GRTS Survey Designs for a Linear Resource

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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.

1 Preliminaries

The intital 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

```
> library(spsurvey)
```

```
Version 2.1 of the spsurvey package was loaded successfully.
```

2 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 "perint", and Strahler stream order is contained in a variable named "strahcat". For stream type, streams are clasified 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

```
> att <- read.dbf("luck_ash")
```

Display the initial six lines in the attribute data frame

```
> head(att)

        perint strahcat 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

```
> addmargins(table(`Stream Type` = att$perint, `Strahler Order` = att$strahcat))

               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

```
> temp <- tapply(att$length_km, list(att$perint, att$strahcat),
+      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 stream order category. To produce the figure, first the read.shape function in the spsurvey package is used to read the shapefile and assign it to an object named

shp. The shp object takes the form of a spatial data object defined in the sp package. Specifically, shp belongs to class "SpatialLinesDataFrame". For further information about spatial data objects, see documentation for the sp package. The spplot function in the sp package is used to create the figures.

Read the shapefile

```
> shp <- read.shape("luck_ash")
```

Plot streams in the Luckiamute watershed classified by stream type

```
> spplot(shp, zcol="perint", col.regions=c("red", "blue"))
```

Plot streams in the Luckiamute watershed classified by Strahler stream order

```
> spplot(shp, zcol="strahcat", col.regions=c("red", "green", "blue"))
```

3 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"; (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.

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

```
> set.seed(19742003)
```

Create the design list

```
> Equaldsgn <- list(None = list(panel = c(PanelOne = 50), seltype = "Equal"))
```
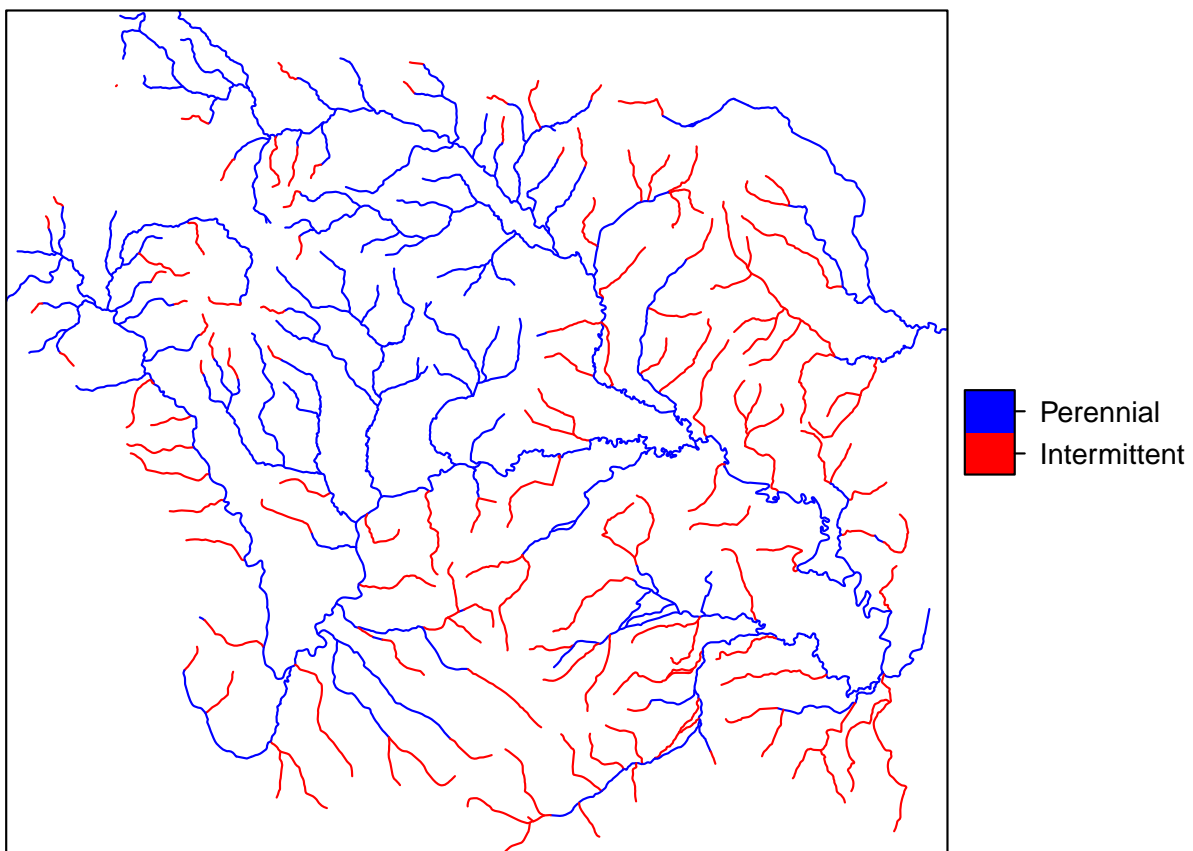
Select the sample

Figure 1: Streams in the Luckiamute Watershed Classified by Stream Type.
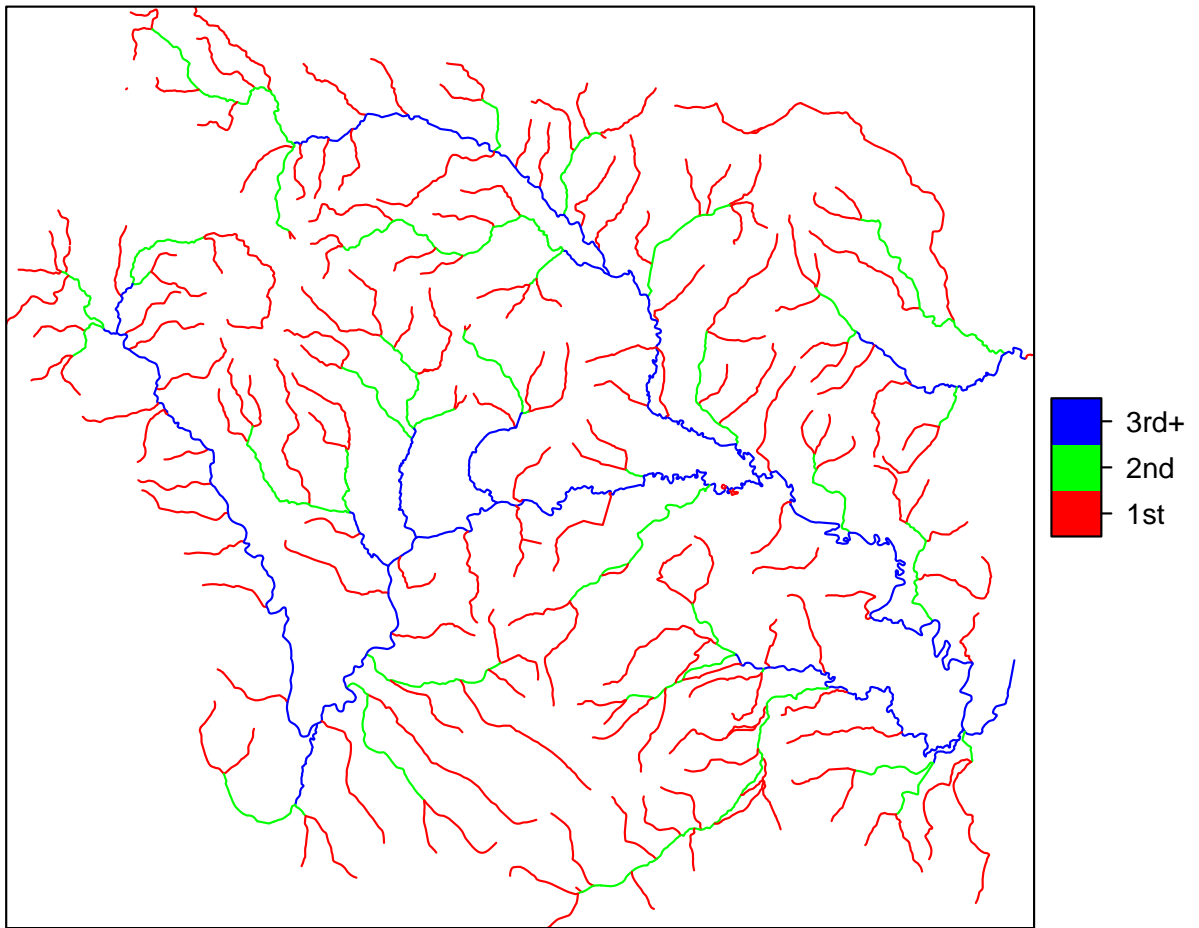
Figure 2: Streams in the Luckiamute Watershed Classified by Strahler Stream Order Category.

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

```
> head(Equalsites@data)

    siteID   xcoord  ycoord mdcaty       wgt stratum      panel EvalStatus
1 EQUAL-01 -2150812 2735224  Equal 16449.76    None PanelOne    NotEval
2 EQUAL-02 -2144418 2735266  Equal 16449.76    None PanelOne    NotEval
3 EQUAL-03 -2141716 2742115  Equal 16449.76    None PanelOne    NotEval
4 EQUAL-04 -2124993 2721669  Equal 16449.76    None PanelOne    NotEval
5 EQUAL-05 -2129214 2731968  Equal 16449.76    None PanelOne    NotEval
6 EQUAL-06 -2141493 2721389  Equal 16449.76    None PanelOne    NotEval
  EvalReason        perint strahcat length_km
1            Perennial         1st 1.5970450
2         Intermittent         1st 1.4952739
3            Perennial         1st 0.6707707
4            Perennial         2nd 2.7419852
5            Perennial        3rd+ 3.6578044
6            Perennial        3rd+ 2.7692863
```

Print the survey design summary

```
> dsgnsum(Equalsites)

Design Summary: Number of Sites

stratum
None  Sum
  50   50
```

4   Stratified, equal probability, GRTS survey design with an over-sample

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"; (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 "perint"; 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",
+                 att.frame=att,
+                 stratum="perint",
+                 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
Final number of levels: 5
```

Print the initial six lines of the survey design

```
> head(Stratsites@data)
```

```
        siteID    xcoord  ycoord mdcaty      wgt    stratum     panel EvalStatus
1 STRATIFIED-001 -2140465 2743111  Equal 9868.44 Perennial PanelOne    NotEval
2 STRATIFIED-002 -2151407 2737845  Equal 9868.44 Perennial PanelOne    NotEval
3 STRATIFIED-003 -2137700 2727590  Equal 9868.44 Perennial PanelOne    NotEval
4 STRATIFIED-004 -2151808 2736499  Equal 9868.44 Perennial PanelOne    NotEval
5 STRATIFIED-005 -2144328 2737853  Equal 9868.44 Perennial PanelOne    NotEval
6 STRATIFIED-006 -2139729 2726615  Equal 9868.44 Perennial PanelOne    NotEval
  EvalReason strahcat length_km
1               1st   2.148345
2               1st   1.081804
3               3rd+  2.026988
4               1st   3.711475
5               1st   5.890572
6               3rd+  2.024677
```

Print the survey design summary

```
> dsgnsum(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
```

5 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 ommitted 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. Recall that the read.shape function was used to read the shapefile and assign its output to an sp object named shp. 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 "perint"; (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 "strahcat"; (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

```
> 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="perint",
+                       mdcaty="strahcat",
+                       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

```
> head(Unequalsites@data)

      siteID   xcoord  ycoord mdcaty      wgt    stratum     panel EvalStatus
1 UNEQUAL-001 -2135601 2731417   3rd+ 6391.609 Perennial PanelOne    NotEval
2 UNEQUAL-002 -2138626 2735785    1st 8021.238 Perennial PanelOne    NotEval
3 UNEQUAL-003 -2131014 2714764    2nd 5324.034 Perennial PanelOne    NotEval
4 UNEQUAL-004 -2146969 2738402    2nd 5324.034 Perennial PanelOne    NotEval
5 UNEQUAL-005 -2129903 2732867   3rd+ 6391.609 Perennial PanelOne    NotEval
6 UNEQUAL-006 -2141733 2721328   3rd+ 6391.609 Perennial PanelOne    NotEval
```

9

```
  EvalReason length_km
1          4.805305
2          1.772859
3          1.345379
4          4.091204
5          2.963369
6          2.769286
```

Print the survey design summary

```
> dsgnsum(Unequalsites)
```

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

       stratum
mdcaty Perennial Intermittent Sum
  1st         31           26  57
  2nd         46            3  49
  3rd+        34            3  37
  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        13       18  31
  2nd        12       34  46
  3rd+       11       23  34
  Sum        36       75 111

, , stratum = Intermittent

       panel
mdcaty OverSamp PanelOne Sum
```

```
   1st           0        26  26
   2nd           0         3   3
   3rd+          0         3   3
   Sum           0        32  32

, , stratum = Sum

        panel
mdcaty OverSamp PanelOne Sum
   1st          13       44  57
   2nd          12       37  49
   3rd+         11       26  37
   Sum          36      107 143
```

6 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 "YearOnce" 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 the "Perennial" stratum, the oversample is not proportionate to the multidensity category sample sizes, and the warning message is printed by calling the warnings function.

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"; (6) att.frame: assigned the att data frame; 7) stratum: assigned the value "perint"; (8) mdcaty: assigned the value "strahcat"; (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(Year1=17, Year2=17, YearAll=16),
+                                 seltype="Unequal",
+                                 caty.n=c("1st"=15, "2nd"=15, "3rd+"=20),
+                                 over=50),
+                  Intermittent=list(panel=c(YearOnce=27),
+                                    seltype="Unequal",
```

Select the sample

```
> Panelsites <- grts(design=Paneldsgn,
+                    DesignID="UNEQUAL",
+                    type.frame="linear",
+                    src.frame="shapefile",
+                    in.shape="luck_ash",
+                    att.frame=att,
+                    stratum="perint",
+                    mdcaty="strahcat",
+                    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
Final number of levels: 5
```

Print the warning message

```
> warnings()
```

```
Warning message:
In grts(design = Paneldsgn, DesignID = "UNEQUAL", type.frame = "linear",  :
```

```
Oversample size is not proportional to category sample sizes for stratum
"Perennial".
```

Print the initial six lines of the survey design

```
> head(Panelsites@data)
```

```
        siteID   xcoord  ycoord mdcaty       wgt   stratum panel EvalStatus
1 UNEQUAL-001 -2121914 2742158    1st 13368.731 Perennial Year1    NotEval
2 UNEQUAL-002 -2134368 2736824    1st 13368.731 Perennial Year1    NotEval
3 UNEQUAL-003 -2141032 2729224    2nd  8873.391 Perennial Year1    NotEval
4 UNEQUAL-004 -2137683 2733743    1st 13368.731 Perennial Year1    NotEval
5 UNEQUAL-005 -2141244 2742218   3rd+  7989.511 Perennial Year1    NotEval
6 UNEQUAL-006 -2149405 2737599    1st 13368.731 Perennial Year1    NotEval
  EvalReason length_km
1            11.251478
2             2.023301
```

```
3                2.670265
4                3.810946
5                1.058053
6                2.735620
```

Print the survey design summary

```
> dsgnsum(Panelsites)
```

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

       stratum
mdcaty Perennial Intermittent Sum
  1st          35           23  58
  2nd          28            2  30
  3rd+         37            2  39
  Sum         100           27 127
```

```
Design Summary: Number of Sites Classified by panel and stratum

           stratum
panel      Perennial Intermittent Sum
  OverSamp        50            0  50
  Year1           17            0  17
  Year2           17            0  17
  YearAll         16            0  16
  YearOnce         0           27  27
  Sum            100           27 127
```

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

, , stratum = Perennial

       panel
mdcaty OverSamp Year1 Year2 YearAll YearOnce Sum
  1st        17     7     4       7        0  35
  2nd        15     5     6       2        0  28
  3rd+       18     5     7       7        0  37
  Sum        50    17    17      16        0 100

, , stratum = Intermittent

       panel
mdcaty OverSamp Year1 Year2 YearAll YearOnce Sum
```

```
    1st             0       0       0       0       23   23
    2nd             0       0       0       0        2    2
    3rd+            0       0       0       0        2    2
    Sum             0       0       0       0       27   27

, , stratum = Sum

        panel
mdcaty OverSamp Year1 Year2 YearAll YearOnce  Sum
    1st           17       7       4       7       23   58
    2nd           15       5       6       2        2   30
    3rd+          18       5       7       7        2   39
    Sum           50      17      17      16       27  127
```