

GRTS Survey Designs for an Area Resource

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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 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 3.5.0 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

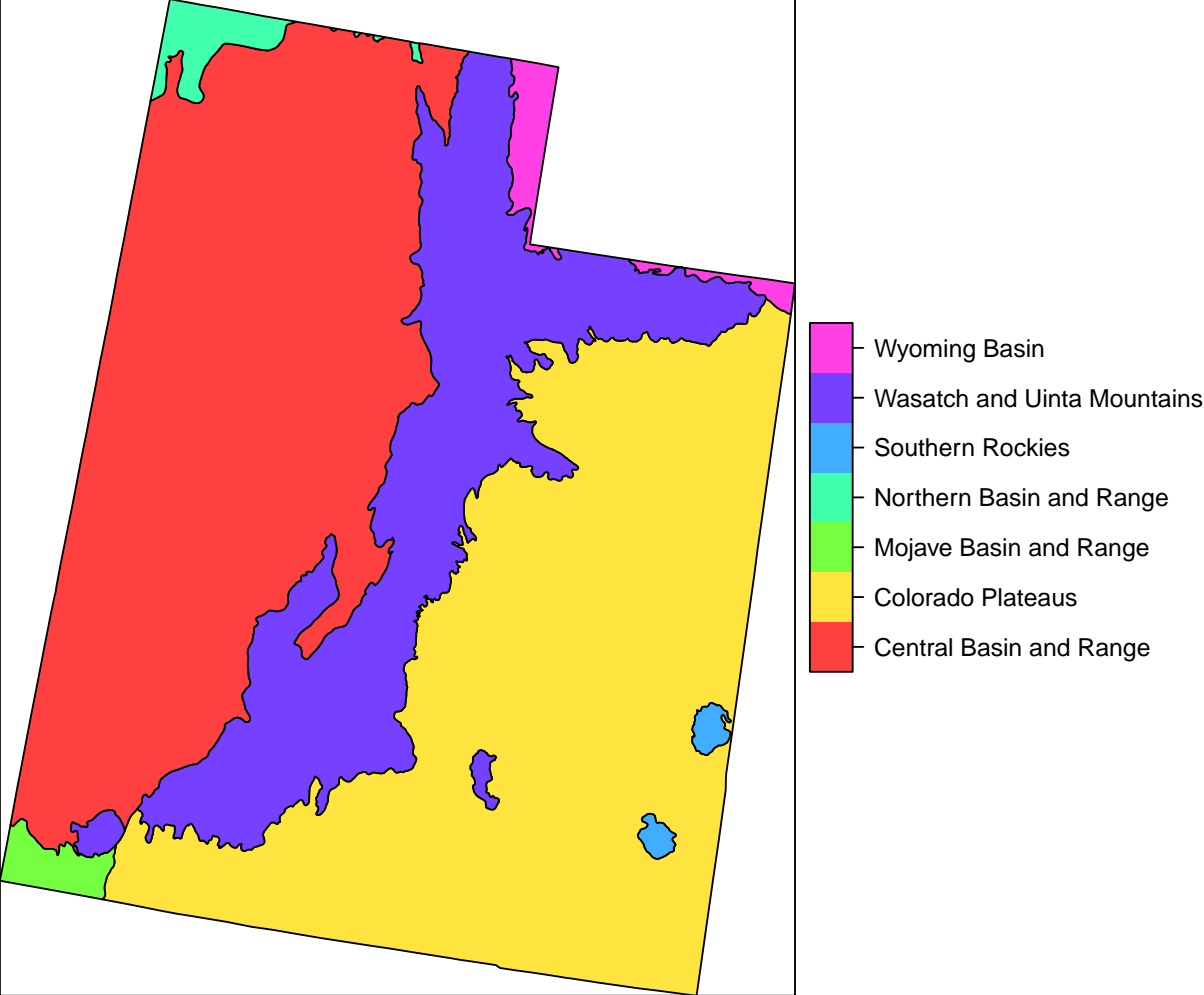


Figure 1: Location of the seven ecoregions in Utah.

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
                        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(Panel=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="UT_ecoregions",
+                    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

mdcaty	panel						Sum
	OverSamp	Year1	Year2	Year3	Year4	Year5	
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

>