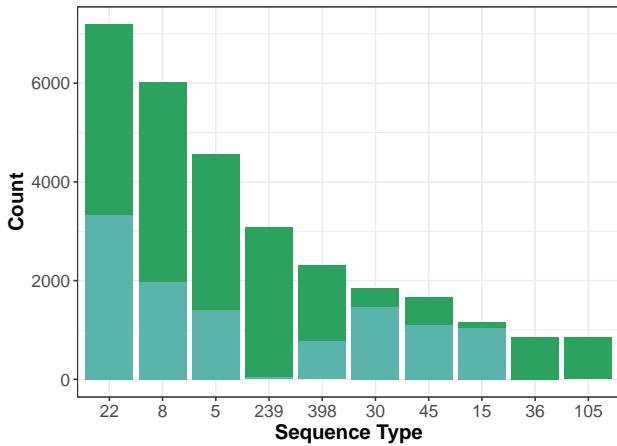
B



C



D



■ Resistant ■ Susceptible

```

# Output plot to PDF and PNG
pdf(paste0(
  getwd(),
  '/../../figures/figure-04-resistance-facet-top-10-sequence-types.pdf'
), height=6, width=12)
grid_arrange_shared(p1,p2,p3,p4, nrow=2, ncol=2)
dev_null <- dev.off()

png(paste0(

```

```

getwd(),
'../figures/figure-04-resistance-facet-top-10-sequence-types.png'
), height=600, width=1200)
gridArrangeShared(p1,p2,p3,p4, nrow=2, ncol=2)
dev_null <- dev.off()

```

Session Info

```

sessionInfo()

## R version 3.4.3 (2017-11-30)
## Platform: x86_64-pc-linux-gnu (64-bit)
## Running under: Ubuntu 16.04.2 LTS
##
## Matrix products: default
## BLAS: /usr/lib/libblas/libblas.so.3.6.0
## LAPACK: /usr/lib/lapack/liblapack.so.3.6.0
##
## locale:
## [1] LC_CTYPE=en_US.UTF-8          LC_NUMERIC=C
## [3] LC_TIME=en_US.UTF-8          LC_COLLATE=en_US.UTF-8
## [5] LC_MONETARY=en_US.UTF-8       LC_MESSAGES=en_US.UTF-8
## [7] LC_PAPER=en_US.UTF-8         LC_NAME=C
## [9] LC_ADDRESS=C                  LC_TELEPHONE=C
## [11] LC_MEASUREMENT=en_US.UTF-8   LC_IDENTIFICATION=C
##
## attached base packages:
## [1] grid      stats     graphics grDevices utils     datasets methods
## [8] base
##
## other attached packages:
## [1] bindrcpp_0.2    gridExtra_2.3    dplyr_0.7.4    scales_0.5.0
## [5] reshape2_1.4.3  ggplot2_2.2.1   strophe_0.1.9
##
## loaded via a namespace (and not attached):
## [1] Rcpp_0.12.15      bindr_0.1.1      knitr_1.20
## [4] magrittr_1.5       munsell_0.4.3    colorspace_1.3-2
## [7] R6_2.2.2          rlang_0.1.6      httr_1.3.1
## [10] stringr_1.2.0     plyr_1.8.4      tools_3.4.3
## [13] data.table_1.10.4-3 gtable_0.2.0    htmltools_0.3.6
## [16] assertthat_0.2.0   yaml_2.1.18     lazyeval_0.2.1
## [19] rprojroot_1.3-2    digest_0.6.15    tibble_1.4.2
## [22] curl_3.1          glue_1.2.0      evaluate_0.10.1
## [25] rmarkdown_1.9       labeling_0.3    stringi_1.1.6
## [28] compiler_3.4.3     pillar_1.1.0    backports_1.1.2
## [31] jsonlite_1.5       pkgconfig_2.0.1

```