

**Linear Models** –  $Y_{ij} = \mu + \tau_{li} + \gamma_{ij} + \tau_{2k} + \tau_1\tau_{2ik} + \varepsilon_{ijkl}$  This is a Split-plot Design with a fixed single factor treatment arrangement in the main plot and a 2 by 3 factorial subplot.

```

1          *****;
2          *** Seaweed grazer study ***;
3          *** This study of marine grazers used exclusion
4          *** cages to examine the effect of different
5          *** categories and types of grazers on intertidal
6          *** populaitons of seaweed. ***;
7          *****;
8
9          dm'log;clear;output;clear';
10         options nodate nocenter nonumber ps=512 ls=132 nolabel;
11         ODS HTML style=minimal rs=none
body='C:\Geaghan\Current\EXST3201\Fall2005\SAS\SeaWeed01.html' ;
NOTE: Writing HTML Body file:
C:\Geaghan\Current\EXST3201\Fall2005\SAS\SeaWeed01.html
12
13         Title1 'Chapter 13 : Seaweed grazer study';
14         filename input1 'C:\Geaghan\Current\EXST3201\Datasets\ASCII\case1301.csv';
15
16         data seaweed; infile input1 missover DSD dlm="," firstobs=2;
17             input COVER BLOCK $ TREAT $;
18                 label cover = 'Percentage of seaweed cover'
19                     block = 'Intertidal zone'
20                     treat = 'Exclosure treatment';
21             rep = 1; if lag1(block) eq block then rep = 2;
22             if block = 'BLOCK 1' then do; zone = 'below'; orientation = 'exposed'; end;
23             if block = 'BLOCK 2' then do; zone = 'below'; orientation = 'protected'; end;
24             if block = 'BLOCK 3' then do; zone = 'mid'; orientation = 'exposed'; end;
25             if block = 'BLOCK 4' then do; zone = 'mid'; orientation = 'protected'; end;
26             if block = 'BLOCK 5' then do; zone = 'above'; orientation = 'exposed'; end;
27             if block = 'BLOCK 6' then do; zone = 'above'; orientation = 'protected'; end;
28             if block = 'BLOCK 7' then do; zone = 'vertM'; orientation = 'protected'; end;
29             if block = 'BLOCK 8' then do; zone = 'vertA'; orientation = 'protected'; end;
30             site = compress(zone||'-'||orientation);
31             limpet = 'Yes'; if findc('L',treat) eq 0 then limpet = 'No';
32                 if treat eq 'CONTROL' then limpet = 'No';
33             fish = 'None'; if findc('f',treat) gt 0 then fish = 'Small';
34                 if findc('F',treat) gt 0 then fish = 'Both';
35         datalines;
NOTE: The infile INPUT1 is:
File Name=C:\Geaghan\Current\EXST3201\Datasets\ASCII\case1301.csv,
RECFM=V,LRECL=256
NOTE: 96 records were read from the infile INPUT1.
The minimum record length was 15.
The maximum record length was 22.
NOTE: The data set WORK.SEAWEEED has 96 observations and 9 variables.
NOTE: DATA statement used (Total process time):
real time          0.02 seconds
cpu time           0.01 seconds
36         run;
37
38         PROC PRINT DATA=seaweed; TITLE2 'Data Listing'; RUN;
NOTE: There were 96 observations read from the data set WORK.SEAWEEED.
NOTE: The PROCEDURE PRINT printed page 1.
NOTE: PROCEDURE PRINT used (Total process time):
real time          0.29 seconds
cpu time           0.06 seconds

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Chapter 13 : Seaweed grazer study  
Data Listing

Obs	COVER	BLOCK	TREAT	rep	zone	orientation	site	limpet	fish
1	14	BLOCK 1	CONTROL	1	below	exposed	below-exposed	No	None
2	23	BLOCK 1	CONTROL	2	below	exposed	below-exposed	No	None
3	22	BLOCK 2	CONTROL	1	below	protect	below-protect	No	None
4	35	BLOCK 2	CONTROL	2	below	protect	below-protect	No	None
5	67	BLOCK 3	CONTROL	1	mid	exposed	mid-exposed	No	None
6	82	BLOCK 3	CONTROL	2	mid	exposed	mid-exposed	No	None
7	94	BLOCK 4	CONTROL	1	mid	protect	mid-protect	No	None
8	95	BLOCK 4	CONTROL	2	mid	protect	mid-protect	No	None
9	34	BLOCK 5	CONTROL	1	above	exposed	above-exposed	No	None
10	53	BLOCK 5	CONTROL	2	above	exposed	above-exposed	No	None
11	58	BLOCK 6	CONTROL	1	above	protect	above-protect	No	None
12	75	BLOCK 6	CONTROL	2	above	protect	above-protect	No	None
13	19	BLOCK 7	CONTROL	1	vertM	protect	vertM-protect	No	None
14	47	BLOCK 7	CONTROL	2	vertM	protect	vertM-protect	No	None
15	53	BLOCK 8	CONTROL	1	vertA	protect	vertA-protect	No	None
16	61	BLOCK 8	CONTROL	2	vertA	protect	vertA-protect	No	None
17	4	BLOCK 1	L	1	below	exposed	below-exposed	Yes	None
18	4	BLOCK 1	L	2	below	exposed	below-exposed	Yes	None
19	7	BLOCK 2	L	1	below	protect	below-protect	Yes	None
20	8	BLOCK 2	L	2	below	protect	below-protect	Yes	None
21	28	BLOCK 3	L	1	mid	exposed	mid-exposed	Yes	None
22	58	BLOCK 3	L	2	mid	exposed	mid-exposed	Yes	None
23	27	BLOCK 4	L	1	mid	protect	mid-protect	Yes	None
24	35	BLOCK 4	L	2	mid	protect	mid-protect	Yes	None
25	11	BLOCK 5	L	1	above	exposed	above-exposed	Yes	None
26	33	BLOCK 5	L	2	above	exposed	above-exposed	Yes	None
27	16	BLOCK 6	L	1	above	protect	above-protect	Yes	None
28	31	BLOCK 6	L	2	above	protect	above-protect	Yes	None
29	6	BLOCK 7	L	1	vertM	protect	vertM-protect	Yes	None
30	8	BLOCK 7	L	2	vertM	protect	vertM-protect	Yes	None
31	15	BLOCK 8	L	1	vertA	protect	vertA-protect	Yes	None
32	17	BLOCK 8	L	2	vertA	protect	vertA-protect	Yes	None
33	11	BLOCK 1	f	1	below	exposed	below-exposed	No	Smal
34	24	BLOCK 1	f	2	below	exposed	below-exposed	No	Smal
35	14	BLOCK 2	f	1	below	protect	below-protect	No	Smal
36	31	BLOCK 2	f	2	below	protect	below-protect	No	Smal
37	52	BLOCK 3	f	1	mid	exposed	mid-exposed	No	Smal
38	59	BLOCK 3	f	2	mid	exposed	mid-exposed	No	Smal
39	83	BLOCK 4	f	1	mid	protect	mid-protect	No	Smal
40	89	BLOCK 4	f	2	mid	protect	mid-protect	No	Smal
41	33	BLOCK 5	f	1	above	exposed	above-exposed	No	Smal
42	34	BLOCK 5	f	2	above	exposed	above-exposed	No	Smal
43	39	BLOCK 6	f	1	above	protect	above-protect	No	Smal
44	52	BLOCK 6	f	2	above	protect	above-protect	No	Smal
45	43	BLOCK 7	f	1	vertM	protect	vertM-protect	No	Smal
46	53	BLOCK 7	f	2	vertM	protect	vertM-protect	No	Smal
47	30	BLOCK 8	f	1	vertA	protect	vertA-protect	No	Smal
48	37	BLOCK 8	f	2	vertA	protect	vertA-protect	No	Smal
49	3	BLOCK 1	Lf	1	below	exposed	below-exposed	Yes	Smal
50	5	BLOCK 1	Lf	2	below	exposed	below-exposed	Yes	Smal
51	3	BLOCK 2	Lf	1	below	protect	below-protect	Yes	Smal
52	6	BLOCK 2	Lf	2	below	protect	below-protect	Yes	Smal
53	9	BLOCK 3	Lf	1	mid	exposed	mid-exposed	Yes	Smal
54	31	BLOCK 3	Lf	2	mid	exposed	mid-exposed	Yes	Smal
55	21	BLOCK 4	Lf	1	mid	protect	mid-protect	Yes	Smal
56	57	BLOCK 4	Lf	2	mid	protect	mid-protect	Yes	Smal
57	5	BLOCK 5	Lf	1	above	exposed	above-exposed	Yes	Smal
58	9	BLOCK 5	Lf	2	above	exposed	above-exposed	Yes	Smal
59	26	BLOCK 6	Lf	1	above	protect	above-protect	Yes	Smal
60	43	BLOCK 6	Lf	2	above	protect	above-protect	Yes	Smal
61	4	BLOCK 7	Lf	1	vertM	protect	vertM-protect	Yes	Smal
62	12	BLOCK 7	Lf	2	vertM	protect	vertM-protect	Yes	Smal
63	12	BLOCK 8	Lf	1	vertA	protect	vertA-protect	Yes	Smal
64	18	BLOCK 8	Lf	2	vertA	protect	vertA-protect	Yes	Smal
65	10	BLOCK 1	fF	1	below	exposed	below-exposed	No	Both
66	13	BLOCK 1	fF	2	below	exposed	below-exposed	No	Both
67	10	BLOCK 2	fF	1	below	protect	below-protect	No	Both
68	15	BLOCK 2	fF	2	below	protect	below-protect	No	Both
69	44	BLOCK 3	fF	1	mid	exposed	mid-exposed	No	Both
70	50	BLOCK 3	fF	2	mid	exposed	mid-exposed	No	Both
71	57	BLOCK 4	fF	1	mid	protect	mid-protect	No	Both
72	73	BLOCK 4	fF	2	mid	protect	mid-protect	No	Both
73	26	BLOCK 5	fF	1	above	exposed	above-exposed	No	Both

74	42	BLOCK 5	fF	2	above	exposed	above-exposed	No	Both
75	38	BLOCK 6	fF	1	above	protect	above-protect	No	Both
76	42	BLOCK 6	fF	2	above	protect	above-protect	No	Both
77	29	BLOCK 7	fF	1	vertM	protect	vertM-protect	No	Both
78	36	BLOCK 7	fF	2	vertM	protect	vertM-protect	No	Both
79	11	BLOCK 8	fF	1	vertA	protect	vertA-protect	No	Both
80	40	BLOCK 8	fF	2	vertA	protect	vertA-protect	No	Both
81	1	BLOCK 1	LfF	1	below	exposed	below-exposed	Yes	Both
82	2	BLOCK 1	LfF	2	below	exposed	below-exposed	Yes	Both
83	3	BLOCK 2	LfF	1	below	protect	below-protect	Yes	Both
84	5	BLOCK 2	LfF	2	below	protect	below-protect	Yes	Both
85	6	BLOCK 3	LfF	1	mid	exposed	mid-exposed	Yes	Both
86	9	BLOCK 3	LfF	2	mid	exposed	mid-exposed	Yes	Both
87	7	BLOCK 4	LfF	1	mid	protect	mid-protect	Yes	Both
88	22	BLOCK 4	LfF	2	mid	protect	mid-protect	Yes	Both
89	5	BLOCK 5	LfF	1	above	exposed	above-exposed	Yes	Both
90	6	BLOCK 5	LfF	2	above	exposed	above-exposed	Yes	Both
91	10	BLOCK 6	LfF	1	above	protect	above-protect	Yes	Both
92	17	BLOCK 6	LfF	2	above	protect	above-protect	Yes	Both
93	5	BLOCK 7	LfF	1	vertM	protect	vertM-protect	Yes	Both
94	14	BLOCK 7	LfF	2	vertM	protect	vertM-protect	Yes	Both
95	5	BLOCK 8	LfF	1	vertA	protect	vertA-protect	Yes	Both
96	7	BLOCK 8	LfF	2	vertA	protect	vertA-protect	Yes	Both

*LfF*: All three grazers were allowed access.

*fF*: Limpets were excluded by surrounding the plot with caustic paint.

*Lf*: Large fish were excluded by covering the plot with a coarse net.

*f*: Limpets and large fish were excluded.

*L*: Small and large fish were excluded by covering the plot with a fine net.

*C*: Control: limpets, small fish, and large fish were all excluded.

Block #1: Just below high tide level, exposed to heavy surf

Block #2: Just below high tide level, protected from the surf

Block #3: Midtide, exposed

Block #4: Midtide, protected

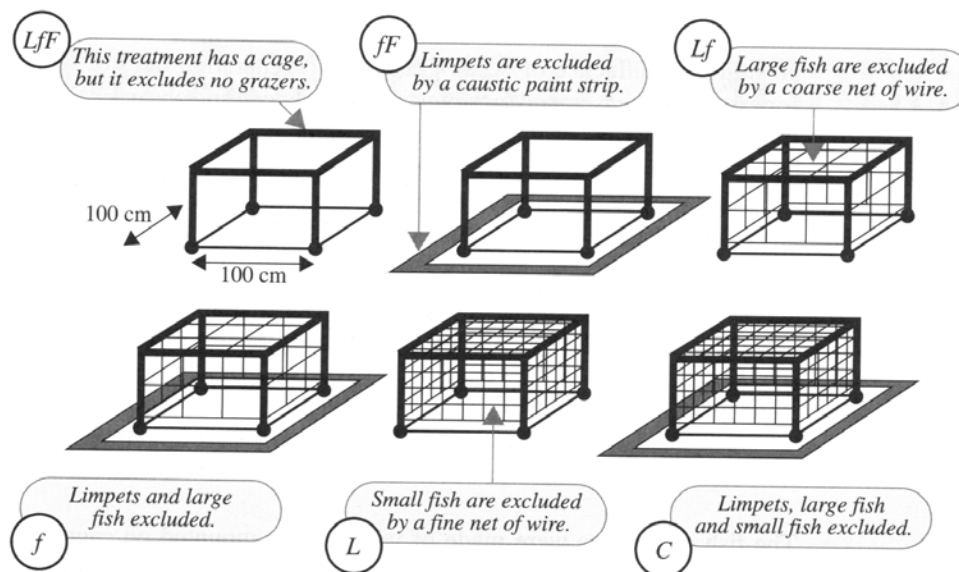
Block #5: Just above low tide level, exposed

Block #6: Just above low tide level, protected

Block #7: On near-vertical rock wall, midtide level, protected

Block #8: On near-vertical rock wall, above low tide level, protected

**Display 13.1** Six treatments excluding three kinds of intertidal grazers from regenerating seaweed on the Oregon coast



```

40      PROC mixed DATA=seaweed cl covtest; class limpet fish rep site;
41          Title2 'Split-plot design - PROC MIXED';
42          MODEL cover = site | limpet | fish / outp=resids;
43          random rep(site);
44          *
45          contrast 'protected' site      above-exp above-prot below-exp below-prot  mid-exp mid-prot  vertA-prot  vertM-prot;
46          contrast 'level'      site      1          1          0          0          -1          -1          0          0,
47          contrast 'level'      site      0          0          1          1          -1          -1          0          0;
48          contrast 'prot*levl' site      -1          1          0          0          1          -1          0          0,
49          contrast 'prot*levl' site      0          0          -1          1          1          -1          0          0;
50          contrast 'vert prot' site      0          -2          0          -2          0          -2          3          3;
51          contrast 'vert levl' site      0          -1          0          0          0          -1          1          1;
52          lsmeans site | limpet | fish / pdiff adjust=tukey cl;
53          ods output diffs=ppp lsmeans=mmm;
54          ods listing exclude diffs;* lsmeans; *this is now just a comment;
55      run;

```

NOTE: Convergence criteria met.

NOTE: The data set WORK.MMM has 107 observations and 12 variables.

NOTE: The data set WORK.PPP has 1571 observations and 19 variables.

NOTE: The data set WORK.RESIDS has 96 observations and 16 variables.

NOTE: The PROCEDURE MIXED printed page 2.

NOTE: PROCEDURE MIXED used (Total process time):

real time 4.01 seconds

cpu time 3.83 seconds

```

56      TITLE3 'Post hoc adjustment with macro by Arnold Saxton';
57      * SAS Macro by Arnold Saxton: Saxton, A.M. 1998. A macro for ;
58      * converting mean separation output to letter groupings in Proc Mixed. ;
59      * In Proc. 23rd SAS Users Group Intl., SAS Institute, Cary, NC, pp1243-1246.;
60      %include 'C:\Geaghan\Current\EXST3201\Fall2005\SAS\pdmix800.sas';
733     %pdmix800(ppp,mmm,alpha=.01,sort=yes);

```

PDMIX800 08.08.2003 processing

7.4748013744

Tukey values for site are 39.6338 (avg) 39.6338 (min) 39.6338 (max).

3.8246883983

Tukey-Kramer values for limpet are 3.48052 (avg) 3.48052 (min) 3.48052 (max).

6.0167823497

Tukey-Kramer values for limpet\*site are 32.5138 (avg) 15.4866 (min) 33.73 (max).

4.3670920758

Tukey-Kramer values for fish are 4.86728 (avg) 4.86728 (min) 4.86728 (max).

6.3619891577

Tukey-Kramer values for fish\*site are 35.981 (avg) 20.0554 (min) 37.4978 (max).

5.1144900653

Tukey-Kramer values for limpet\*fish are 8.06141 (avg) 8.06141 (min) 8.06141 (max).

6.9273964742

Tukey-Kramer values for limpet\*fish\*site are 44.6629 (avg) 30.8833 (min) 46.3034 (max).

734 RUN; QUIT;

Chapter 13 : Seaweed grazer study  
Split-plot design - PROC MIXED

The Mixed Procedure

Model Information

Data Set	WORK.SEAWEED
Dependent Variable	COVER
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information

Class	Levels	Values
limpet	2	No Yes
fish	3	Both None Smal
rep	2	1 2
site	8	above-exposed above-protect below-exposed below-protect mid-exposed mid-protect vertA-protect vertM-protect

Dimensions

Covariance Parameters	2
Columns in X	108
Columns in Z	16
Subjects	1
Max Obs Per Subject	96

Number of Observations

Number of Observations Read	96
Number of Observations Used	96
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	385.13434179	
1	1	363.36311807	0.00000000

Convergence criteria met.

CovarianceParameter Estimates

Cov Parm	Estimate	Standard Error	Z Value	Pr Z	Alpha	Lower	Upper
rep(site)	49.6042	28.1536	1.76	0.0390	0.05	20.8380	231.86
Residual	39.7500	8.8884	4.47	<.0001	0.05	26.7940	65.0758

Fit Statistics

-2 Res Log Likelihood	363.4
AIC (smaller is better)	367.4
AICC (smaller is better)	367.6
BIC (smaller is better)	368.9

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
site	7	8	8.09	0.0042
limpet	1	40	481.85	<.0001
limpet*site	7	40	11.98	<.0001
fish	2	40	45.89	<.0001
fish*site	14	40	3.99	0.0003
limpet*fish	2	40	3.07	0.0575
limpet*fish*site	14	40	1.91	0.0555

## Contrasts

Label	Num DF	Den DF	F Value	Pr > F
protected	1	8	5.51	0.0468
level	2	8	24.04	0.0004
prot*levl	2	8	0.55	0.5964
vert prot	1	8	5.09	0.0541
vert lev1	1	8	17.02	0.0033

## Least Squares Means

Effect	limpet	fish	site	Estimate	Standard Error	DF	t Value	Pr >  t	Alpha	Lower	Upper
site			above-exposed	24.2500	5.3023	8	4.57	0.0018	0.05	12.0228	36.4772
site			above-protect	37.2500	5.3023	8	7.03	0.0001	0.05	25.0228	49.4772
site			below-exposed	9.5000	5.3023	8	1.79	0.1110	0.05	-2.7272	21.7272
site			below-protect	13.2500	5.3023	8	2.50	0.0370	0.05	1.0228	25.4772
site			mid-exposed	41.2500	5.3023	8	7.78	<.0001	0.05	29.0228	53.4772
site			mid-protect	55.0000	5.3023	8	10.37	<.0001	0.05	42.7728	67.2272
site			vertA-protect	25.5000	5.3023	8	4.81	0.0013	0.05	13.2728	37.7272
site			vertM-protect	23.0000	5.3023	8	4.34	0.0025	0.05	10.7728	35.2272
limpet	No			42.7500	1.9820	40	21.57	<.0001	0.05	38.7442	46.7558
limpet	Yes			14.5000	1.9820	40	7.32	<.0001	0.05	10.4942	18.5058
limpet*site	No		above-exposed	37.0000	5.6060	40	6.60	<.0001	0.05	25.6699	48.3301
limpet*site	No		above-protect	50.6667	5.6060	40	9.04	<.0001	0.05	39.3365	61.9968
limpet*site	No		below-exposed	15.8333	5.6060	40	2.82	0.0074	0.05	4.5032	27.1635
limpet*site	No		below-protect	21.1667	5.6060	40	3.78	0.0005	0.05	9.8365	32.4968
limpet*site	No		mid-exposed	59.0000	5.6060	40	10.52	<.0001	0.05	47.6699	70.3301
limpet*site	No		mid-protect	81.8333	5.6060	40	14.60	<.0001	0.05	70.5032	93.1635
limpet*site	No		vertA-protect	38.6667	5.6060	40	6.90	<.0001	0.05	27.3365	49.9968
limpet*site	No		vertM-protect	37.8333	5.6060	40	6.75	<.0001	0.05	26.5032	49.1635
limpet*site	Yes		above-exposed	11.5000	5.6060	40	2.05	0.0468	0.05	0.1699	22.8301
limpet*site	Yes		above-protect	23.8333	5.6060	40	4.25	0.0001	0.05	12.5032	35.1635
limpet*site	Yes		below-exposed	3.1667	5.6060	40	0.56	0.5753	0.05	-8.1635	14.4968
limpet*site	Yes		below-protect	5.3333	5.6060	40	0.95	0.3471	0.05	-5.9968	16.6635
limpet*site	Yes		mid-exposed	23.5000	5.6060	40	4.19	0.0001	0.05	12.1699	34.8301
limpet*site	Yes		mid-protect	28.1667	5.6060	40	5.02	<.0001	0.05	16.8365	39.4968
limpet*site	Yes		vertA-protect	12.3333	5.6060	40	2.20	0.0336	0.05	1.0032	23.6635
limpet*site	Yes		vertM-protect	8.1667	5.6060	40	1.46	0.1530	0.05	-3.1635	19.4968
fish		Both		20.6250	2.0839	40	9.90	<.0001	0.05	16.4134	24.8366
fish		None		35.6250	2.0839	40	17.10	<.0001	0.05	31.4134	39.8366
fish		Smal		29.6250	2.0839	40	14.22	<.0001	0.05	25.4134	33.8366
fish*site		Both	above-exposed	19.7500	5.8940	40	3.35	0.0018	0.05	7.8377	31.6623
fish*site		Both	above-protect	26.7500	5.8940	40	4.54	<.0001	0.05	14.8377	38.6623
fish*site		Both	below-exposed	6.5000	5.8940	40	1.10	0.2767	0.05	-5.4123	18.4123
fish*site		Both	below-protect	8.2500	5.8940	40	1.40	0.1693	0.05	-3.6623	20.1623
fish*site		Both	mid-exposed	27.2500	5.8940	40	4.62	<.0001	0.05	15.3377	39.1623
fish*site		Both	mid-protect	39.7500	5.8940	40	6.74	<.0001	0.05	27.8377	51.6623
fish*site		Both	vertA-protect	15.7500	5.8940	40	2.67	0.0108	0.05	3.8377	27.6623
fish*site		Both	vertM-protect	21.0000	5.8940	40	3.56	0.0010	0.05	9.0877	32.9123
fish*site		None	above-exposed	32.7500	5.8940	40	5.56	<.0001	0.05	20.8377	44.6623
fish*site		None	above-protect	45.0000	5.8940	40	7.63	<.0001	0.05	33.0877	56.9123
fish*site		None	below-exposed	11.2500	5.8940	40	1.91	0.0635	0.05	-0.6623	23.1623
fish*site		None	below-protect	18.0000	5.8940	40	3.05	0.0040	0.05	6.0877	29.9123

fish*site		None	mid-exposed	58.7500	5.8940	40	9.97	<.0001	0.05	46.8377	70.6623
fish*site		None	mid-protect	62.7500	5.8940	40	10.65	<.0001	0.05	50.8377	74.6623
fish*site		None	vertA-protect	36.5000	5.8940	40	6.19	<.0001	0.05	24.5877	48.4123
fish*site		None	vertM-protect	20.0000	5.8940	40	3.39	0.0016	0.05	8.0877	31.9123
fish*site		Smal	above-exposed	20.2500	5.8940	40	3.44	0.0014	0.05	8.3377	32.1623
fish*site		Smal	above-protect	40.0000	5.8940	40	6.79	<.0001	0.05	28.0877	51.9123
fish*site		Smal	below-exposed	10.7500	5.8940	40	1.82	0.0756	0.05	-1.1623	22.6623
fish*site		Smal	below-protect	13.5000	5.8940	40	2.29	0.0273	0.05	1.5877	25.4123
fish*site		Smal	mid-exposed	37.7500	5.8940	40	6.40	<.0001	0.05	25.8377	49.6623
fish*site		Smal	mid-protect	62.5000	5.8940	40	10.60	<.0001	0.05	50.5877	74.4123
fish*site		Smal	vertA-protect	24.2500	5.8940	40	4.11	0.0002	0.05	12.3377	36.1623
fish*site		Smal	vertM-protect	28.0000	5.8940	40	4.75	<.0001	0.05	16.0877	39.9123
limpet*fish	No	Both		33.5000	2.3632	40	14.18	<.0001	0.05	28.7238	38.2762
limpet*fish	No	None		52.0000	2.3632	40	22.00	<.0001	0.05	47.2238	56.7762
limpet*fish	No	Smal		42.7500	2.3632	40	18.09	<.0001	0.05	37.9738	47.5262
limpet*fish	Yes	Both		7.7500	2.3632	40	3.28	0.0022	0.05	2.9738	12.5262
limpet*fish	Yes	None		19.2500	2.3632	40	8.15	<.0001	0.05	14.4738	24.0262
limpet*fish	Yes	Smal		16.5000	2.3632	40	6.98	<.0001	0.05	11.7238	21.2762
limpet*fish*site	No	Both	above-exposed	34.0000	6.6841	40	5.09	<.0001	0.05	20.4909	47.5091
limpet*fish*site	No	Both	above-protect	40.0000	6.6841	40	5.98	<.0001	0.05	26.4909	53.5091
limpet*fish*site	No	Both	below-exposed	11.5000	6.6841	40	1.72	0.0931	0.05	-2.0091	25.0091
limpet*fish*site	No	Both	below-protect	12.5000	6.6841	40	1.87	0.0688	0.05	-1.0091	26.0091
limpet*fish*site	No	Both	mid-exposed	47.0000	6.6841	40	7.03	<.0001	0.05	33.4909	60.5091
limpet*fish*site	No	Both	mid-protect	65.0000	6.6841	40	9.72	<.0001	0.05	51.4909	78.5091
limpet*fish*site	No	Both	vertA-protect	25.5000	6.6841	40	3.82	0.0005	0.05	11.9909	39.0091
limpet*fish*site	No	Both	vertM-protect	32.5000	6.6841	40	4.86	<.0001	0.05	18.9909	46.0091
limpet*fish*site	No	None	above-exposed	43.5000	6.6841	40	6.51	<.0001	0.05	29.9909	57.0091
limpet*fish*site	No	None	above-protect	66.5000	6.6841	40	9.95	<.0001	0.05	52.9909	80.0091
limpet*fish*site	No	None	below-exposed	18.5000	6.6841	40	2.77	0.0085	0.05	4.9909	32.0091
limpet*fish*site	No	None	below-protect	28.5000	6.6841	40	4.26	0.0001	0.05	14.9909	42.0091
limpet*fish*site	No	None	mid-exposed	74.5000	6.6841	40	11.15	<.0001	0.05	60.9909	88.0091
limpet*fish*site	No	None	mid-protect	94.5000	6.6841	40	14.14	<.0001	0.05	80.9909	108.01
limpet*fish*site	No	None	vertA-protect	57.0000	6.6841	40	8.53	<.0001	0.05	43.4909	70.5091
limpet*fish*site	No	None	vertM-protect	33.0000	6.6841	40	4.94	<.0001	0.05	19.4909	46.5091
limpet*fish*site	No	Smal	above-exposed	33.5000	6.6841	40	5.01	<.0001	0.05	19.9909	47.0091
limpet*fish*site	No	Smal	above-protect	45.5000	6.6841	40	6.81	<.0001	0.05	31.9909	59.0091
limpet*fish*site	No	Smal	below-exposed	17.5000	6.6841	40	2.62	0.0124	0.05	3.9909	31.0091
limpet*fish*site	No	Smal	below-protect	22.5000	6.6841	40	3.37	0.0017	0.05	8.9909	36.0091
limpet*fish*site	No	Smal	mid-exposed	55.5000	6.6841	40	8.30	<.0001	0.05	41.9909	69.0091
limpet*fish*site	No	Smal	mid-protect	86.0000	6.6841	40	12.87	<.0001	0.05	72.4909	99.5091
limpet*fish*site	No	Smal	vertA-protect	33.5000	6.6841	40	5.01	<.0001	0.05	19.9909	47.0091
limpet*fish*site	No	Smal	vertM-protect	48.0000	6.6841	40	7.18	<.0001	0.05	34.4909	61.5091
limpet*fish*site	Yes	Both	above-exposed	5.5000	6.6841	40	0.82	0.4155	0.05	-8.0091	19.0091
limpet*fish*site	Yes	Both	above-protect	13.5000	6.6841	40	2.02	0.0501	0.05	-0.00905	27.0091
limpet*fish*site	Yes	Both	below-exposed	1.5000	6.6841	40	0.22	0.8236	0.05	-12.0091	15.0091
limpet*fish*site	Yes	Both	below-protect	4.0000	6.6841	40	0.60	0.5529	0.05	-9.5091	17.5091
limpet*fish*site	Yes	Both	mid-exposed	7.5000	6.6841	40	1.12	0.2685	0.05	-6.0091	21.0091
limpet*fish*site	Yes	Both	mid-protect	14.5000	6.6841	40	2.17	0.0361	0.05	0.9909	28.0091
limpet*fish*site	Yes	Both	vertA-protect	6.0000	6.6841	40	0.90	0.3747	0.05	-7.5091	19.5091
limpet*fish*site	Yes	Both	vertM-protect	9.5000	6.6841	40	1.42	0.1630	0.05	-4.0091	23.0091
limpet*fish*site	Yes	None	above-exposed	22.0000	6.6841	40	3.29	0.0021	0.05	8.4909	35.5091
limpet*fish*site	Yes	None	above-protect	23.5000	6.6841	40	3.52	0.0011	0.05	9.9909	37.0091
limpet*fish*site	Yes	None	below-exposed	4.0000	6.6841	40	0.60	0.5529	0.05	-9.5091	17.5091
limpet*fish*site	Yes	None	below-protect	7.5000	6.6841	40	1.12	0.2685	0.05	-6.0091	21.0091
limpet*fish*site	Yes	None	mid-exposed	43.0000	6.6841	40	6.43	<.0001	0.05	29.4909	56.5091

limpet*fish*site	Yes	None	mid-protect	31.0000	6.6841	40	4.64	<.0001	0.05	17.4909	44.5091
limpet*fish*site	Yes	None	vertA-protect	16.0000	6.6841	40	2.39	0.0215	0.05	2.4909	29.5091
limpet*fish*site	Yes	None	vertM-protect	7.0000	6.6841	40	1.05	0.3013	0.05	-6.5091	20.5091
limpet*fish*site	Yes	Smal	above-exposed	7.0000	6.6841	40	1.05	0.3013	0.05	-6.5091	20.5091
limpet*fish*site	Yes	Smal	above-protect	34.5000	6.6841	40	5.16	<.0001	0.05	20.9909	48.0091
limpet*fish*site	Yes	Smal	below-exposed	4.0000	6.6841	40	0.60	0.5529	0.05	-9.5091	17.5091
limpet*fish*site	Yes	Smal	below-protect	4.5000	6.6841	40	0.67	0.5047	0.05	-9.0091	18.0091
limpet*fish*site	Yes	Smal	mid-exposed	20.0000	6.6841	40	2.99	0.0047	0.05	6.4909	33.5091
limpet*fish*site	Yes	Smal	mid-protect	39.0000	6.6841	40	5.83	<.0001	0.05	25.4909	52.5091
limpet*fish*site	Yes	Smal	vertA-protect	15.0000	6.6841	40	2.24	0.0304	0.05	1.4909	28.5091
limpet*fish*site	Yes	Smal	vertM-protect	8.0000	6.6841	40	1.20	0.2384	0.05	-5.5091	21.5091

## Chapter 13 : Seaweed grazer study

Split-plot design - PROC MIXED

Post hoc adjustment with macro by Arnold Saxton

Effect=site ADJUSTMENT=Tukey(P&lt;.01) bygroup=1

Obs	limpet	fish	site	Estimate	StdErr	Alpha	Lower	Upper	MSGROUP
1			mid-protect	55.0000	5.3023	0.05	42.7728	67.2272	A
2			mid-exposed	41.2500	5.3023	0.05	29.0228	53.4772	AB
3			above-protect	37.2500	5.3023	0.05	25.0228	49.4772	AB
4			vertA-protect	25.5000	5.3023	0.05	13.2728	37.7272	AB
5			above-exposed	24.2500	5.3023	0.05	12.0228	36.4772	AB
6			vertM-protect	23.0000	5.3023	0.05	10.7728	35.2272	AB
7			below-protect	13.2500	5.3023	0.05	1.0228	25.4772	B
8			below-exposed	9.5000	5.3023	0.05	-2.7272	21.7272	B

Effect=limpet ADJUSTMENT=Tukey-Kramer(P&lt;.01) bygroup=2

Obs	limpet	fish	site	Estimate	StdErr	Alpha	Lower	Upper	MSGROUP
9	No			42.7500	1.9820	0.05	38.7442	46.7558	A
10	Yes			14.5000	1.9820	0.05	10.4942	18.5058	B

Effect=limpet\*site ADJUSTMENT=Tukey-Kramer(P&lt;.01) bygroup=3

Obs	limpet	fish	site	Estimate	StdErr	Alpha	Lower	Upper	MSGROUP
11	No		mid-protect	81.8333	5.6060	0.05	70.5032	93.1635	A
12	No		mid-exposed	59.0000	5.6060	0.05	47.6699	70.3301	AB
13	No		above-protect	50.6667	5.6060	0.05	39.3365	61.9968	ABC
14	No		vertA-protect	38.6667	5.6060	0.05	27.3365	49.9968	BCDEFG
15	No		vertM-protect	37.8333	5.6060	0.05	26.5032	49.1635	BCDEGH
16	No		above-exposed	37.0000	5.6060	0.05	25.6699	48.3301	BCDFGH
17	Yes		mid-protect	28.1667	5.6060	0.05	16.8365	39.4968	BCDEFGHI
18	Yes		above-protect	23.8333	5.6060	0.05	12.5032	35.1635	DEFGHI
19	Yes		mid-exposed	23.5000	5.6060	0.05	12.1699	34.8301	CDEFGHI
20	No		below-protect	21.1667	5.6060	0.05	9.8365	32.4968	CDEFHI
21	No		below-exposed	15.8333	5.6060	0.05	4.5032	27.1635	DEFGHI



22	Yes	vertA-protect	12.3333	5.6060	0.05	1.0032	23.6635	HIJ
23	Yes	above-exposed	11.5000	5.6060	0.05	0.1699	22.8301	EIJ
24	Yes	vertM-protect	8.1667	5.6060	0.05	-3.1635	19.4968	FIJ
25	Yes	below-protect	5.3333	5.6060	0.05	-5.9968	16.6635	GJ
26	Yes	below-exposed	3.1667	5.6060	0.05	-8.1635	14.4968	IJ

Effect=fish ADJUSTMENT=Tukey-Kramer(P<.01) bygroup=4

Obs	limpet	fish	site	Estimate	StdErr	Alpha	Lower	Upper	MSGROUP
27		None		35.6250	2.0839	0.05	31.4134	39.8366	A
28		Smal		29.6250	2.0839	0.05	25.4134	33.8366	B
29		Both		20.6250	2.0839	0.05	16.4134	24.8366	C

Effect=fish\*site ADJUSTMENT=Tukey-Kramer(P<.01) bygroup=5

Obs	limpet	fish	site	Estimate	StdErr	Alpha	Lower	Upper	MSGROUP
30		None	mid-protect	62.7500	5.8940	0.05	50.8377	74.6623	AB
31		Smal	mid-protect	62.5000	5.8940	0.05	50.5877	74.4123	AB
32		None	mid-exposed	58.7500	5.8940	0.05	46.8377	70.6623	AC
33		None	above-protect	45.0000	5.8940	0.05	33.0877	56.9123	ABCDE
34		Smal	above-protect	40.0000	5.8940	0.05	28.0877	51.9123	ABCDEF
35		Both	mid-protect	39.7500	5.8940	0.05	27.8377	51.6623	CDEFG
36		Smal	mid-exposed	37.7500	5.8940	0.05	25.8377	49.6623	BDEFG
37		None	vertA-protect	36.5000	5.8940	0.05	24.5877	48.4123	ABCDF
38		None	above-exposed	32.7500	5.8940	0.05	20.8377	44.6623	ABCDEF
39		Smal	vertM-protect	28.0000	5.8940	0.05	16.0877	39.9123	ABCDEF
40		Both	mid-exposed	27.2500	5.8940	0.05	15.3377	39.1623	BDEFG
41		Both	above-protect	26.7500	5.8940	0.05	14.8377	38.6623	ABCDEF
42		Smal	vertA-protect	24.2500	5.8940	0.05	12.3377	36.1623	CDEFG
43		Both	vertM-protect	21.0000	5.8940	0.05	9.0877	32.9123	DEF
44		Smal	above-exposed	20.2500	5.8940	0.05	8.3377	32.1623	DEF
45		None	vertM-protect	20.0000	5.8940	0.05	8.0877	31.9123	DEF
46		Both	above-exposed	19.7500	5.8940	0.05	7.8377	31.6623	DEF
47		None	below-protect	18.0000	5.8940	0.05	6.0877	29.9123	DEF
48		Both	vertA-protect	15.7500	5.8940	0.05	3.8377	27.6623	EH
49		Smal	below-protect	13.5000	5.8940	0.05	1.5877	25.4123	DEF
50		None	below-exposed	11.2500	5.8940	0.05	-0.6623	23.1623	DEF
51		Smal	below-exposed	10.7500	5.8940	0.05	-1.1623	22.6623	DEF
52		Both	below-protect	8.2500	5.8940	0.05	-3.6623	20.1623	DEF
53		Both	below-exposed	6.5000	5.8940	0.05	-5.4123	18.4123	FH

Effect=limpet\*fish ADJUSTMENT=Tukey-Kramer(P<.01) bygroup=6

Obs	limpet	fish	site	Estimate	StdErr	Alpha	Lower	Upper	MSGROUP
54	No	None		52.0000	2.3632	0.05	47.2238	56.7762	A
55	No	Smal		42.7500	2.3632	0.05	37.9738	47.5262	B
56	No	Both		33.5000	2.3632	0.05	28.7238	38.2762	C

57	Yes	None	19.2500	2.3632	0.05	14.4738	24.0262	D
58	Yes	Smal	16.5000	2.3632	0.05	11.7238	21.2762	D
59	Yes	Both	7.7500	2.3632	0.05	2.9738	12.5262	E

Effect=limpet\*fish\*site ADJUSTMENT=Tukey-Kramer(P<.01) bygroup=7

Obs	limpet	fish	site	Estimate	StdErr	Alpha	Lower	Upper	MSGROUP
60	No	None	mid-protect	94.5000	6.6841	0.05	80.9909	108.01	A
61	No	Smal	mid-protect	86.0000	6.6841	0.05	72.4909	99.5091	ABC
62	No	None	mid-exposed	74.5000	6.6841	0.05	60.9909	88.0091	ABDEF
63	No	None	above-protect	66.5000	6.6841	0.05	52.9909	80.0091	ABCDFG
64	No	Both	mid-protect	65.0000	6.6841	0.05	51.4909	78.5091	ABCDEFGHI
65	No	None	vertA-protect	57.0000	6.6841	0.05	43.4909	70.5091	ABCDEFGHIJK
66	No	Smal	mid-exposed	55.5000	6.6841	0.05	41.9909	69.0091	ABCDEFGHIJKLM
67	No	Smal	vertM-protect	48.0000	6.6841	0.05	34.4909	61.5091	BCDEFGHIJKLNO
68	No	Both	mid-exposed	47.0000	6.6841	0.05	33.4909	60.5091	BCDEFGHIJKLMOP
69	No	Smal	above-protect	45.5000	6.6841	0.05	31.9909	59.0091	BCDEFGHIJLMNOP
70	No	None	above-exposed	43.5000	6.6841	0.05	29.9909	57.0091	BCDEFGHIJKLMNP
71	Yes	None	mid-exposed	43.0000	6.6841	0.05	29.4909	56.5091	CGHIJKLMOPQ
72	No	Both	above-protect	40.0000	6.6841	0.05	26.4909	53.5091	BCDEFGHIJKLMNOP
73	Yes	Smal	mid-protect	39.0000	6.6841	0.05	25.4909	52.5091	DEFGHIJKLMNOPQ
74	Yes	Smal	above-protect	34.5000	6.6841	0.05	20.9909	48.0091	EHIJKLMNOPQ
75	No	Both	above-exposed	34.0000	6.6841	0.05	20.4909	47.5091	DEFGHIJKLMNOPQ
76	No	Smal	above-exposed	33.5000	6.6841	0.05	19.9909	47.0091	DEFGHIJKLMNOPQ
77	No	Smal	vertA-protect	33.5000	6.6841	0.05	19.9909	47.0091	DEFGHIJKLMNOPQ
78	No	None	vertM-protect	33.0000	6.6841	0.05	19.4909	46.5091	DEFGHIJKLMNOPQ
79	No	Both	vertM-protect	32.5000	6.6841	0.05	18.9909	46.0091	DEFGHIJKLMNOPQ
80	Yes	None	mid-protect	31.0000	6.6841	0.05	17.4909	44.5091	FJKLMNOPQ
81	No	None	below-protect	28.5000	6.6841	0.05	14.9909	42.0091	DEFGHIJKLMNOPQ
82	No	Both	vertA-protect	25.5000	6.6841	0.05	11.9909	39.0091	GLMNOPQR
83	Yes	None	above-protect	23.5000	6.6841	0.05	9.9909	37.0091	HIJKLMNOPQR
84	No	Smal	below-protect	22.5000	6.6841	0.05	8.9909	36.0091	GHIJKLMNOP
85	Yes	None	above-exposed	22.0000	6.6841	0.05	8.4909	35.5091	GHIJKLMNOP
86	Yes	Smal	mid-exposed	20.0000	6.6841	0.05	6.4909	33.5091	INOPQR
87	No	None	below-exposed	18.5000	6.6841	0.05	4.9909	32.0091	JKLMNOPR
88	No	Smal	below-exposed	17.5000	6.6841	0.05	3.9909	31.0091	JKLMNOPR
89	Yes	None	vertA-protect	16.0000	6.6841	0.05	2.4909	29.5091	LMNOPR
90	Yes	Smal	vertA-protect	15.0000	6.6841	0.05	1.4909	28.5091	LMNOPR
91	Yes	Both	mid-protect	14.5000	6.6841	0.05	0.9909	28.0091	JKLMNOPR
92	Yes	Both	above-protect	13.5000	6.6841	0.05	-0.00905	27.0091	KR
93	No	Both	below-protect	12.5000	6.6841	0.05	-1.0091	26.0091	JKLMNOPR
94	No	Both	below-exposed	11.5000	6.6841	0.05	-2.0091	25.0091	JKLMNOPR
95	Yes	Both	vertM-protect	9.5000	6.6841	0.05	-4.0091	23.0091	MPRS
96	Yes	Smal	vertM-protect	8.0000	6.6841	0.05	-5.5091	21.5091	PRS
97	Yes	Both	mid-exposed	7.5000	6.6841	0.05	-6.0091	21.0091	NRS

98	Yes	None	below-protect	7.5000	6.6841	0.05	-6.0091	21.0091	NOPR
99	Yes	None	vertM-protect	7.0000	6.6841	0.05	-6.5091	20.5091	PRS
100	Yes	Smal	above-exposed	7.0000	6.6841	0.05	-6.5091	20.5091	ORS
101	Yes	Both	vertA-protect	6.0000	6.6841	0.05	-7.5091	19.5091	NOPR
102	Yes	Both	above-exposed	5.5000	6.6841	0.05	-8.0091	19.0091	ORS
103	Yes	Smal	below-protect	4.5000	6.6841	0.05	-9.0091	18.0091	NOPR
104	Yes	Both	below-protect	4.0000	6.6841	0.05	-9.5091	17.5091	NOPR
105	Yes	None	below-exposed	4.0000	6.6841	0.05	-9.5091	17.5091	NOPR
106	Yes	Smal	below-exposed	4.0000	6.6841	0.05	-9.5091	17.5091	NOPR
107	Yes	Both	below-exposed	1.5000	6.6841	0.05	-12.0091	15.0091	PRS

```
737      data mmm; set mmm; format estimate f5.1; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.MMM has 107 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.00 seconds
      cpu time           0.01 seconds
```

```
738
739      proc print data=mmm;
740          TITLE3 'LSMeans output dataset of estimates';
741      run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The PROCEDURE PRINT printed page 4.
NOTE: PROCEDURE PRINT used (Total process time):
      real time          0.14 seconds
      cpu time           0.08 seconds
```

Chapter 13 : Seaweed grazer study  
Split-plot design - PROC MIXED  
LSMeans output dataset of estimates

Obs	Effect	limpet	fish	site	Estimate	StdErr	DF	tValue	Probt	Alpha	Lower	Upper
1	site			above-exposed	24.3	5.3023	8	4.57	0.0018	0.05	12.0228	36.4772
2	site			above-protect	37.3	5.3023	8	7.03	0.0001	0.05	25.0228	49.4772
3	site			below-exposed	9.5	5.3023	8	1.79	0.1110	0.05	-2.7272	21.7272
4	site			below-protect	13.2	5.3023	8	2.50	0.0370	0.05	1.0228	25.4772
5	site			mid-exposed	41.2	5.3023	8	7.78	<.0001	0.05	29.0228	53.4772
6	site			mid-protect	55.0	5.3023	8	10.37	<.0001	0.05	42.7728	67.2272
7	site			vertA-protect	25.5	5.3023	8	4.81	0.0013	0.05	13.2728	37.7272
8	site			vertM-protect	23.0	5.3023	8	4.34	0.0025	0.05	10.7728	35.2272
9	limpet	No			42.8	1.9820	40	21.57	<.0001	0.05	38.7442	46.7558
10	limpet	Yes			14.5	1.9820	40	7.32	<.0001	0.05	10.4942	18.5058
11	limpet*site	No		above-exposed	37.0	5.6060	40	6.60	<.0001	0.05	25.6699	48.3301

12	limpet*site	No	above-protect	50.7	5.6060	40	9.04	<.0001	0.05	39.3365	61.9968	
13	limpet*site	No	below-exposed	15.8	5.6060	40	2.82	0.0074	0.05	4.5032	27.1635	
14	limpet*site	No	below-protect	21.2	5.6060	40	3.78	0.0005	0.05	9.8365	32.4968	
15	limpet*site	No	mid-exposed	59.0	5.6060	40	10.52	<.0001	0.05	47.6699	70.3301	
16	limpet*site	No	mid-protect	81.8	5.6060	40	14.60	<.0001	0.05	70.5032	93.1635	
17	limpet*site	No	vertA-protect	38.7	5.6060	40	6.90	<.0001	0.05	27.3365	49.9968	
18	limpet*site	No	vertM-protect	37.8	5.6060	40	6.75	<.0001	0.05	26.5032	49.1635	
19	limpet*site	Yes	above-exposed	11.5	5.6060	40	2.05	0.0468	0.05	0.1699	22.8301	
20	limpet*site	Yes	above-protect	23.8	5.6060	40	4.25	0.0001	0.05	12.5032	35.1635	
21	limpet*site	Yes	below-exposed	3.2	5.6060	40	0.56	0.5753	0.05	-8.1635	14.4968	
22	limpet*site	Yes	below-protect	5.3	5.6060	40	0.95	0.3471	0.05	-5.9968	16.6635	
23	limpet*site	Yes	mid-exposed	23.5	5.6060	40	4.19	0.0001	0.05	12.1699	34.8301	
24	limpet*site	Yes	mid-protect	28.2	5.6060	40	5.02	<.0001	0.05	16.8365	39.4968	
25	limpet*site	Yes	vertA-protect	12.3	5.6060	40	2.20	0.0336	0.05	1.0032	23.6635	
26	limpet*site	Yes	vertM-protect	8.2	5.6060	40	1.46	0.1530	0.05	-3.1635	19.4968	
27	fish		Both	20.6	2.0839	40	9.90	<.0001	0.05	16.4134	24.8366	
28	fish		None	35.6	2.0839	40	17.10	<.0001	0.05	31.4134	39.8366	
29	fish		Smal	29.6	2.0839	40	14.22	<.0001	0.05	25.4134	33.8366	
30	fish*site		Both	above-exposed	19.8	5.8940	40	3.35	0.0018	0.05	7.8377	31.6623
31	fish*site		Both	above-protect	26.8	5.8940	40	4.54	<.0001	0.05	14.8377	38.6623
32	fish*site		Both	below-exposed	6.5	5.8940	40	1.10	0.2767	0.05	-5.4123	18.4123
33	fish*site		Both	below-protect	8.2	5.8940	40	1.40	0.1693	0.05	-3.6623	20.1623
34	fish*site		Both	mid-exposed	27.2	5.8940	40	4.62	<.0001	0.05	15.3377	39.1623
35	fish*site		Both	mid-protect	39.7	5.8940	40	6.74	<.0001	0.05	27.8377	51.6623
36	fish*site		Both	vertA-protect	15.8	5.8940	40	2.67	0.0108	0.05	3.8377	27.6623
37	fish*site		Both	vertM-protect	21.0	5.8940	40	3.56	0.0010	0.05	9.0877	32.9123
38	fish*site		None	above-exposed	32.8	5.8940	40	5.56	<.0001	0.05	20.8377	44.6623
39	fish*site		None	above-protect	45.0	5.8940	40	7.63	<.0001	0.05	33.0877	56.9123
40	fish*site		None	below-exposed	11.2	5.8940	40	1.91	0.0635	0.05	-0.6623	23.1623
41	fish*site		None	below-protect	18.0	5.8940	40	3.05	0.0040	0.05	6.0877	29.9123
42	fish*site		None	mid-exposed	58.8	5.8940	40	9.97	<.0001	0.05	46.8377	70.6623
43	fish*site		None	mid-protect	62.7	5.8940	40	10.65	<.0001	0.05	50.8377	74.6623
44	fish*site		None	vertA-protect	36.5	5.8940	40	6.19	<.0001	0.05	24.5877	48.4123
45	fish*site		None	vertM-protect	20.0	5.8940	40	3.39	0.0016	0.05	8.0877	31.9123
46	fish*site		Smal	above-exposed	20.3	5.8940	40	3.44	0.0014	0.05	8.3377	32.1623
47	fish*site		Smal	above-protect	40.0	5.8940	40	6.79	<.0001	0.05	28.0877	51.9123
48	fish*site		Smal	below-exposed	10.7	5.8940	40	1.82	0.0756	0.05	-1.1623	22.6623
49	fish*site		Smal	below-protect	13.5	5.8940	40	2.29	0.0273	0.05	1.5877	25.4123
50	fish*site		Smal	mid-exposed	37.7	5.8940	40	6.40	<.0001	0.05	25.8377	49.6623
51	fish*site		Smal	mid-protect	62.5	5.8940	40	10.60	<.0001	0.05	50.5877	74.4123
52	fish*site		Smal	vertA-protect	24.2	5.8940	40	4.11	0.0002	0.05	12.3377	36.1623
53	fish*site		Smal	vertM-protect	28.0	5.8940	40	4.75	<.0001	0.05	16.0877	39.9123
54	limpet*fish	No	Both	33.5	2.3632	40	14.18	<.0001	0.05	28.7238	38.2762	
55	limpet*fish	No	None	52.0	2.3632	40	22.00	<.0001	0.05	47.2238	56.7762	
56	limpet*fish	No	Smal	42.8	2.3632	40	18.09	<.0001	0.05	37.9738	47.5262	
57	limpet*fish	Yes	Both	7.8	2.3632	40	3.28	0.0022	0.05	2.9738	12.5262	
58	limpet*fish	Yes	None	19.3	2.3632	40	8.15	<.0001	0.05	14.4738	24.0262	
59	limpet*fish	Yes	Smal	16.5	2.3632	40	6.98	<.0001	0.05	11.7238	21.2762	
60	limpet*fish*site	No	Both	above-exposed	34.0	6.6841	40	5.09	<.0001	0.05	20.4909	47.5091

61	limpet*fish*site	No	Both	above-protect	40.0	6.6841	40	5.98	<.0001	0.05	26.4909	53.5091
62	limpet*fish*site	No	Both	below-exposed	11.5	6.6841	40	1.72	0.0931	0.05	-2.0091	25.0091
63	limpet*fish*site	No	Both	below-protect	12.5	6.6841	40	1.87	0.0688	0.05	-1.0091	26.0091
64	limpet*fish*site	No	Both	mid-exposed	47.0	6.6841	40	7.03	<.0001	0.05	33.4909	60.5091
65	limpet*fish*site	No	Both	mid-protect	65.0	6.6841	40	9.72	<.0001	0.05	51.4909	78.5091
66	limpet*fish*site	No	Both	vertA-protect	25.5	6.6841	40	3.82	0.0005	0.05	11.9909	39.0091
67	limpet*fish*site	No	Both	vertM-protect	32.5	6.6841	40	4.86	<.0001	0.05	18.9909	46.0091
68	limpet*fish*site	No	None	above-exposed	43.5	6.6841	40	6.51	<.0001	0.05	29.9909	57.0091
69	limpet*fish*site	No	None	above-protect	66.5	6.6841	40	9.95	<.0001	0.05	52.9909	80.0091
70	limpet*fish*site	No	None	below-exposed	18.5	6.6841	40	2.77	0.0085	0.05	4.9909	32.0091
71	limpet*fish*site	No	None	below-protect	28.5	6.6841	40	4.26	0.0001	0.05	14.9909	42.0091
72	limpet*fish*site	No	None	mid-exposed	74.5	6.6841	40	11.15	<.0001	0.05	60.9909	88.0091
73	limpet*fish*site	No	None	mid-protect	94.5	6.6841	40	14.14	<.0001	0.05	80.9909	108.01
74	limpet*fish*site	No	None	vertA-protect	57.0	6.6841	40	8.53	<.0001	0.05	43.4909	70.5091
75	limpet*fish*site	No	None	vertM-protect	33.0	6.6841	40	4.94	<.0001	0.05	19.4909	46.5091
76	limpet*fish*site	No	Smal	above-exposed	33.5	6.6841	40	5.01	<.0001	0.05	19.9909	47.0091
77	limpet*fish*site	No	Smal	above-protect	45.5	6.6841	40	6.81	<.0001	0.05	31.9909	59.0091
78	limpet*fish*site	No	Smal	below-exposed	17.5	6.6841	40	2.62	0.0124	0.05	3.9909	31.0091
79	limpet*fish*site	No	Smal	below-protect	22.5	6.6841	40	3.37	0.0017	0.05	8.9909	36.0091
80	limpet*fish*site	No	Smal	mid-exposed	55.5	6.6841	40	8.30	<.0001	0.05	41.9909	69.0091
81	limpet*fish*site	No	Smal	mid-protect	86.0	6.6841	40	12.87	<.0001	0.05	72.4909	99.5091
82	limpet*fish*site	No	Smal	vertA-protect	33.5	6.6841	40	5.01	<.0001	0.05	19.9909	47.0091
83	limpet*fish*site	No	Smal	vertM-protect	48.0	6.6841	40	7.18	<.0001	0.05	34.4909	61.5091
84	limpet*fish*site	Yes	Both	above-exposed	5.5	6.6841	40	0.82	0.4155	0.05	-8.0091	19.0091
85	limpet*fish*site	Yes	Both	above-protect	13.5	6.6841	40	2.02	0.0501	0.05	-0.00905	27.0091
86	limpet*fish*site	Yes	Both	below-exposed	1.5	6.6841	40	0.22	0.8236	0.05	-12.0091	15.0091
87	limpet*fish*site	Yes	Both	below-protect	4.0	6.6841	40	0.60	0.5529	0.05	-9.5091	17.5091
88	limpet*fish*site	Yes	Both	mid-exposed	7.5	6.6841	40	1.12	0.2685	0.05	-6.0091	21.0091
89	limpet*fish*site	Yes	Both	mid-protect	14.5	6.6841	40	2.17	0.0361	0.05	0.9909	28.0091
90	limpet*fish*site	Yes	Both	vertA-protect	6.0	6.6841	40	0.90	0.3747	0.05	-7.5091	19.5091
91	limpet*fish*site	Yes	Both	vertM-protect	9.5	6.6841	40	1.42	0.1630	0.05	-4.0091	23.0091
92	limpet*fish*site	Yes	None	above-exposed	22.0	6.6841	40	3.29	0.0021	0.05	8.4909	35.5091
93	limpet*fish*site	Yes	None	above-protect	23.5	6.6841	40	3.52	0.0011	0.05	9.9909	37.0091
94	limpet*fish*site	Yes	None	below-exposed	4.0	6.6841	40	0.60	0.5529	0.05	-9.5091	17.5091
95	limpet*fish*site	Yes	None	below-protect	7.5	6.6841	40	1.12	0.2685	0.05	-6.0091	21.0091
96	limpet*fish*site	Yes	None	mid-exposed	43.0	6.6841	40	6.43	<.0001	0.05	29.4909	56.5091
97	limpet*fish*site	Yes	None	mid-protect	31.0	6.6841	40	4.64	<.0001	0.05	17.4909	44.5091
98	limpet*fish*site	Yes	None	vertA-protect	16.0	6.6841	40	2.39	0.0215	0.05	2.4909	29.5091
99	limpet*fish*site	Yes	None	vertM-protect	7.0	6.6841	40	1.05	0.3013	0.05	-6.5091	20.5091
100	limpet*fish*site	Yes	Smal	above-exposed	7.0	6.6841	40	1.05	0.3013	0.05	-6.5091	20.5091
101	limpet*fish*site	Yes	Smal	above-protect	34.5	6.6841	40	5.16	<.0001	0.05	20.9909	48.0091
102	limpet*fish*site	Yes	Smal	below-exposed	4.0	6.6841	40	0.60	0.5529	0.05	-9.5091	17.5091
103	limpet*fish*site	Yes	Smal	below-protect	4.5	6.6841	40	0.67	0.5047	0.05	-9.0091	18.0091
104	limpet*fish*site	Yes	Smal	mid-exposed	20.0	6.6841	40	2.99	0.0047	0.05	6.4909	33.5091
105	limpet*fish*site	Yes	Smal	mid-protect	39.0	6.6841	40	5.83	<.0001	0.05	25.4909	52.5091
106	limpet*fish*site	Yes	Smal	vertA-protect	15.0	6.6841	40	2.24	0.0304	0.05	1.4909	28.5091
107	limpet*fish*site	Yes	Smal	vertM-protect	8.0	6.6841	40	1.20	0.2384	0.05	-5.5091	21.5091

```
744      options ps=52 ls=99 nolabel;
745      data site; set mmm; if effect='site'; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.SITE has 8 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.00 seconds
      cpu time           0.01 seconds

746      data limpet; set mmm; if effect='limpet'; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.LIMPET has 2 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.01 seconds
      cpu time           0.02 seconds

747      data limpet_site; set mmm; if effect='limpet*site'; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.LIMPET_SITE has 16 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.01 seconds
      cpu time           0.02 seconds

748      data fish; set mmm; if effect='fish'; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.FISH has 3 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.00 seconds
      cpu time           0.01 seconds

749      data fish_site; set mmm; if effect='fish*site'; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.FISH_SITE has 24 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.01 seconds
      cpu time           0.01 seconds

750      data limpet_fish; set mmm; if effect='limpet*fish'; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.LIMPET_FISH has 6 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.01 seconds
      cpu time           0.02 seconds

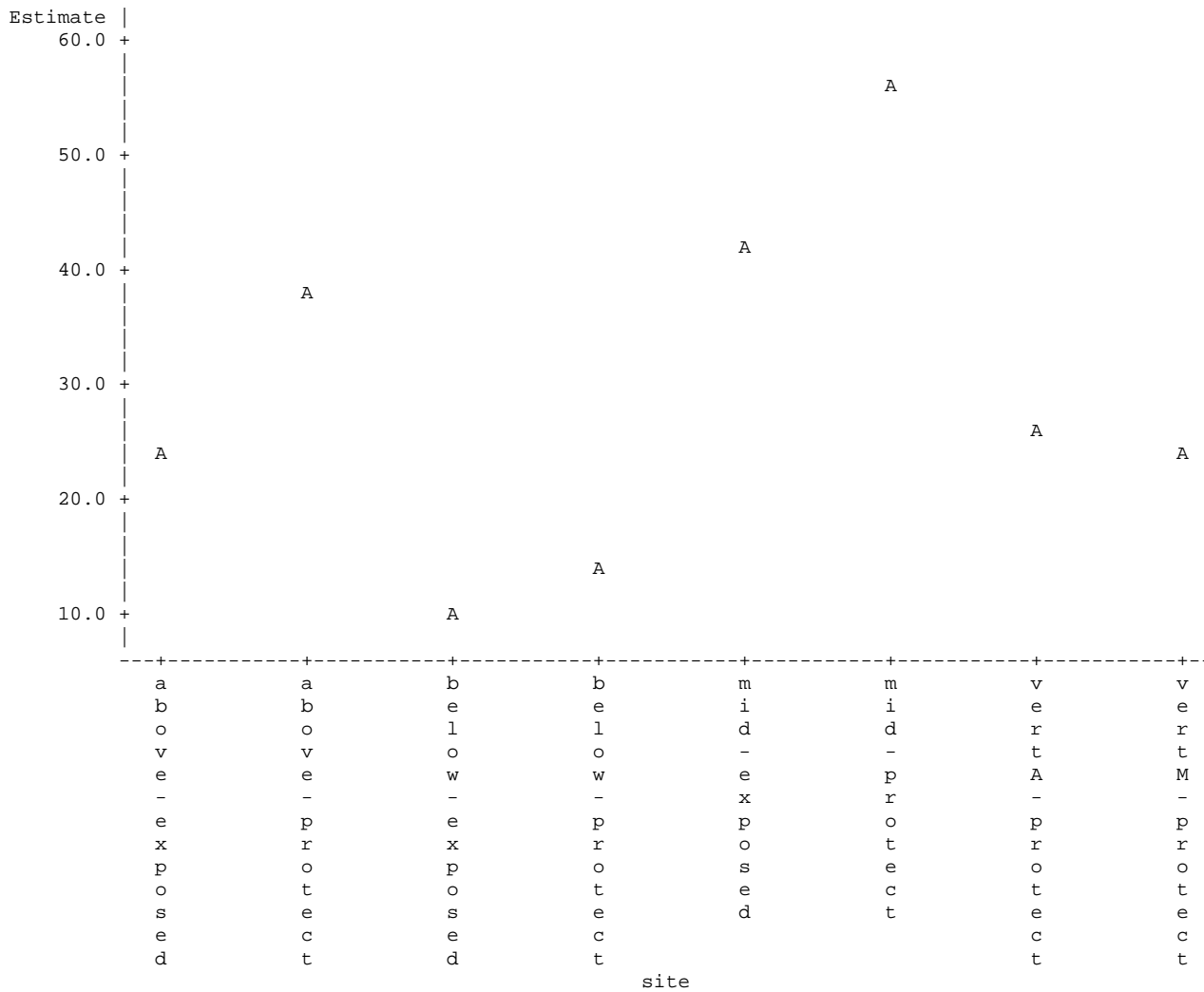
751      data limpet_fish_site; set mmm; if effect='limpet*fish*site'; run;
NOTE: There were 107 observations read from the data set WORK.MMM.
NOTE: The data set WORK.LIMPET_FISH_SITE has 48 observations and 12 variables.
NOTE: DATA statement used (Total process time):
      real time          0.01 seconds
      cpu time           0.02 seconds

752
```

```
753      TITLE3 'Selected graphics';
754      proc plot data=site; plot estimate*site; run;
NOTE: There were 8 observations read from the data set WORK.SITE.
NOTE: The PROCEDURE PLOT printed page 5.
NOTE: PROCEDURE PLOT used (Total process time):
      real time          0.07 seconds
      cpu time           0.01 seconds
```

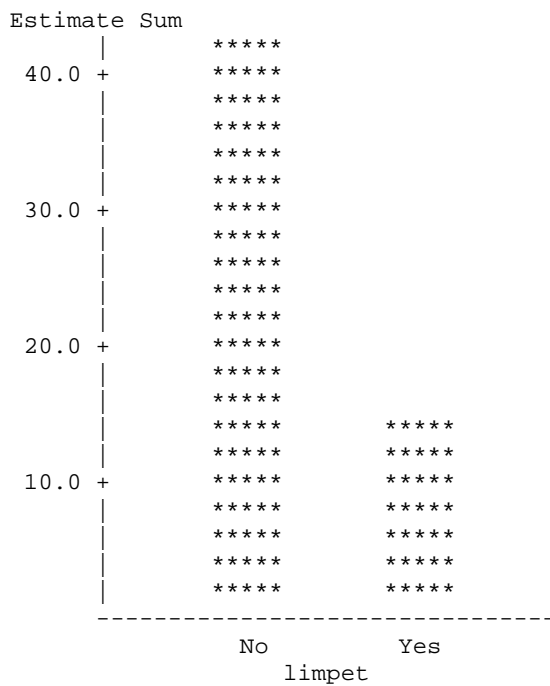
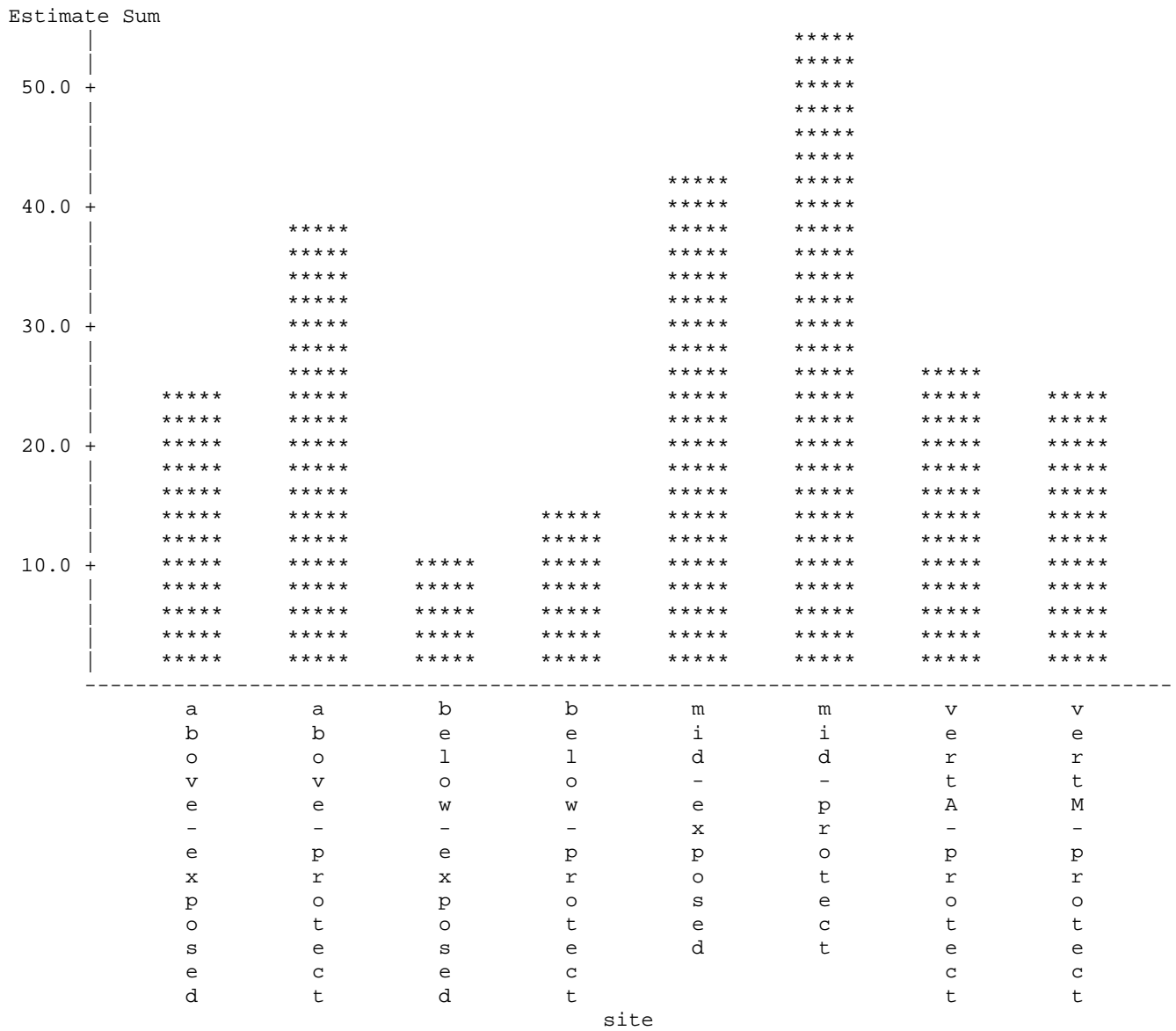
Chapter 13 : Seaweed grazer study  
 Split-plot design - PROC MIXED  
 Selected graphics

Plot of Estimate\*site. Legend: A = 1 obs, B = 2 obs, etc.



```
755      proc chart data=site; vbar site / sumvar=estimate; run;
NOTE: The PROCEDURE CHART printed page 6.
NOTE: PROCEDURE CHART used (Total process time):
      real time          0.06 seconds
      cpu time           0.00 seconds
```

```
756      proc chart data=limpet; vbar limpet / sumvar=estimate; run;
NOTE: The PROCEDURE CHART printed page 7.
NOTE: PROCEDURE CHART used (Total process time):
      real time          0.06 seconds
      cpu time           0.01 seconds
```

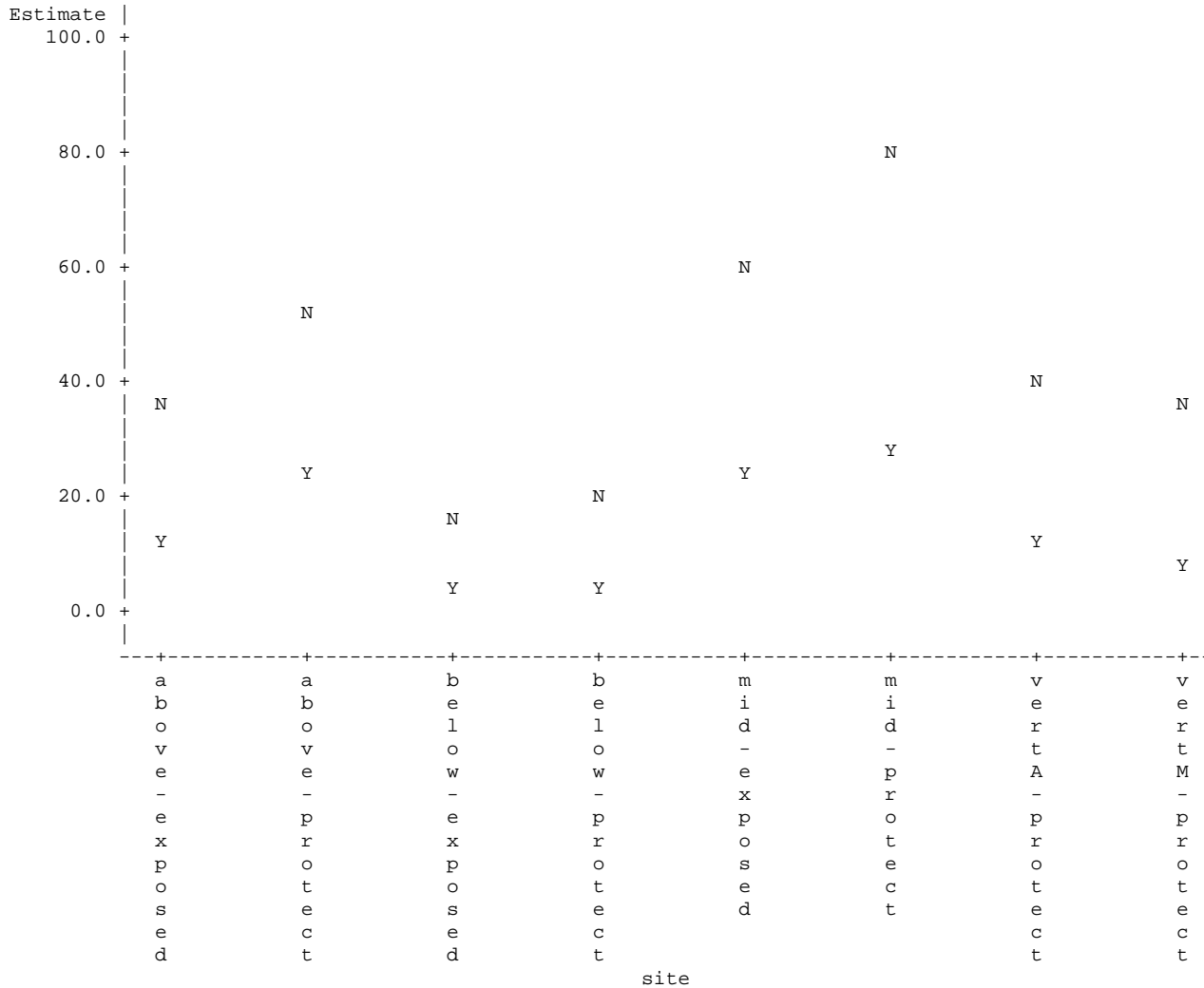




```
757      proc plot data=limpet_site; plot estimate*site=limpet; run;
NOTE: There were 16 observations read from the data set WORK.LIMPET_SITE.
NOTE: The PROCEDURE PLOT printed page 8.
NOTE: PROCEDURE PLOT used (Total process time):
      real time          0.09 seconds
      cpu time           0.00 seconds
```

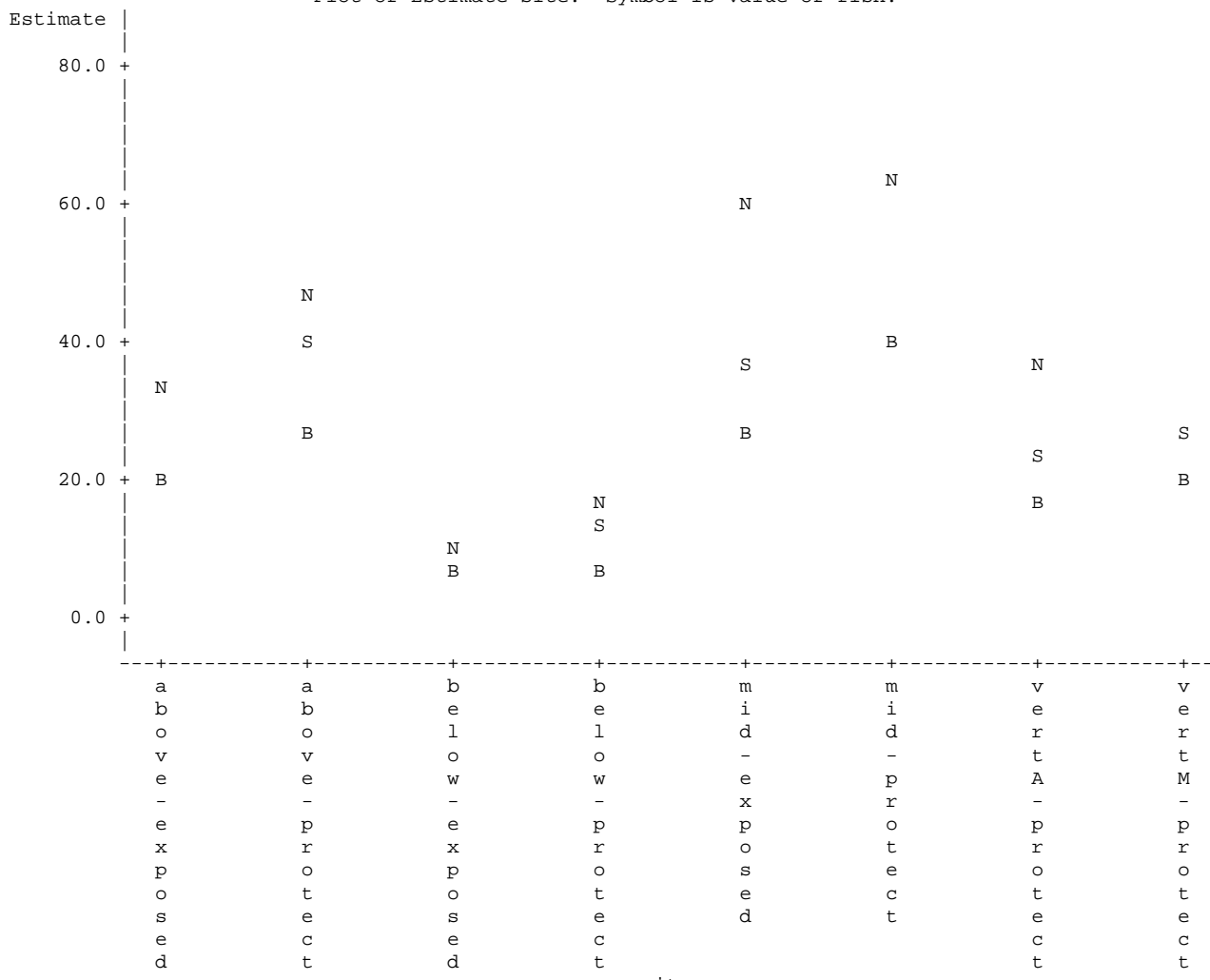
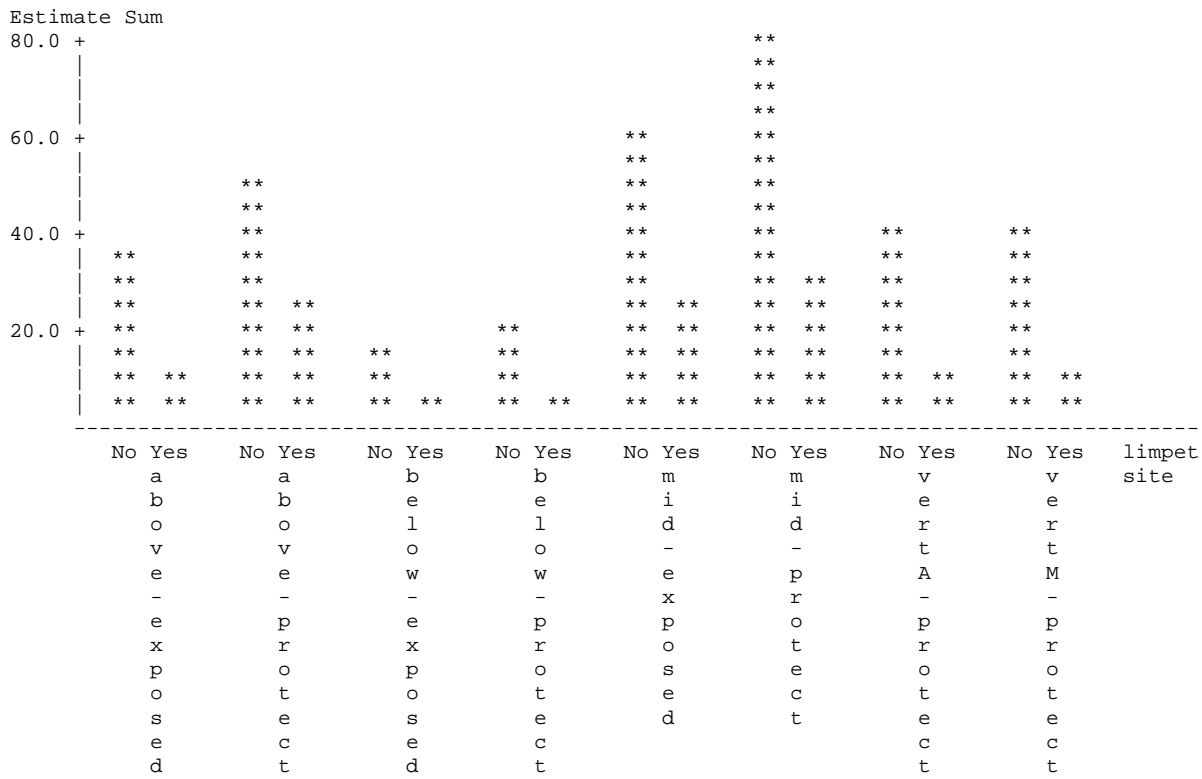
Chapter 13 : Seaweed grazer study  
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 Selected graphics

Plot of Estimate\*site. Symbol is value of limpet.



```
758      proc chart data=limpet_site; vbar limpet / sumvar=estimate group=site; run;
NOTE: The PROCEDURE CHART printed page 9.
NOTE: PROCEDURE CHART used (Total process time):
      real time          0.06 seconds
      cpu time           0.01 seconds
```

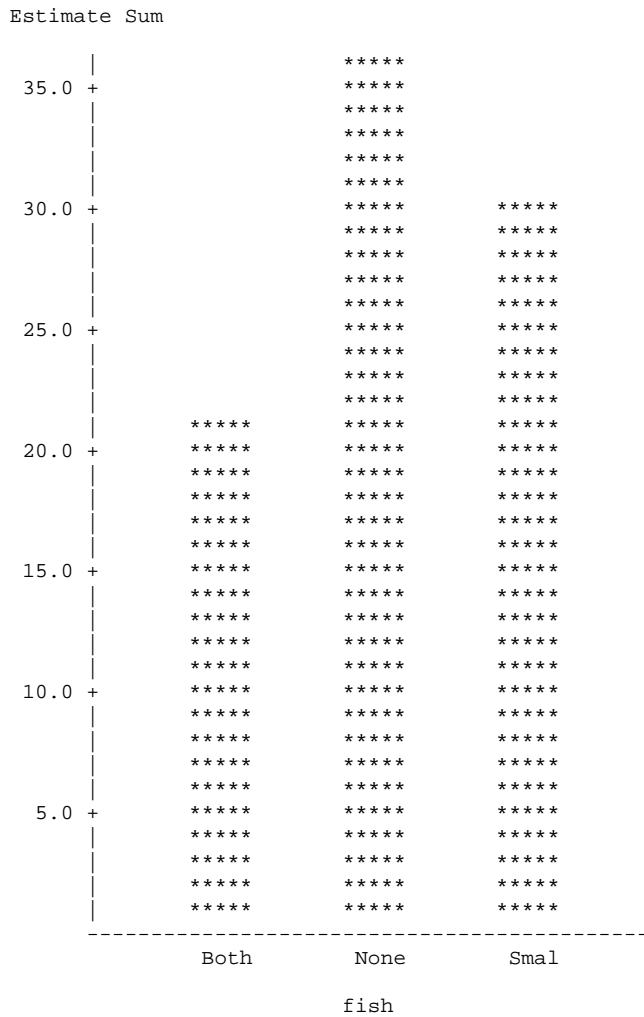
```
759      proc plot data=fish_site; plot estimate*site=fish; run;
NOTE: There were 24 observations read from the data set WORK.FISH_SITE.
NOTE: The PROCEDURE PLOT printed page 10.
NOTE: PROCEDURE PLOT used (Total process time):
      real time          0.09 seconds
      cpu time           0.02 seconds
```



NOTE: 4 obs hidden.

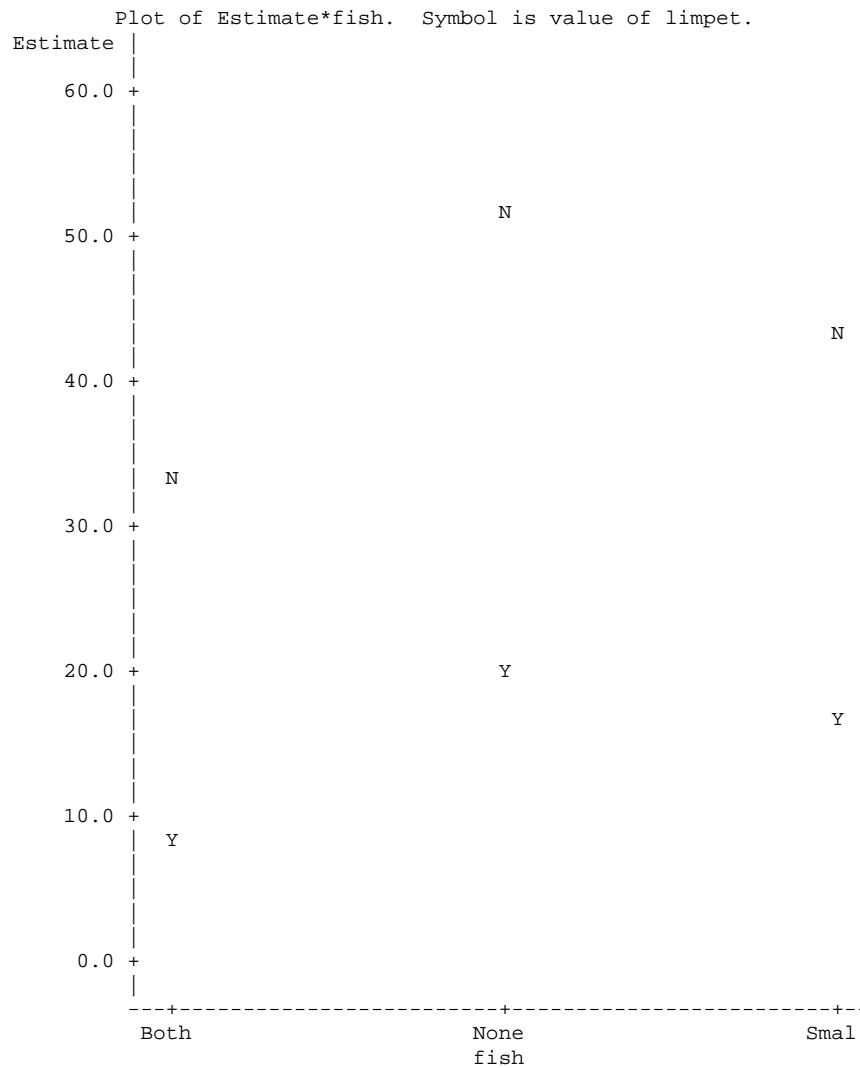
```
760      proc chart data=fish; vbar fish / sumvar=estimate; run;
NOTE: The PROCEDURE CHART printed page 11.
NOTE: PROCEDURE CHART used (Total process time):
      real time      0.07 seconds
      cpu time       0.02 seconds
```

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```
761      proc plot data=limpet_fish; plot estimate*fish=limpet; run;
NOTE: There were 6 observations read from the data set WORK.LIMPET_FISH.
NOTE: The PROCEDURE PLOT printed page 12.
NOTE: PROCEDURE PLOT used (Total process time):
      real time      0.10 seconds
      cpu time       0.02 seconds
```

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 Selected graphics



```
762      proc chart data=limpet_fish; vbar limpet / sumvar=estimate group=fish;
run;
```

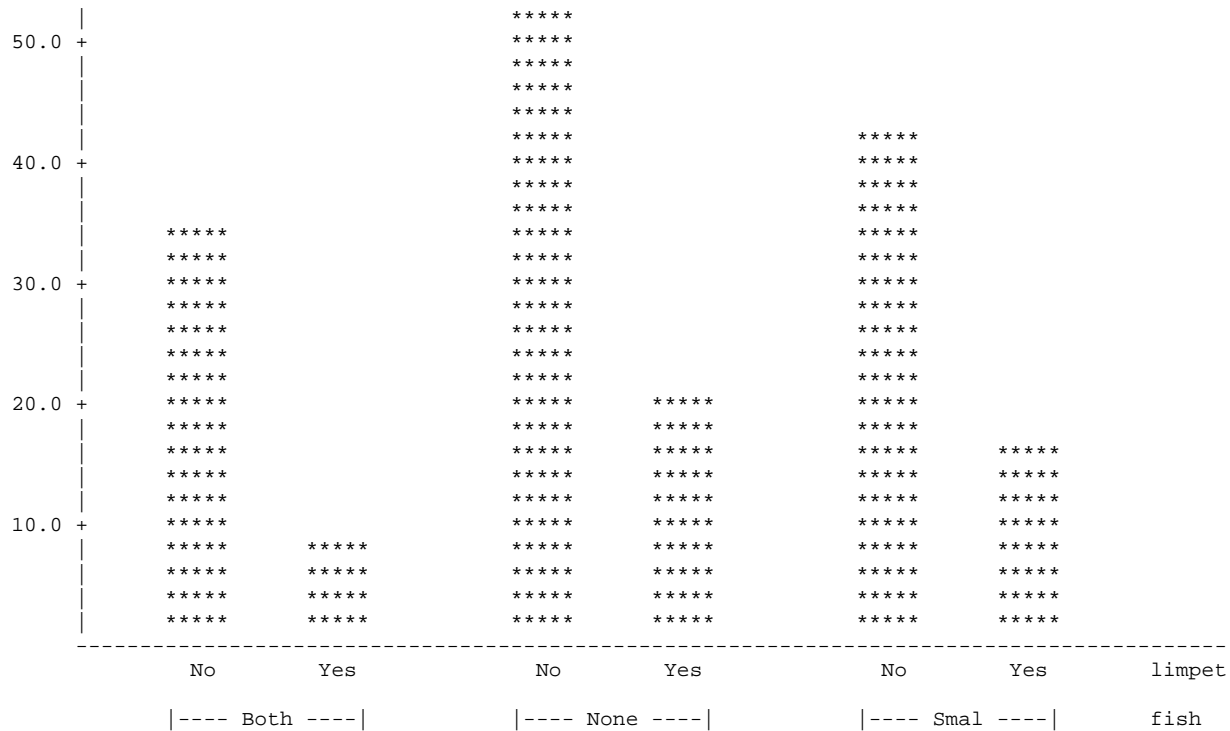
NOTE: The PROCEDURE CHART printed page 13.

NOTE: PROCEDURE CHART used (Total process time):

```
real time      0.06 seconds
cpu time       0.01 seconds
```

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 Split-plot design - PROC MIXED  
 Selected graphics

Estimate Sum

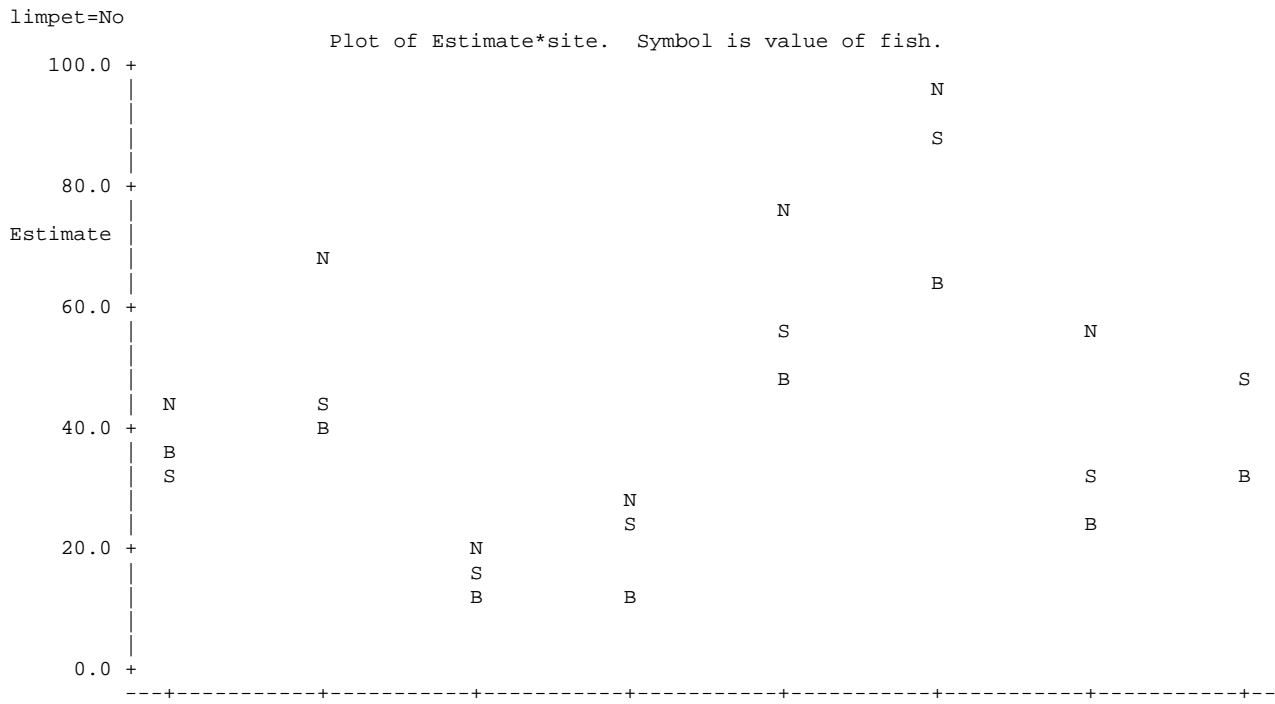


763

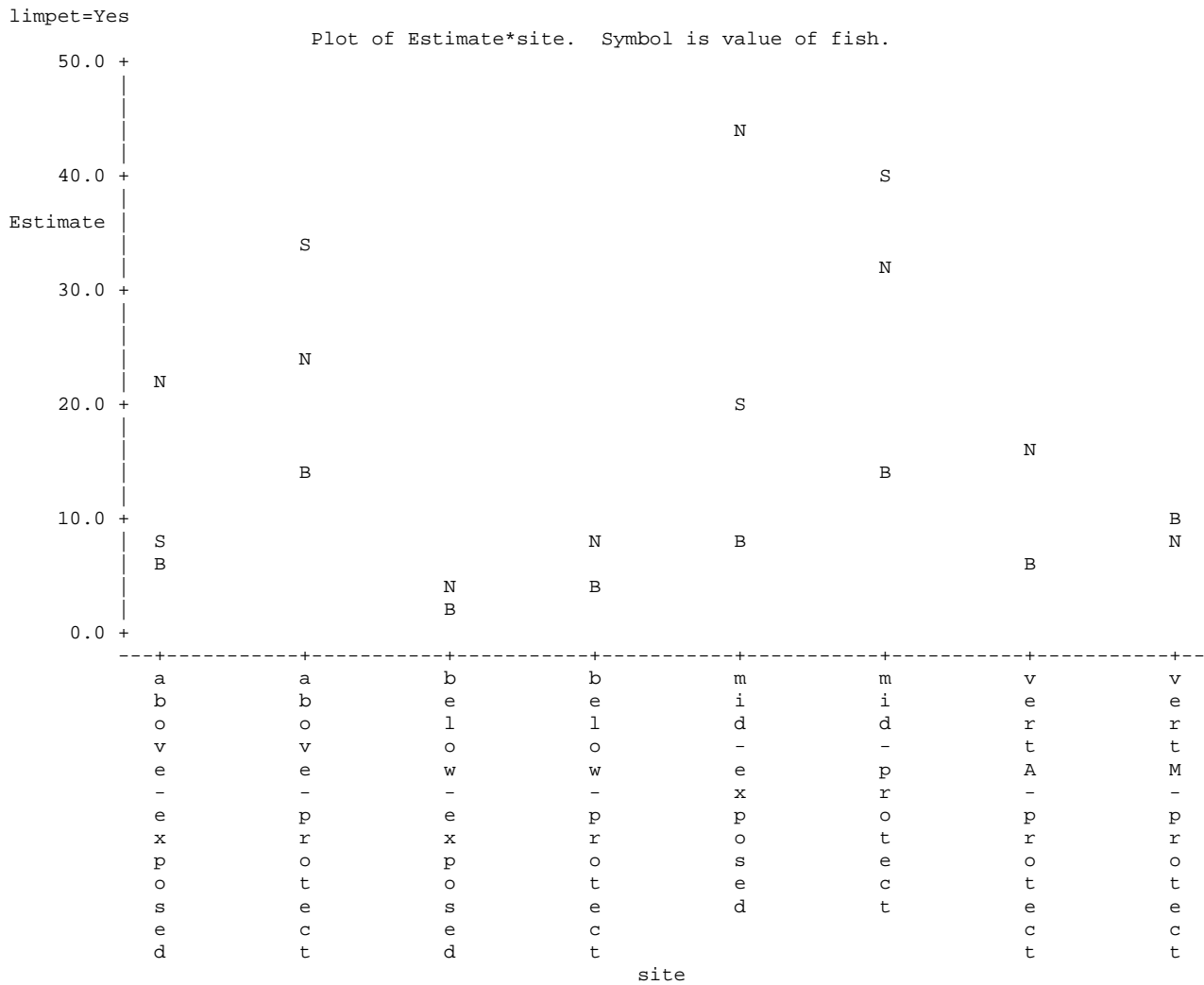
```
764      proc sort data=limpet_fish_site; by limpet; run;
NOTE: There were 48 observations read from the data set WORK.LIMPET_FISH_SITE.
NOTE: The data set WORK.LIMPET_FISH_SITE has 48 observations and 12 variables.
NOTE: PROCEDURE SORT used (Total process time):
      real time          0.04 seconds
      cpu time           0.03 seconds
```

765

```
      proc plot data=limpet_fish_site; by limpet; plot estimate*site=fish;
run;
NOTE: There were 48 observations read from the data set WORK.LIMPET_FISH_SITE.
NOTE: The PROCEDURE PLOT printed pages 14-15.
NOTE: PROCEDURE PLOT used (Total process time):
      real time          0.06 seconds
      cpu time           0.00 seconds
```



NOTE: 1 obs hidden.



NOTE: 4 obs hidden.

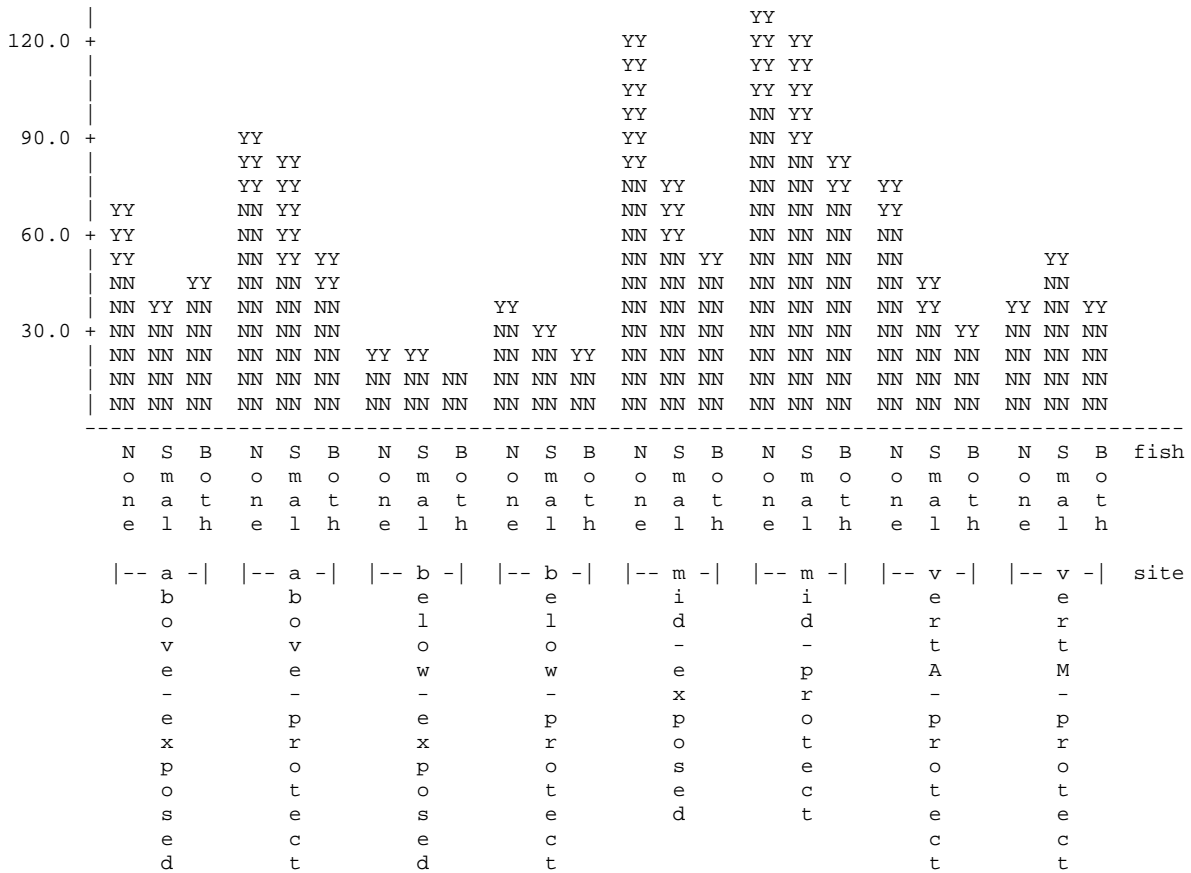
```
766      proc chart data=limpet_fish_site; vbar fish / sumvar=estimate group=site
subgroup=limpet
766      ! midpoints = 'None' 'Smal' 'Both';
767      run;
```

NOTE: The PROCEDURE CHART printed page 16.  
NOTE: PROCEDURE CHART used (Total process time):  
real time 0.05 seconds  
cpu time 0.00 seconds

768

Chapter 13 : Seaweed grazer study  
Split-plot design - PROC MIXED  
Selected graphics

Estimate Sum



Symbol limpet      Symbol limpet  
N No                  Y Yes

```

769          PROC UNIVARIATE DATA=resids NORMAL PLOT; VAR resid;
770          TITLE3 'Residual analysis';
771          RUN;
NOTE: The PROCEDURE UNIVARIATE printed pages 17-20.
NOTE: PROCEDURE UNIVARIATE used (Total process time):
      real time          0.06 seconds
      cpu time           0.02 seconds

```

Chapter 13 : Seaweed grazer study  
Split-plot design - PROC MIXED  
Residual analysis

The UNIVARIATE Procedure  
Variable: Resid

#### Moments

N	96	Sum Weights	96
Mean	0	Sum Observations	0
Std Deviation	4.13898946	Variance	17.1312338
Skewness	0	Kurtosis	1.03114833
Uncorrected SS	1627.46721	Corrected SS	1627.46721
Coeff Variation	.	Std Error Mean	0.42243384

#### Basic Statistical Measures

Location		Variability	
Mean	0.00000	Std Deviation	4.13899
Median	-0.00000	Variance	17.13123
Mode	-4.13144	Range	23.94356
		Interquartile Range	5.23317

NOTE: The mode displayed is the smallest of 2 modes with a count of 2.

#### Tests for Location: Mu0=0

Test	-Statistic-	-----p Value-----	
Student's t	t 0	Pr >  t	1.0000
Sign	M 0	Pr >=  M	1.0000
Signed Rank	S -1	Pr >=  S	0.9971

#### Tests for Normality

Test	--Statistic--	-----p Value-----	
Shapiro-Wilk	W 0.981727	Pr < W	0.2019
Kolmogorov-Smirnov	D 0.054002	Pr > D	>0.1500
Cramer-von Mises	W-Sq 0.048129	Pr > W-Sq	>0.2500
Anderson-Darling	A-Sq 0.466255	Pr > A-Sq	0.2500

Chapter 13 : Seaweed grazer study  
Split-plot design - PROC MIXED  
Residual analysis

The UNIVARIATE Procedure  
Variable: Resid

#### Quantiles (Definition 5)

Quantile	Estimate
100% Max	11.97178
99%	11.97178
95%	6.36856
90%	4.60174
75% Q3	2.61659
50% Median	-0.00000
25% Q1	-2.61659
10%	-4.60174



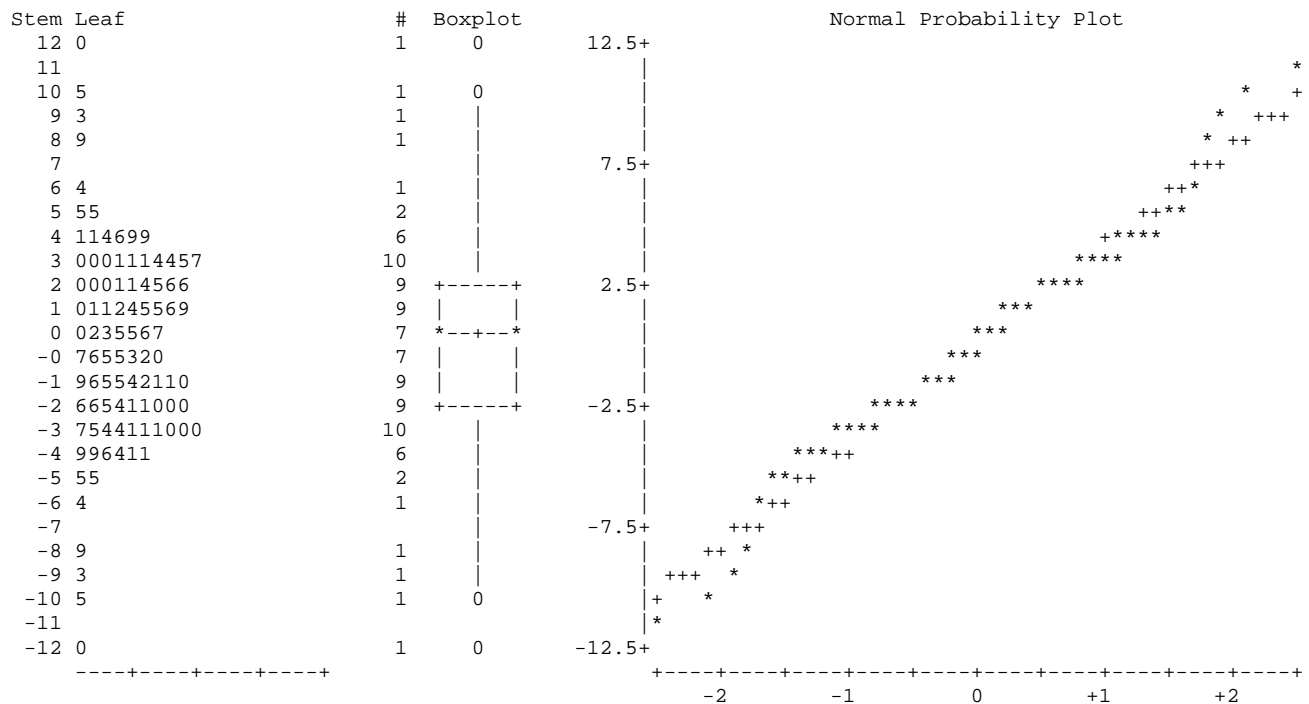
5% -6.36856  
 1% -11.97178  
 0% Min -11.97178

Extreme Observations

-----Lowest-----		-----Highest-----	
Value	Obs	Value	Obs
-11.97178	55	6.36856	26
-10.53020	79	8.89826	22
-9.29505	13	9.29505	14
-8.89826	21	10.53020	80
-6.36856	25	11.97178	56

Chapter 13 : Seaweed grazer study  
 Split-plot design - PROC MIXED  
 Residual analysis

The UNIVARIATE Procedure  
 Variable: Resid



```

775 PROC GLM DATA=seaweed; class limpet fish rep site;
776 Title2 'Split-plot design sith PROC GLM';
777 MODEL cover = site | limpet | fish rep(site);
778 random rep(site);
779 test H=site E=rep(site);
780 RUN;
    
```

NOTE: TYPE I EMS not available without the E1 option.  
 NOTE: The PROCEDURE GLM printed pages 20-22.  
 NOTE: PROCEDURE GLM used (Total process time):  
 real time 0.11 seconds  
 cpu time 0.06 seconds

Chapter 13 : Seaweed grazer study  
 Split-plot design sith PROC GLM

The GLM Procedure

Class Level Information

Class	Levels	Values
limpet	2	No Yes
fish	3	Both None Smal
rep	2	1 2
site	8	above-exposed above-protect below-exposed below-protect mid-exposed mid-protect vertA-protect vertM-protect
Number of Observations Read		96
Number of Observations Used		96

Dependent Variable: COVER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	55	51462.50000	935.68182	23.54	<.0001
Error	40	1590.00000	39.75000		
Corrected Total	95	53052.50000			

R-Square	Coeff Var	Root MSE	COVER Mean
0.970030	22.02536	6.304760	28.62500

Source	DF	Type I SS	Mean Square	F Value	Pr > F
site	7	19105.50000	2729.35714	68.66	<.0001
limpet	1	19153.50000	19153.50000	481.85	<.0001
limpet*site	7	3332.50000	476.07143	11.98	<.0001
fish	2	3648.00000	1824.00000	45.89	<.0001
fish*site	14	2218.50000	158.46429	3.99	0.0003
limpet*fish	2	244.00000	122.00000	3.07	0.0575
limpet*fish*site	14	1061.50000	75.82143	1.91	0.0555
rep(site)	8	2699.00000	337.37500	8.49	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
site	7	19105.50000	2729.35714	68.66	<.0001
limpet	1	19153.50000	19153.50000	481.85	<.0001
limpet*site	7	3332.50000	476.07143	11.98	<.0001
fish	2	3648.00000	1824.00000	45.89	<.0001
fish*site	14	2218.50000	158.46429	3.99	0.0003
limpet*fish	2	244.00000	122.00000	3.07	0.0575
limpet*fish*site	14	1061.50000	75.82143	1.91	0.0555
rep(site)	8	2699.00000	337.37500	8.49	<.0001

Source	Type III Expected Mean Square
site	Var(Error) + 6 Var(rep(site)) + Q(site,limpet*site,fish*site,limpet*fish*site)
rep(site)	Var(Error) + 6 Var(rep(site))
limpet	Var(Error) + Q(limpet,limpet*site,limpet*fish,limpet*fish*site)
limpet*site	Var(Error) + Q(limpet*site,limpet*fish*site)
fish	Var(Error) + Q(fish,fish*site,limpet*fish,limpet*fish*site)
fish*site	Var(Error) + Q(fish*site,limpet*fish*site)
limpet*fish	Var(Error) + Q(limpet*fish,limpet*fish*site)
limpet*fish*site	Var(Error) + Q(limpet*fish*site)

Dependent Variable: COVER

Tests of Hypotheses Using the Type III MS for rep(site) as an Error Term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
site	7	19105.50000	2729.35714	8.09	0.0042