GRTS Survey Designs for an Area 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")
```

1

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

2   Preliminaries

This document presents example GRTS survey designs for an area resource. The area resource used in the designs is Omernik level 3 ecoregions within Utah. Four survey designs will be presented: (1) an unstratified, equal probability design; (2) an unstratified, unequal probability design; (3) a stratified, equal probability design; and (4) an unstratified, 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 polygons that define the area resource in addition to attribute data associated with the polygons. 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 UT_ecoregions. The sp2shape function is used to create a shapefile from the UT_ecoregions 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(UT_ecoregions)
```

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

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 att data frame is printed by entering the data frame name at the R prompt.

The ecoregion attribute will be used to define stratum codes and unequal selection probability (multidensity) categories for the survey designs. Ecoregion is contained in a variable named "level3_nam" and includes seven unique values. Frame area is summarized for the ecoregion attribute. Note that ecoregion area measured in hectares is contained in the variable named "area_ha". The tapply function is used to calculate total area for each ecoregion. The addmargins function is applied to the output from tapply to calculate total area for all all ecoregions, and the round function is used to round value to whole numbers. Finally, the resulting table is displayed.

Read the attribute table from the shapefile

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

Display the attribute data frame

```
> # Display the attribute data frame
> att

   Level3                 Level3_Nam      Area_ha      area_mdm
1      80    Northern Basin and Range 1.42202e+11   2639990439
2      18               Wyoming Basin 1.33312e+11   2910588302
3      13     Central Basin and Range 3.09949e+11  82064546355
4      19 Wasatch and Uinta Mountains 4.47240e+10  42569491524
5      20            Colorado Plateaus 1.26379e+11  85797163092
6      21             Southern Rockies 5.40909e+08    540909129
7      14       Mojave Basin and Range 1.29599e+11   1931860757
8      19 Wasatch and Uinta Mountains 3.43657e+08    343657270
9      19 Wasatch and Uinta Mountains 6.26102e+08    626102339
10     21             Southern Rockies 4.05534e+08    405534288
```

```
>
```

Summarize frame area by ecoregion

```
> # Summarize frame area by ecoregion
> temp <- tapply(att$Area_ha, att$Level3_Nam, sum)
> temp <- round(addmargins(temp), 0)
> temp

    Central Basin and Range            Colorado Plateaus
               309949000000                 126379000000
     Mojave Basin and Range      Northern Basin and Range
               129599000000                 142202000000
          Southern Rockies  Wasatch and Uinta Mountains
                  946443000                   45693759000
              Wyoming Basin                          Sum
               133312000000                 888081202000


>
```

The seven ecoregions in Utah are displayed in Figure 1. Ecoregions are used during creation of several of the survey designs described in this vignette.
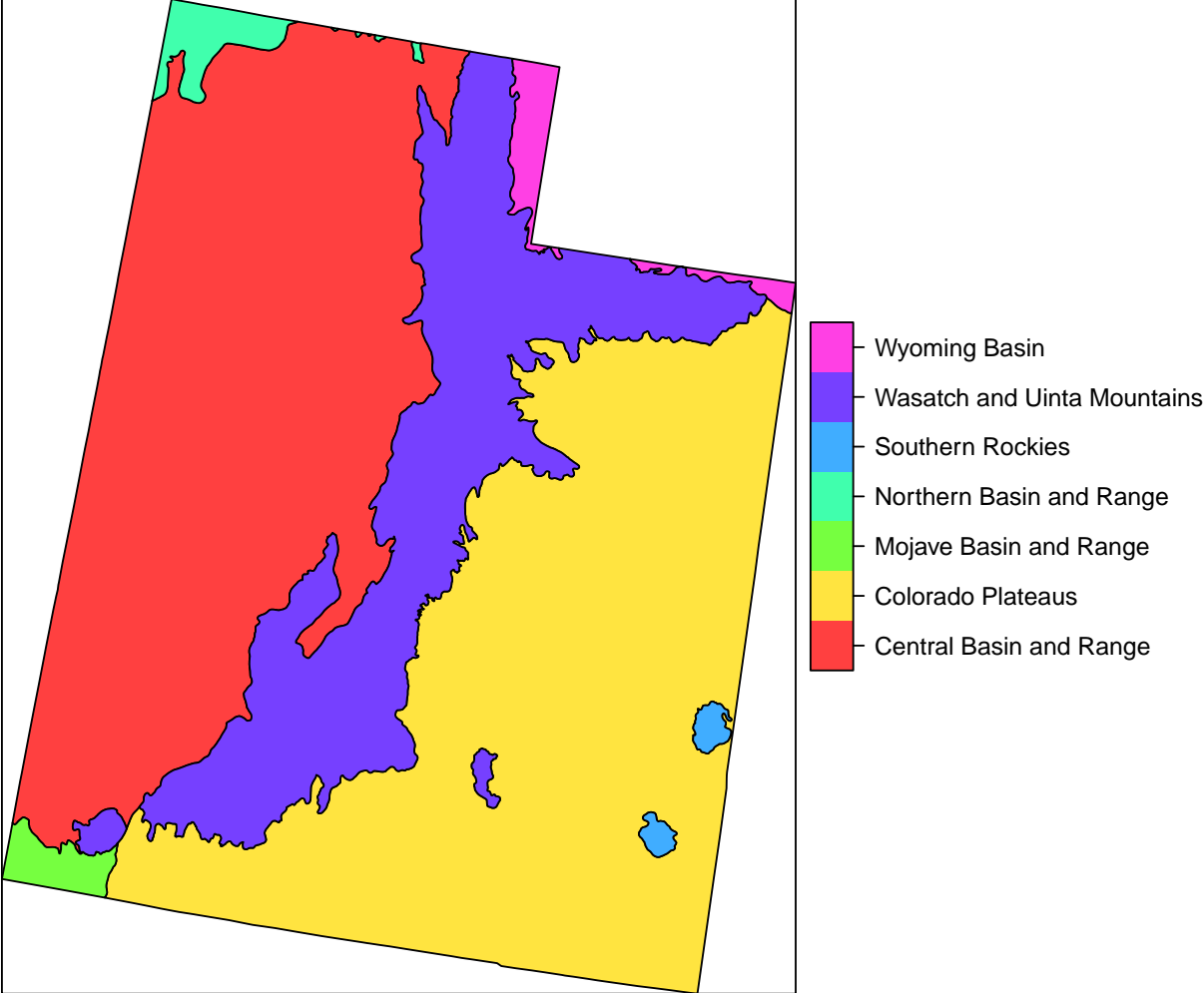
Ecoregions in Utah

Figure 1: Location of the seven ecoregions in Utah.

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 115, 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 "area" to indicate an area 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 "UT_ecoregions"; (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(4447864)
>
```

Create the design list

```
> # Create the design list
> Equaldsgn <- list(None=list(panel=c(PanelOne=115), seltype="Equal"))
>
```

Select the sample

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


Stratum: None
Initial number of levels: 4
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-001 -1361882 1986078  Equal 1911563856    None PanelOne    NotEval
2 EQUAL-002 -1304045 2195914  Equal 1911563856    None PanelOne    NotEval
3 EQUAL-003 -1269657 1803336  Equal 1911563856    None PanelOne    NotEval
4 EQUAL-004 -1311248 1689394  Equal 1911563856    None PanelOne    NotEval
5 EQUAL-005 -1353690 2074387  Equal 1911563856    None PanelOne    NotEval
6 EQUAL-006 -1389763 2190386  Equal 1911563856    None PanelOne    NotEval
  EvalReason Level3          Level3_Nam     Area_ha
1                13 Central Basin and Range 3.09949e+11
2                13 Central Basin and Range 3.09949e+11
3                20       Colorado Plateaus 1.26379e+11
4                20       Colorado Plateaus 1.26379e+11
5                13 Central Basin and Range 3.09949e+11
6                13 Central Basin and Range 3.09949e+11


>
```

Print the survey design summary

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

```
Design Summary: Number of Sites

stratum
None  Sum
 115  115


>
```

6 Unstratified, unequal probability, GRTS survey design

The second survey design is an unstratified, unequal probability design. Ecoregions are used to identify multidensity categories. List Unequaldsgn is assigned design specifications. Since the survey design is unstratified, Unequaldsgn includes a single list named "None" that contains three items: panel, seltype, and caty.n. The value for panel is the same as for the equal probability design, and seltype is assigned "Unequal" to indicate unequal selection probabilities. The third item, caty.n, assigns sample sizes for each of seven multidensity categories, where ecoregion names are used as the categories. Note that the sum of sample sizes provided in caty.n must equal the value in panel.

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 Unequaldsgn list; (2) DesignID: assigned the value "UNEQUAL"; (3) type.frame: assigned the value "area"; (4) src.frame: assigned the value "shapefile"; (5) in.shape: assigned the value "UT_ecoregions"; (6) att.frame: assigned the att data frame; (7) 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 "level3_nam"; 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

```
> Unequaldsgn <- list(None=list(panel=c(PanelOne=115),
+                               seltype="Unequal",
+                               caty.n=c("Central Basin and Range"=25,
+                                        "Colorado Plateaus"=25,
+                                        "Mojave Basin and Range"=10,
+                                        "Northern Basin and Range"=10,
+                                        "Southern Rockies"=10,
+                                        "Wasatch and Uinta Mountains"=25,
 +                                       "Wyoming Basin"=10)))
```

Select the sample

```
> Unequalsites <- grts(design=Unequaldsgn,
+                       DesignID="UNEQUAL",
+                       type.frame="area",
+                       src.frame="shapefile",
+                       in.shape="UT_ecoregions",
+                       att.frame=att,
+                       mdcaty="Level3_Nam",
+                       shapefile=FALSE)


Stratum: None
Initial number of levels: 4
Current number of levels: 4
Current number of levels: 6
Current number of levels: 7
Final number of levels: 7
```

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
1 UNEQUAL-001 -1471013 2106177      Central Basin and Range 3282581854    None
2 UNEQUAL-002 -1354503 1848229 Wasatch and Uinta Mountains 1741570045    None
3 UNEQUAL-003 -1298067 1916720 Wasatch and Uinta Mountains 1741570045    None
4 UNEQUAL-004 -1165284 1728905             Southern Rockies   94644342    None
5 UNEQUAL-005 -1395426 2161246      Central Basin and Range 3282581854    None
6 UNEQUAL-006 -1483098 1743104 Wasatch and Uinta Mountains 1741570045    None
     panel EvalStatus EvalReason Level3     Area_ha
1 PanelOne    NotEval                13 3.09949e+11
2 PanelOne    NotEval                19 4.47240e+10
3 PanelOne    NotEval                19 4.47240e+10
4 PanelOne    NotEval                21 4.05534e+08
5 PanelOne    NotEval                13 3.09949e+11
6 PanelOne    NotEval                19 4.47240e+10


>
```

Print the survey design summary

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

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

mdcaty
    Central Basin and Range            Colorado Plateaus
                         27                           25
    Mojave Basin and Range    Northern Basin and Range
                          9                            9
          Southern Rockies Wasatch and Uinta Mountains
                          9                           25
             Wyoming Basin                         Sum
                         11                          115

>
```

7 Stratified, equal probability, GRTS survey design

The third survey design is a stratified, equal probability design. Ecoregions are used to identify strata. List Stratdsgn is assigned design specifications. The ecoregion attribute is used to identify strata. Stratdsgn includes seven lists, one for each stratum. The names for the lists match the levels of the stratum variable, i.e., the unique values of the ecoregion attribute. Each list in Stratdsgn contains two items: panel and seltype. The value for panel is the same as for the equal probability design, and seltype is assigned "Equal".

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 Stratdsgn list; (2) DesignID: assigned the value "STRATIFIED"; (3) type.frame: assigned the value "area"; (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: 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 "level3_nam"; 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.

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

Create the design list

```
> Stratdsgn <- list("Central Basin and Range"=list(panel=c(PanelOne=25),
```

```
+                                                     seltype="Equal"),
+               "Colorado Plateaus"=list(panel=c(PanelOne=25),
+                                         seltype="Equal"),
+               "Mojave Basin and Range"=list(panel=c(PanelOne=10),
+                                             seltype="Equal"),
+               "Northern Basin and Range"=list(panel=c(PanelOne=10),
+                                               seltype="Equal"),
+               "Southern Rockies"=list(panel=c(PanelOne=10),
+                                       seltype="Equal"),
+               "Wasatch and Uinta Mountains"=list(panel=c(PanelOne=25),
+                                                  seltype="Equal"),
+               "Wyoming Basin"=list(panel=c(PanelOne=10),
+                                    seltype="Equal"))
```

Select the sample

```
> Stratsites <- grts(design=Stratdsgn,
+                DesignID="STRATIFIED",
+                type.frame="area",
+                src.frame="sp.object",
+                sp.object=shp,
+                att.frame=att,
+                stratum="Level3_Nam",
+                shapefile=FALSE)


Stratum: Central Basin and Range
Initial number of levels: 3
Current number of levels: 3
Current number of levels: 4
Final number of levels: 4

Stratum: Colorado Plateaus
Initial number of levels: 3
Current number of levels: 3
Current number of levels: 4
Final number of levels: 4

Stratum: Mojave Basin and Range
Initial number of levels: 2
Current number of levels: 2
Current number of levels: 3
Final number of levels: 3

Stratum: Northern Basin and Range
```

```
Initial number of levels: 2
Current number of levels: 2
Current number of levels: 4
Final number of levels: 4


Stratum: Southern Rockies
Initial number of levels: 2
Current number of levels: 2
Current number of levels: 3
Current number of levels: 4
Final number of levels: 4


Stratum: Wasatch and Uinta Mountains
Initial number of levels: 3
Current number of levels: 3
Current number of levels: 4
Final number of levels: 4


Stratum: Wyoming Basin
Initial number of levels: 2
Current number of levels: 2
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(Stratsites@data)


          siteID   xcoord  ycoord mdcaty        wgt                stratum
1 STRATIFIED-001 -1529774 1751713  Equal 3282581854 Central Basin and Range
2 STRATIFIED-002 -1456864 2008542  Equal 3282581854 Central Basin and Range
3 STRATIFIED-003 -1382436 1851915  Equal 3282581854 Central Basin and Range
4 STRATIFIED-004 -1376583 2129989  Equal 3282581854 Central Basin and Range
5 STRATIFIED-005 -1542866 1885916  Equal 3282581854 Central Basin and Range
6 STRATIFIED-006 -1509108 1963177  Equal 3282581854 Central Basin and Range
     panel EvalStatus EvalReason Level3    Area_ha
1 PanelOne    NotEval                13 3.09949e+11
2 PanelOne    NotEval                13 3.09949e+11
3 PanelOne    NotEval                13 3.09949e+11
4 PanelOne    NotEval                13 3.09949e+11
5 PanelOne    NotEval                13 3.09949e+11
6 PanelOne    NotEval                13 3.09949e+11
```

```
>
```

Print the survey design summary

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

Design Summary: Number of Sites

stratum
    Central Basin and Range            Colorado Plateaus
                        25                            25
     Mojave Basin and Range    Northern Basin and Range
                        10                            10
            Southern Rockies  Wasatch and Uinta Mountains
                        10                            25
              Wyoming Basin                          Sum
                        10                           115


>
```

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

The fourth survey design is an unstratified, unequal probability design with an oversample and a panel structure for survey over time. List Paneldsgn is assigned design specifications. Since the survey design is unstratified, Paneldsgn includes a single list named "None" that contains four items: panel, seltype, caty.n, and over. A vector identifying sample sizes for five panels is assigned to panel. The value "Unequal" is assigned to seltype, which indicates unequal selection probabilities. The third item, caty.n, assigns sample sizes for each of seven multidensity categories, where ecoregion names are used as the categories. Note that the sum of sample sizes provided in caty.n must equal the sum of sample sizes in panel. The value 100 is assigned to over, which specifies an oversample of 100 sites. An oversample is replacement sites for the survey design. 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 example, the oversample is not proportionate to the 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 "area"; (4) src.frame: assigned the value "shapefile"; (5) in.shape: assigned the value "UT_ecoregions"; (6) att.frame: assigned the att data frame; (7) mdcaty: assigned the value "level3_nam"; 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

```
> Paneldsgn <- list(None=list(panel=c(Year1=50, Year2=50, Year3=50,
+                                     Year4=50, Year5=50),
+                     seltype="Unequal",
+                     caty.n=c("Central Basin and Range"=64,
+                              "Colorado Plateaus"=63,
+                              "Mojave Basin and Range"=15,
+                              "Northern Basin and Range"=15,
+                              "Southern Rockies"=15,
+                              "Wasatch and Uinta Mountains"=63,
+                              "Wyoming Basin"=15),
+                     over=100))
```

Select the sample

```
> Panelsites <- grts(design=Paneldsgn,
+                DesignID="UNEQUAL",
+                type.frame="area",
+                src.frame="shapefile",
+                in.shape="reg1_lakes",
+                att.frame=att,
+                mdcaty="Level3_Nam",
+                shapefile=FALSE)


Stratum: None
Initial number of levels: 5
Current number of levels: 5
Current number of levels: 7
Final number of levels: 7
```

Print the warning message

```
> # Print the warning message
> warnings()
>
```

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

Oversample size is not proportional to category sample sizes for stratum
"None".
```

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
1 UNEQUAL-001 -1157287 1661084        Colorado Plateaus 1361859732    None Year1
2 UNEQUAL-002 -1213951 1954093        Colorado Plateaus 1361859732    None Year1
3 UNEQUAL-003 -1542076 1770381 Central Basin and Range 1282258537    None Year1
4 UNEQUAL-004 -1261338 2135698           Wyoming Basin  194039220    None Year1
5 UNEQUAL-005 -1185851 1770761        Colorado Plateaus 1361859732    None Year1
6 UNEQUAL-006 -1138910 1801524         Southern Rockies   63096228    None Year1
  EvalStatus EvalReason Level3     Area_ha
1    NotEval                20 1.26379e+11
2    NotEval                20 1.26379e+11
3    NotEval                13 3.09949e+11
4    NotEval                18 1.33312e+11
5    NotEval                20 1.26379e+11
6    NotEval                21 5.40909e+08


>
```

Print the survey design summary

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


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


                          panel
mdcaty                    OverSamp Year1 Year2 Year3 Year4 Year5 Sum
   Central Basin and Range      28    11    13    11    12    14  89
   Colorado Plateaus            23    18    14    10    14    11  90
   Mojave Basin and Range        5     4     3     3     3     4  22
   Northern Basin and Range      7     3     3     3     2     3  21
```

```
Southern Rockies                          6      4      2      5      1      2  20
Wasatch and Uinta Mountains              26      8     10     15     16     15  90
Wyoming Basin                             7      2      5      3      2      1  20
Sum                                     102     50     50     50     50     50 352
```

>