GRTS Survey Designs for a Linear Resource

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Contents

1 Processor

A little-endian processor is required for this vignette. The .Platform function is used to ensure that the processor is little-endian.

```
> # Ensure that the processor is little-endian
>
> if(.Platform$endian == "big")
```

```
+    stop("\nA little-endian processor is required for this vignette.")
>
```

2 Preliminaries

This document presents example GRTS survey designs for a linear resource. The linear resource used in the designs is streams that comprise the Luckiamute watershed in Oregon. Four survey designs will be presented: (1) an unstratified, equal probability design; (2) a stratified, equal probability design with an oversample; (3) a stratified, unequal probability design with an oversample; and (4) a stratified, unequal probability design with an oversample and a panel structure for survey over time. The sampling frame used for the survey designs is contained in either an ESRI shapefile or an sp package object. The frame contains the coordinates for a set of line segments that define the linear resource in addition to attribute data associated with the line segments. The coordinate system for the set of points in the sampling frame is an equal area projection rather than latitude and longitude. An equal area projection is used so that calculation of distance between points is valid.

The initial step is to use the library function to load the spsurvey package. After the package is loaded, a message is printed to the R console indicating that the spsurvey package was loaded successfully.

Load the spsurvey package

```
> # Load the spsurvey package
> library(spsurvey)
>
```

```
Version 3.4 of the spsurvey package was loaded successfully.
```

3 Create a shapefile

For creating a survey design using the spsurvey package, the standard form of input regarding the resource is a shapefile. In order to conserve storage space, shapefiles are not included with the package. Instead, a data set from which a shapefile can be created is included in the data directory of the package. The data function is used to load the data set stored in the data directory into an object named Luck_Ash_streams. The sp2shape function is used to create a shapefile from the Luck_Ash_streams object. Note that objects loaded from the data sets in the data directory are stored in formats that are defined in the sp package. See documentation for the sp package for additional information regarding format of the objects.

```
> # Load the sp object in the data directory
> data(Luck_Ash_streams)
```

```
> # Create a shapefile
> sp2shape(sp.obj=Luck_Ash_streams, shpfilename="Luck_Ash_streams")
>
```

4 Shapefile attribute data

The next step is to read the attribute data from the shapefile. The read.dbf function in the spsurvey package is used to read the attribute (dbf) file in the shapefile and assign it to a data frame named att. The initial six lines in the att data frame are printed using the head function

Next, two attributes, stream type and Strahler stream order, that will be used to define, respectively, stratum codes and unequal selection probability (multidensity) categories for the survey designs are examined. Stream type is contained in a variable named "Per_Int", and Strahler stream order is contained in a variable named "Strah_Cat". For stream type, streams are classified as either perennial or intermittent. For Strahler stream order, streams are classified as either first order ("1st"), second order ("2nd"), or third order and higher ("3rd+"). The table and addmargin functions are used to produce a table displaying number of stream segments for each combination of values for the strata and multidensity category variables.

Finally, frame stream length is summarized for the strata and multidensity category attributes. Note that stream length measured in kilometers is contained in the variable named "Length_km". The tapply function is used to calculate total stream length for each combination of stream type and Strahler stream order. The addmargins function is applied to the output from tapply to calculate stream length for each category of stream type and Strahler stream order, and the round function is used to round value to two decimal places. Finally, the resulting cross-tabulation of sum of stream length in kilometers for Strahler stream order and stream type is displayed.

Read the attribute table from the shapefile

```
> # Read the attribute table from the shapefile
> att <- read.dbf("Luck_Ash_streams")
>
```

Display the initial six lines in the attribute data frame

```
> # Display the initial six lines in the attribute data frame
> head(att)
```

```
       Per_Int Strah_Cat Length_km length_mdm
1    Perennial       2nd 2.3261097  2326.1097
```

```
2 Intermittent       1st 0.5785829   578.5829
3 Intermittent       1st 0.7796058   779.6058
4    Perennial       1st 1.8757176  1875.7176
5 Intermittent       1st 1.0012245  1001.2245
6    Perennial       1st 1.6464196  1646.4196

>
```

Display number of stream segments cross-classified by the strata and multidensity category variables

```
> # Display number of stream segments cross-classified by the  strata and
> # multidensity category variables
>
> addmargins(table("Stream Type"=att$Per_Int, "Strahler Order"=att$Strah_Cat))

              Strahler Order
Stream Type    1st 2nd 3rd+ Sum
  Intermittent 137  20    2 159
  Perennial    104  78   88 270
  Sum          241  98   90 429

>
```

Summarize frame stream length by stratum and multidensity category

```
> # Summarize frame stream length by stratum and multidensity category
> temp <- tapply(att$Length_km, list(att$Per_Int, att$Strah_Cat), sum)
> temp <- round(addmargins(temp), 2)
> names(dimnames(temp)) <- list("Stream Type", "Strahler Order")
> temp

              Strahler Order
Stream Type       1st    2nd   3rd+    Sum
  Intermittent 305.53  20.51   3.03 329.07
  Perennial    200.53 133.10 159.79 493.42
  Sum          506.06 153.61 162.82 822.49

>
```

Streams in the Luckiamute watershed are displayed in Figure 1 classified by stream type and in Figure 2 classified by Strahler order category.

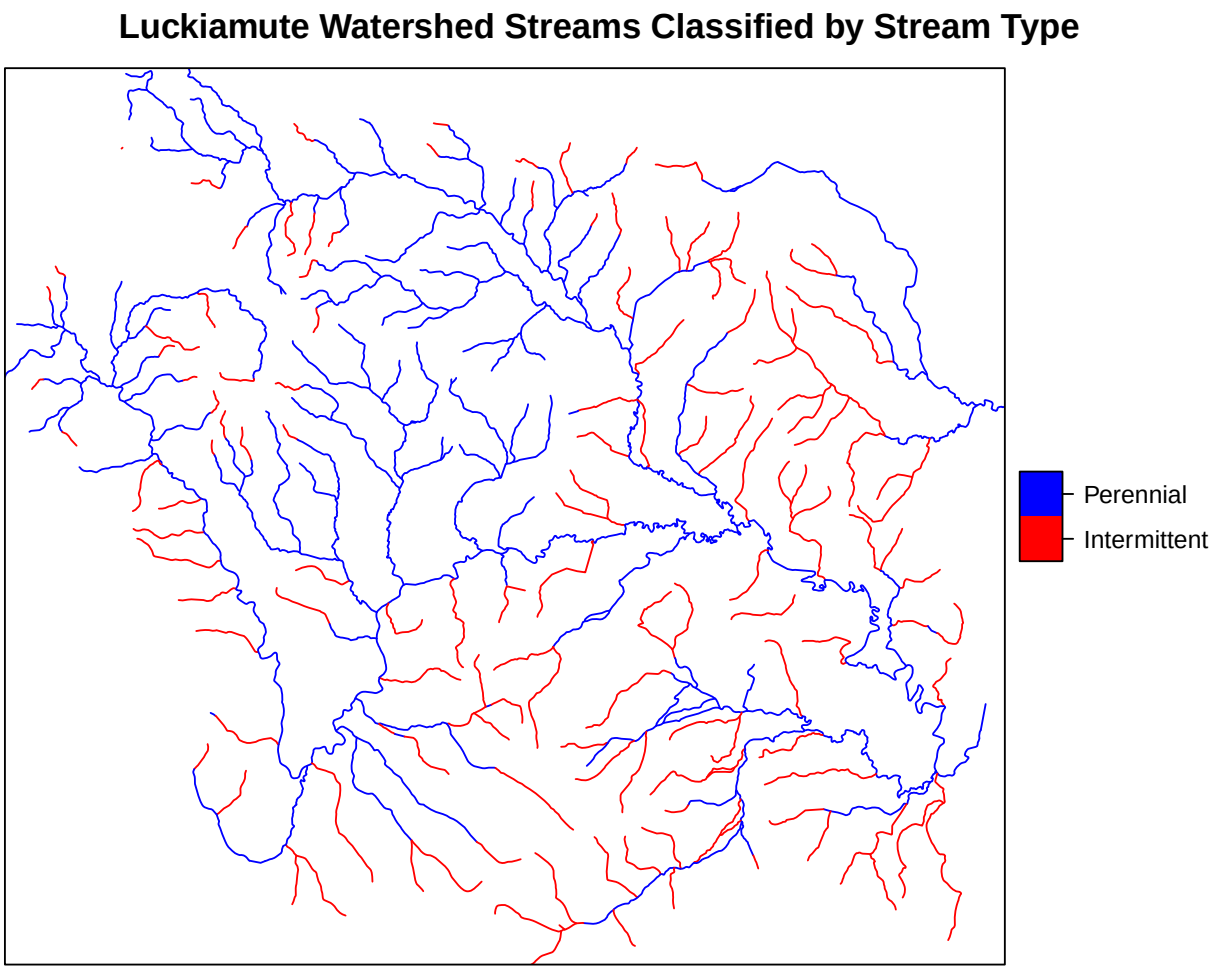

Figure 1: Location of streams in the Luckiamute watershed classified by stream type.

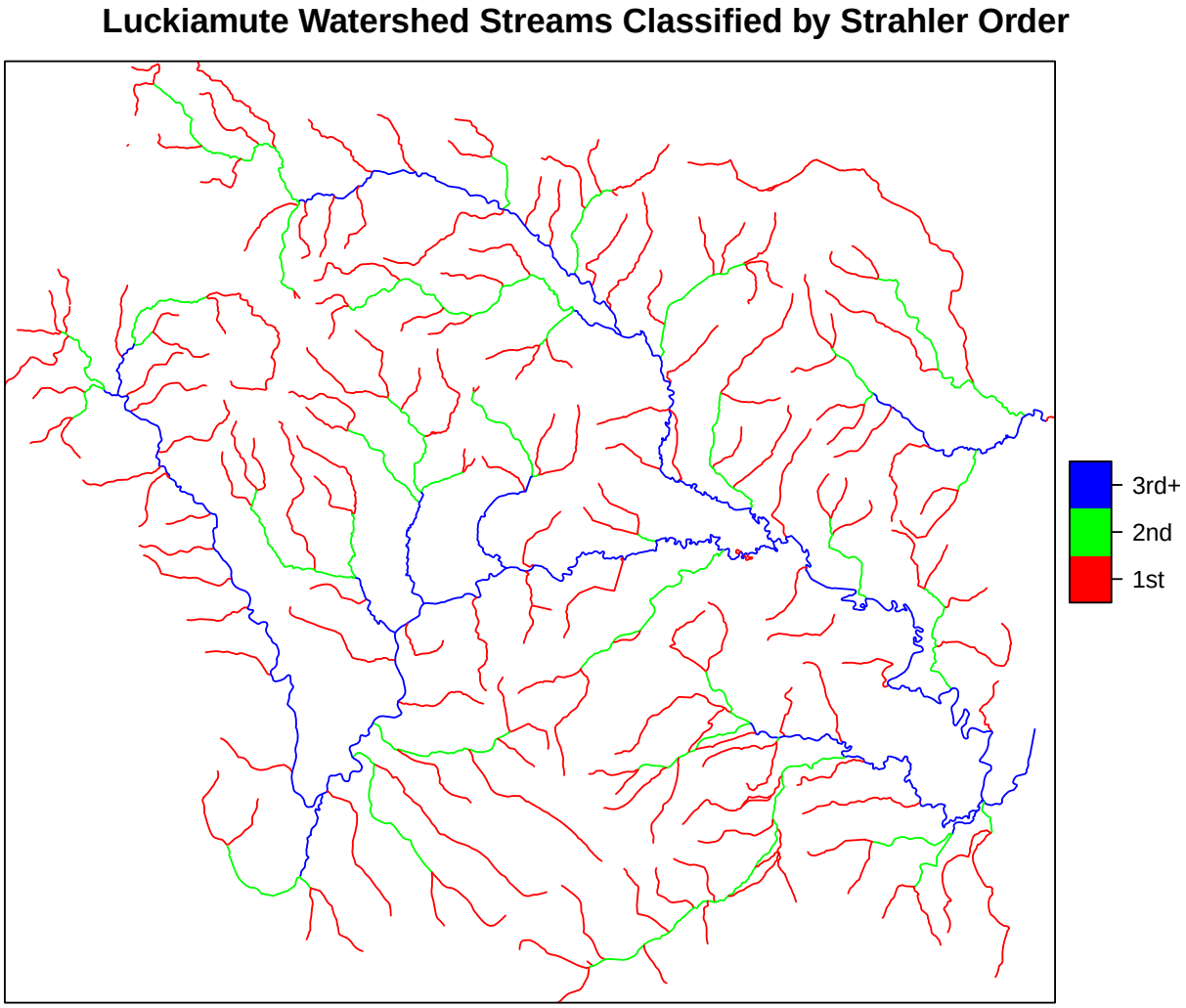

Figure 2: Location of streams in the Luckiamute watershed classified by Strahler order category.

5 Unstratified, equal probability, GRTS survey design

The first survey design is an unstratified, equal probability design. The set.seed function is called so that, if necessary, the designs can be replicated.

The initial step is to create a list named Equaldsgn that contains information for specifying the survey design. Since the survey design is unstratified, the list contains a single item named "None" that also is a list. The "None" list includes two items: panel, which is used to specify the sample size for each panel, and seltype, which is used to input the type of random selection for the design. For this example, panel is assigned a single value named "PanelOne" that is set equal to 50, and seltype is assigned the value "Equal", which indicates equal probability selection.

The grts function in the spsurvey package is called to select the survey design. The following arguments are included in the call to grts: (1) design: the named list of stratum design specifications, which is assigned the Equaldsgn list; (2) DesignID: name for the design, which is used to create a site ID for each site and is assigned the value "EQUAL"; (3) type.frame: the type of frame, which is assigned the value "linear" to indicate a linear resource; (4) src.frame: source of the frame, which is assigned the value "shapefile" to indicate a shapefile frame; (5) in.shape: name of the input shapefile, which is assigned the value "Luck_Ash_streams"; (6) att.frame: the data frame of attributes associated with elements in the frame, which is assigned the att data frame; and (7) shapefile: option to create a shapefile containing the survey design information, which is assigned FALSE.

During execution of the grts function, messages are printed that indicate the initial number of hierarchical levels used for the GRTS grid, the current number of levels, and the final number of levels. The set of messages is printed for each stratum, and is labeled with the stratum name. For this example, the set of messages is labeled "None", i.e., the name used in the Equaldsgn list. Upon completion of the call to grts, the initial six sites for the survey design and a design summary are printed. The output object created by the grts function is assigned class "SpatialDesign". The design summary is created using the summary method for that class. In addition to summary, a plot method is available for the SpatialDesign class. For assistance using the summary and plot methods, see documentation for "SpatialDesign-class" on the R help page for spsurvey.

Call the set.seed function so that the design can be replicated

```
> # Call the set.seed function so that the survey designs can be replicate
> set.seed(19742003)
>
```

Create the design list

```
> # Create the design list
> Equaldsgn <- list(None=list(panel=c(PanelOne=50), seltype="Equal"))
>
```

Select the sample

```
> Equalsites <- grts(design=Equaldsgn,
+                    DesignID="EQUAL",
+                    type.frame="linear",
+                    src.frame="shapefile",
+                    in.shape="Luck_Ash_streams",
+                    att.frame=att,
+                    shapefile=FALSE)

Stratum: None
Initial number of levels: 3
Current number of levels: 3
Current number of levels: 4
Final number of levels: 4
```

Print the initial six lines of the survey design

```
> # Print the initial six lines of the survey design
> head(Equalsites@data)
```

```
    siteID   xcoord  ycoord mdcaty      wgt stratum    panel EvalStatus
1 EQUAL-01 -2119063 2739299  Equal 16449.76    None PanelOne    NotEval
2 EQUAL-02 -2117586 2726770  Equal 16449.76    None PanelOne    NotEval
3 EQUAL-03 -2140807 2721474  Equal 16449.76    None PanelOne    NotEval
4 EQUAL-04 -2143508 2728881  Equal 16449.76    None PanelOne    NotEval
5 EQUAL-05 -2127398 2735785  Equal 16449.76    None PanelOne    NotEval
6 EQUAL-06 -2125650 2721219  Equal 16449.76    None PanelOne    NotEval
  EvalReason      Per_Int Strah_Cat  Length_km
1               Perennial       1st 11.2514779
2            Intermittent       1st  2.5907186
3               Perennial      3rd+  2.7692863
4               Perennial       2nd  3.8583344
5               Perennial       1st  2.5709407
6            Intermittent       1st  0.9140192

>
```

Print the survey design summary

```
> # Print the survey design summary
> summary(Equalsites)

Design Summary: Number of Sites

stratum
None  Sum
  50   50

>
```

6 Stratified, equal probability, GRTS survey design with an oversample

The second survey design is a stratified, equal probability design with an oversample. The stream type attribute is used to identify strata. List Stratdsgn is assigned design specifications. Since the survey design is stratified, Stratdsgn includes two lists named "Perennial" and "Intermittent" that contains three items: panel, seltype, and over. Note that the names for the two lists match the levels of the stratum variable. For both lists, the values for panel and seltype are the same as the ones used for the equal probability design. The third item, over, assigns the value 50 for size of the oversample. An oversample provides additional sample sites to replace sites that cannot be used, e.g., to replace sites in the sample that are not accessible.

For this survey design, a shapefile will be used as the sampling frame. The following arguments are included in the call to grts: (1) design: assigned the Stratdsgn list; (2) DesignID: assigned the value "STRATIFIED"; (3) type.frame: assigned the value "linear"; (4) src.frame: assigned the value "shapefile"; (5) in.shape: assigned the value "Luck_Ash_streams"; (6) att.frame: assigned the att data frame; (7) stratum: name of the column in the attributes data frame that identifies the stratum code for each element in the frame, which is assigned the value "Per_Int"; and (8) shapefile: assigned the value FALSE. Upon completion of the call to grts, the initial six sites for the survey design and a design summary are printed.

Create the design list

```
> Stratdsgn <- list(Perennial=list(panel=c(PanelOne=50),
+                                  seltype="Equal",
+                                  over=50),
+                   Intermittent=list(panel=c(PanelOne=50),
+                                     seltype="Equal",
+                                     over=50))
```

Select the sample

```
> Stratsites <- grts(design=Stratdsgn,
+                    DesignID="STRATIFIED",
+                    type.frame="linear",
+                    src.frame="shapefile",
+                    in.shape="Luck_Ash_streams",
+                    att.frame=att,
+                    stratum="Per_Int",
+                    shapefile=FALSE)

Stratum: Perennial
Initial number of levels: 4
Current number of levels: 4
Current number of levels: 5
Final number of levels: 5

Stratum: Intermittent
Initial number of levels: 4
Current number of levels: 4
Current number of levels: 5
Current number of levels: 6
Final number of levels: 6
```

Print the initial six lines of the survey design

```
> # Print the initial six lines of the survey design
> head(Stratsites@data)

          siteID   xcoord  ycoord mdcaty      wgt   stratum    panel EvalStatus
1 STRATIFIED-001 -2148177 2746498  Equal 9868.441 Perennial PanelOne    NotEval
2 STRATIFIED-002 -2130818 2739798  Equal 9868.441 Perennial PanelOne    NotEval
3 STRATIFIED-003 -2129984 2733147  Equal 9868.441 Perennial PanelOne    NotEval
4 STRATIFIED-004 -2141371 2730953  Equal 9868.441 Perennial PanelOne    NotEval
5 STRATIFIED-005 -2138567 2738921  Equal 9868.441 Perennial PanelOne    NotEval
6 STRATIFIED-006 -2119534 2738224  Equal 9868.441 Perennial PanelOne    NotEval
  EvalReason Strah_Cat Length_km
1                  1st  1.875718
2                  1st  3.351032
3                 3rd+  2.963369
4                  1st  2.248107
5                  2nd  2.097773
6                  1st 11.251478

>
```

Print the survey design summary

```
> # Print the survey design summary
> summary(Stratsites)

Design Summary: Number of Sites Classified by panel and stratum

          stratum
panel      Perennial Intermittent Sum
  OverSamp        50           50 100
  PanelOne        50           50 100
  Sum            100          100 200

>
```

7 Stratified, unequal probability, GRTS survey design with an oversample

The third survey design is a stratified, unequal probability design with an oversample. As for the second survey design, the stream type attribute is used to identify strata. Strahler order categories are used to identify multidensity categories. List Unequaldsgn is assigned design specifications. Unequaldsgn includes the same two lists with three items (panel, seltype, and over) as used for the stratified, equal probability design plus a value for caty.n. For both lists, panel specifies a single panel, and seltype is assigned "Unequal" to indicate unequal probability sampling. Note that the value 0 is assigned to over for the "Intermittent" stratum, i.e., no oversample. The over item could have been omitted from the list for "Intermittent". The vector assigned to caty.n specifies sample sizes for each of the three multidensity categories. Note that the sum of values provided in caty.n must equal the value in panel.

For this survey design, an sp package object will be used as the sampling frame. The read.shape function will be used to read the shapefile and assign its output to an sp object named shp. Note that the object created by the read.shape function is identical to the object that was loaded from the data directory at the beginning of this vignette. The following arguments are included in the call to grts: (1) design: assigned the Unequaldsgn list; (2) DesignID: assigned the value "UNEQUAL"; (3) type.frame: assigned the value "linear"; (4) src.frame: assigned the value "sp.object" to indicate that the sampling frame is provided by an sp object; (5) sp.object: name of the sp object, which is assigned the shp object; (6) att.frame: assigned the att data frame; (7) stratum: assigned the value "Per_Int"; (8) mdcaty: name of the column in the attributes data frame that identifies the unequal probability category for each element in the frame, which is assigned the value "Strah_Cat"; (9) shapefile: assigned the value FALSE. Upon completion of the call to grts, the initial six sites for the survey design and a design summary are printed.

```
> # Read the shapefile
> shp <- read.shape("Luck_Ash_streams")
>
```

Create the design list

```
> Unequaldsgn <- list(Perennial=list(panel=c(PanelOne=75),
+                                    seltype="Unequal",
+                                    caty.n=c("1st"=25, "2nd"=25, "3rd+"=25),
+                                    over=36),
+                     Intermittent=list(panel=c(PanelOne=32),
+                                       seltype="Unequal",
+                                       caty.n=c("1st"=25, "2nd"=5, "3rd+"=2),
+                                       over=0))
```

Select the sample

```
> Unequalsites <- grts(design=Unequaldsgn,
+                      DesignID="UNEQUAL",
+                      type.frame="linear",
+                      src.frame="sp.object",
+                      sp.object=shp,
+                      att.frame=att,
+                      stratum="Per_Int",
+                      mdcaty="Strah_Cat",
+                      shapefile=FALSE)

Stratum: Perennial
Initial number of levels: 4
Current number of levels: 4
Current number of levels: 5
Current number of levels: 6
Final number of levels: 6

Stratum: Intermittent
Initial number of levels: 3
Current number of levels: 3
Current number of levels: 4
Current number of levels: 5
Final number of levels: 5
```

Print the initial six lines of the survey design

```
> # Print the initial six lines of the survey design
> head(Unequalsites@data)
```

```
       siteID   xcoord  ycoord mdcaty      wgt   stratum    panel EvalStatus
1 UNEQUAL-001 -2124367 2743509    1st 8021.238 Perennial PanelOne    NotEval
2 UNEQUAL-002 -2133590 2738266    2nd 5324.034 Perennial PanelOne    NotEval
3 UNEQUAL-003 -2139340 2726639   3rd+ 6391.609 Perennial PanelOne    NotEval
4 UNEQUAL-004 -2131126 2726422    2nd 5324.034 Perennial PanelOne    NotEval
5 UNEQUAL-005 -2138546 2743004   3rd+ 6391.609 Perennial PanelOne    NotEval
6 UNEQUAL-006 -2149032 2736713   3rd+ 6391.609 Perennial PanelOne    NotEval
  EvalReason Length_km
1            1.7852580
2            2.5738358
3            0.5642644
4            1.0838318
5            3.9999820
6            0.6595996

>
```

Print the survey design summary

```
> # Print the survey design summary
> summary(Unequalsites)

Design Summary: Number of Sites Classified by mdcaty (Multidensity Category)
and stratum

      stratum
mdcaty Perennial Intermittent Sum
  1st         36           24  60
  2nd         33            6  39
  3rd+        42            2  44
  Sum        111           32 143


Design Summary: Number of Sites Classified by panel and stratum

          stratum
panel      Perennial Intermittent Sum
  OverSamp        36            0  36
  PanelOne        75           32 107
  Sum            111           32 143


Design Summary: Number of Sites Classified by mdcaty (Multidensity Category),
panel, and stratum
```

```
, , stratum = Perennial

      panel
mdcaty OverSamp PanelOne Sum
  1st         9       27  36
  2nd        10       23  33
  3rd+       17       25  42
  Sum        36       75 111

, , stratum = Intermittent

      panel
mdcaty OverSamp PanelOne Sum
  1st         0       24  24
  2nd         0        6   6
  3rd+        0        2   2
  Sum         0       32  32

, , stratum = Sum

      panel
mdcaty OverSamp PanelOne Sum
  1st         9       51  60
  2nd        10       29  39
  3rd+       17       27  44
  Sum        36      107 143

>
```

8 Stratified, unequal probability, GRTS survey design with an oversample and a panel structure for survey over time

The fourth survey design is a stratified, unequal probability design with an oversample and a panel structure for survey over time. List Paneldsgn is assigned design specifications. Analogous to the stratified, unequal probability design, Paneldsgn includes two lists named "Perennial" and "Intermittent". For the "Perennial" stratum, a vector identifying sample sizes for three panels is assigned to panel. For the "Intermittent" stratum, the sample size for a single panel named "Annual" is assigned to panel. The value "Unequal" is assigned to seltype for both lists, which indicates unequal selection probabilities. For both lists, the third item, caty.n, assigns sample sizes for each of the three multidensity categories. Again, note that

the sum of sample sizes provided in caty.n must equal the sum of sample sizes in panel. For the "Perennial" stratum, the value 50 is assigned to over, which specifies an oversample of 50 sites. No oversample is specified for the "Intermittent" stratum, and so over is not included in the list. The grts function attempts to distribute the oversample proportionately among sample sizes for the multidensity categories. If the oversample proportion for one or more categories is not a whole number, a warning message is printed and the proportion is rounded to the next higher integer.

For this survey design, a shapefile will be used as the sampling frame. The following arguments are included in the call to grts: (1) design: assigned the Paneldsgn list; (2) DesignID: assigned the value "UNEQUAL"; (3) type.frame: assigned the value "linear"; (4) src.frame: assigned the value "shapefile"; (5) in.shape: assigned the value "Luck_Ash_streams"; (6) att.frame: assigned the att data frame; 7) stratum: assigned the value "Per_Int"; (8) mdcaty: assigned the value "Strah_Cat"; (9) shapefile: assigned the value FALSE. Upon completion of the call to grts, the initial six sites for the survey design and a design summary are printed.

Create the design list

```
> Paneldsgn <- list(Perennial=list(panel=c(Annual=16, Year1=17, Year2=17),
+                                  seltype="Unequal",
+                                  caty.n=c("1st"=15, "2nd"=15, "3rd+"=20),
+                                  over=50),
+                   Intermittent=list(panel=c(Annual=27),
+                                     seltype="Unequal",
+                                     caty.n=c("1st"=20, "2nd"=5, "3rd+"=2)))
```

Select the sample

```
> Panelsites <- grts(design=Paneldsgn,
+                    DesignID="UNEQUAL",
+                    type.frame="linear",
+                    src.frame="shapefile",
+                    in.shape="Luck_Ash_streams",
+                    att.frame=att,
+                    stratum="Per_Int",
+                    mdcaty="Strah_Cat",
+                    shapefile=FALSE)


Stratum: Perennial
Initial number of levels: 4
Current number of levels: 4
Current number of levels: 5
Final number of levels: 5

Stratum: Intermittent
```

```
Initial number of levels: 3
Current number of levels: 3
Current number of levels: 4
Current number of levels: 5
Current number of levels: 6
Final number of levels: 6
```

Print the initial six lines of the survey design

```
> # Print the initial six lines of the survey design
> head(Panelsites@data)
```

```
       siteID   xcoord  ycoord mdcaty       wgt   stratum  panel EvalStatus
1 UNEQUAL-001 -2134568 2740846   3rd+  7989.511 Perennial Annual    NotEval
2 UNEQUAL-002 -2151457 2736794    1st 13368.731 Perennial Annual    NotEval
3 UNEQUAL-003 -2129716 2733538   3rd+  7989.511 Perennial Annual    NotEval
4 UNEQUAL-004 -2121378 2739006    2nd  8873.391 Perennial Annual    NotEval
5 UNEQUAL-005 -2135252 2741591   3rd+  7989.511 Perennial Annual    NotEval
6 UNEQUAL-006 -2139503 2726319   3rd+  7989.511 Perennial Annual    NotEval
  EvalReason Length_km
1             1.331251
2             3.711475
3             2.963369
4             4.690253
5             1.042877
6             1.034233
```

```
>
```

Print the survey design summary

```
> # Print the survey design summary
> summary(Panelsites)
```

```
Design Summary: Number of Sites Classified by mdcaty (Multidensity Category)
and stratum
```

```
      stratum
mdcaty Perennial Intermittent Sum
  1st         36           20  56
  2nd         24            4  28
  3rd+        40            3  43
```

```
  Sum        100           27 127


Design Summary: Number of Sites Classified by panel and stratum

          stratum
panel      Perennial Intermittent Sum
  Annual          16           27  43
  OverSamp        50            0  50
  Year1           17            0  17
  Year2           17            0  17
  Sum            100           27 127


Design Summary: Number of Sites Classified by mdcaty (Multidensity Category),
panel, and stratum

, , stratum = Perennial

      panel
mdcaty Annual OverSamp Year1 Year2 Sum
  1st       4       18     6     8  36
  2nd       5       12     2     5  24
  3rd+      7       20     9     4  40
  Sum      16       50    17    17 100

, , stratum = Intermittent

      panel
mdcaty Annual OverSamp Year1 Year2 Sum
  1st      20        0     0     0  20
  2nd       4        0     0     0   4
  3rd+      3        0     0     0   3
  Sum      27        0     0     0  27

, , stratum = Sum

      panel
mdcaty Annual OverSamp Year1 Year2 Sum
  1st      24       18     6     8  56
  2nd       9       12     2     5  28
  3rd+     10       20     9     4  43
  Sum      43       50    17    17 127

>
```