MEC 1983 SAND CRAB PROJECT
FINAL REPORT

VOLUME 2 APPENDICES

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APPENDIX A

EQUIPMENT CALIBRATION

A.1 Sorting Sieve Calibration

Calibrations were completed for the four sets of sorting sieves that were used to live-sort sand crabs into size categories. Each set, made up of 18 sieves, was color coded black, blue, green or red. The calibration procedure involved measuring animals retained on each sieve of a set and comparing the variability between the sieves. The methods used for this procedure are discussed below.

Animals collected with sleds or with shovels during the three surveys were used for the calibrations. The animals were sorted live in the field through the four sets of color-coded sieves. Animals retained on each of the 18 sieves comprising a sieve set were kept separate, preserved in formalin, and returned to the laboratory. A technician randomly selected five preserved animals from a jar that corresponded to a color-coded sieve size and measured the animals. The longest carapace length was measured to the nearest tenth of a millimeter with calipers (Figure A-1). Animals were then returned to the jar. This procedure was repeated for each sieve size for each of the four sieve sets. The entire procedure was independently performed by five technicians.

The mean length of animals retained on the 18 sieves (numbered from 20 to 3) for each sieve set was calculated (Table A-1). A total of 25 measurements (5 technicians x 5 measurements) were used to compute the mean values. The number of observations were less than 25 in three cases (i.e. blue sieve 16, blue sieve 3, and green sieve 3) because animals of those sizes had been damaged during the calibration procedure, and there were no animals to replace them.

The difference in mean carapace length between adjacent sieves ranged between 0.6 and 1.7 mm with the following exceptions. The difference in mean size of animals retained on sieves 19 and 20 was greater than 2 mm for the green and red sieves because several extremely large (>23 mm) individuals were captured on sieve 20.

Measurements by each technician for each sieve of the four color-coded sieve sets were examined using a three-way factorial ANOVA (Table A-2). The results indicated a highly significant ($P < 0.0001$) sieve color by sieve size interaction, as well as sieve color by technician interaction, but no sieve size by technician interaction. The significant interaction term containing color and sieve size indicates that estimates of size of sand crabs must take into account the set of sieves used to sort them.

The relationship between animal size and sieve was examined for each sieve set using linear regression (Fig. A-2). The resultant equations for the sieve sets are as follows:

Black sieves, carapace length (mm) = .983 (sieve #) + 1.723;

Blue sieves, carapace length (mm) = 1.036 (sieve #) + 1.379;

Green sieves, carapace length (mm) =1.028 (sieve #) + 1.290; and

Red sieves, carpace length (mm) = 1.068 (sieve #) + 0.988.

Wenner's (1982) equation with an equivalence between his tub (= sieve) numbers (64's of an inch) and MEC's sieve numbers (32's of an inch), is as follows:

Carapace length = .526 (2)(tub#) + 1.05 (see MEC July Quarterly Report).

Wenner's equation is most similar to the MEC equation for red sieves. The variation in size predicted by Wenner's equation and MEC's equation for the red sieve is within three tenths of a millimeter (Table A-3). The other MEC equations predict sizes within 0 to 7 tenths of a millimeter, depending on sieve size, of Wenner's equation.

The measurements of the animals from the sieve calibration procedure rather than values estimated from the regression equations were considered the best estimators of size for animals sorted with the sieve sets. The means of the measured lengths of animals from sieves of a color-coded set were incorporated into the data base establishment program. Raw biological data entered in the data base by sieve color and sieve number were equated to the appropriate length (mm) during the data base establishment.

A.2 Folsom Splitter

The accuracy associated with splitting sand crab samples was investigated for ten samples having eighty of more crabs. Samples were split in half and the number of crabs (N) that were retained in each side of the splitter was recorded. The mean (x), standard deviation (SD), and coefficient of variation (CV = s/x) were calculated (Sokal and Rohlf, 1981). The coefficients of variation in the number of crabs between sides of the splitter ranged from 0 to 16%; the mean coefficient of variation for the ten samples was less than 10% (Table A-4).

Table A-1. Mean length of measured sandcrabs retained on each sieve of the four color-coded sieve sets.

SIEVE	BLACK				BLUE				GREEN				RED			
	N	MEAN	SD	CV	N	MEAN	SD	CV	N	MEAN	SD	CV	N	MEAN	SD	CV
20	25	21.1	0.78	3.71	25	22.09	0.71	3.24	25	22.7	1.20	5.29	25	23.7	1.62	6.83
19	25	20.5	1.02	4.95	25	21.2	0.69	3.25	25	20.5	0.81	3.94	25	21.2	1.69	8.29
18	25	19.2	1.04	5.40	25	20.2	0.36	1.80	25	19.4	0.39	2.02	25	20.4	0.69	3.37
17	25	18.6	1.12	6.04	25	18.9	0.53	2.79	25	18.7	0.54	2.89	25	19.3	0.49	2.52
16	25	17.3	0.89	5.15	24	18.4	0.52	2.81	25	17.7	0.28	1.56	25	17.5	0.63	3.58
15	25	16.6	0.70	4.20	25	16.9	0.48	2.82	25	16.3	0.54	3.30	25	16.0	0.43	2.66
14	25	15.3	0.73	4.75	25	15.3	0.49	3.19	25	15.3	0.37	2.42	25	15.3	0.65	4.26
13	25	14.6	0.36	2.48	25	14.5	0.83	5.74	25	14.6	0.37	2.56	25	14.5	0.67	4.62
12	25	13.8	0.60	4.36	25	13.7	0.35	2.57	25	13.8	0.31	2.23	25	13.8	0.43	3.11
11	25	12.7	0.51	4.05	25	12.6	0.66	5.22	25	12.9	0.45	3.48	25	12.9	0.54	4.15
10	25	11.7	0.42	3.60	25	11.8	0.44	3.69	25	11.9	0.40	3.31	25	11.7	0.39	3.33
9	25	11.0	0.28	2.53	25	10.9	0.38	3.50	25	11.0	0.52	4.74	25	10.8	0.55	5.12
8	25	9.8	0.39	3.97	25	9.9	0.53	5.35	25	9.8	0.45	4.56	25	9.5	0.48	5.06
7	25	8.0	0.32	3.93	25	8.6	0.48	5.55	25	8.1	0.46	5.69	25	8.4	0.41	4.92
6	25	7.4	0.60	8.03	25	8.0	0.45	5.67	25	7.4	0.36	4.86	25	7.5	0.40	5.36
5	25	6.6	0.43	6.50	25	6.6	0.53	8.14	25	6.3	0.40	6.32	25	6.7	0.38	5.74
4	25	5.6	0.40	7.27	25	5.3	0.43	8.03	25	5.4	0.45	8.42	25	5.5	0.38	6.82
3	25	4.7	0.55	11.67	24	4.5	0.46	10.34	23	4.2	0.38	9.00	25	4.2	0.42	10.07

Table A-2. Results of a three-way factorial ANOVA of sieve calibration data.

Source of Variation	df	SS	MS	F	P
Color	3	17.25	5.75		
Sieve	17	50783.70	2987.28		
Technician	4	8.29	2.07		
Color x Sieve	51	171.50	3.36	8.89	0.0001*
Color x Technician	12	21.53	1.79	4.74	0.0001*
Sieve x Technician	68	24.18	0.36	0.94	0.6156
Color x Sieve x Technician	204	67.33	0.33	0.87	0.8921
Error	1436	543.03	0.38		

* $P < .0001$

Table A-3. Comparison of carapace lengths (mm) for each sieve size as predicted by MEC and Wenner (1982) regression equations.

	Mean Carapace Length (mm)				
	MEC Equations for color-coded sieve sets				
Sieve	Black	Blue	Green	Red	Wenner's Equation
20	21.4	22.1	21.8	22.3	22.1
19	20.4	21.1	20.8	21.3	21.0
18	19.4	20.0	19.8	20.2	20.0
17	18.4	19.0	18.8	19.1	18.9
16	17.4	18.0	17.7	18.1	17.9
15	16.5	16.9	16.7	17.0	16.8
14	15.5	15.9	15.7	15.9	15.8
13	14.5	14.8	14.6	14.9	14.7
12	13.5	13.8	13.6	13.7	13.7
11	12.5	12.8	12.6	12.7	12.6
10	11.5	11.7	11.6	11.7	11.6
9	10.6	10.7	10.5	10.6	10.5
8	9.6	9.7	9.5	9.5	9.5
7	8.6	8.6	8.5	8.5	8.4
6	7.6	7.6	7.5	7.4	7.4
5	6.6	6.6	6.4	6.3	6.3
4	5.7	5.5	5.4	5.3	5.3
3	4.7	4.5	4.4	4.2	4.2

Table A-4. The number (N) of animals that resulted from splitting ten sand crab samples in half with a Folsom plankton splitter.

SAMPLE	N(SIDE 1)	N(SIDE 2)	MEAN	SD	CV (%)
1	209	246	227.5	26.1630	11.5002
2	70	81	75.5	7.77882	10.3022
3	84	79	81.5	3.5355	4.3381
4	172	170	171.0	1.4142	0.8270
5	45	36	40.5	6.3640	15.7135
6	38	42	40.0	2.8284	7.0711
7	53	43	48.0	7.0711	14.7314
8	53	51	52.0	1.4142	2.7196
9	60	60	60.0	0.0000	0.0000
10	63	57	60.0	4.2426	7.0711

mean CV = 7.4274

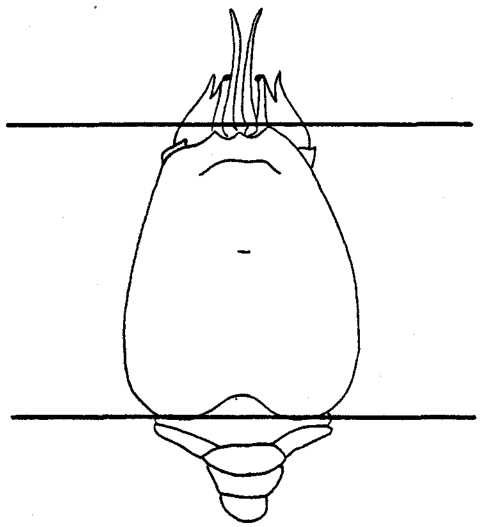


Figure A-1. Dorsal aspect of the thoracic carapace of the sand crab, Emerita analoga. Horizontal lines indicate the portion that was measured to determine the carapace length.

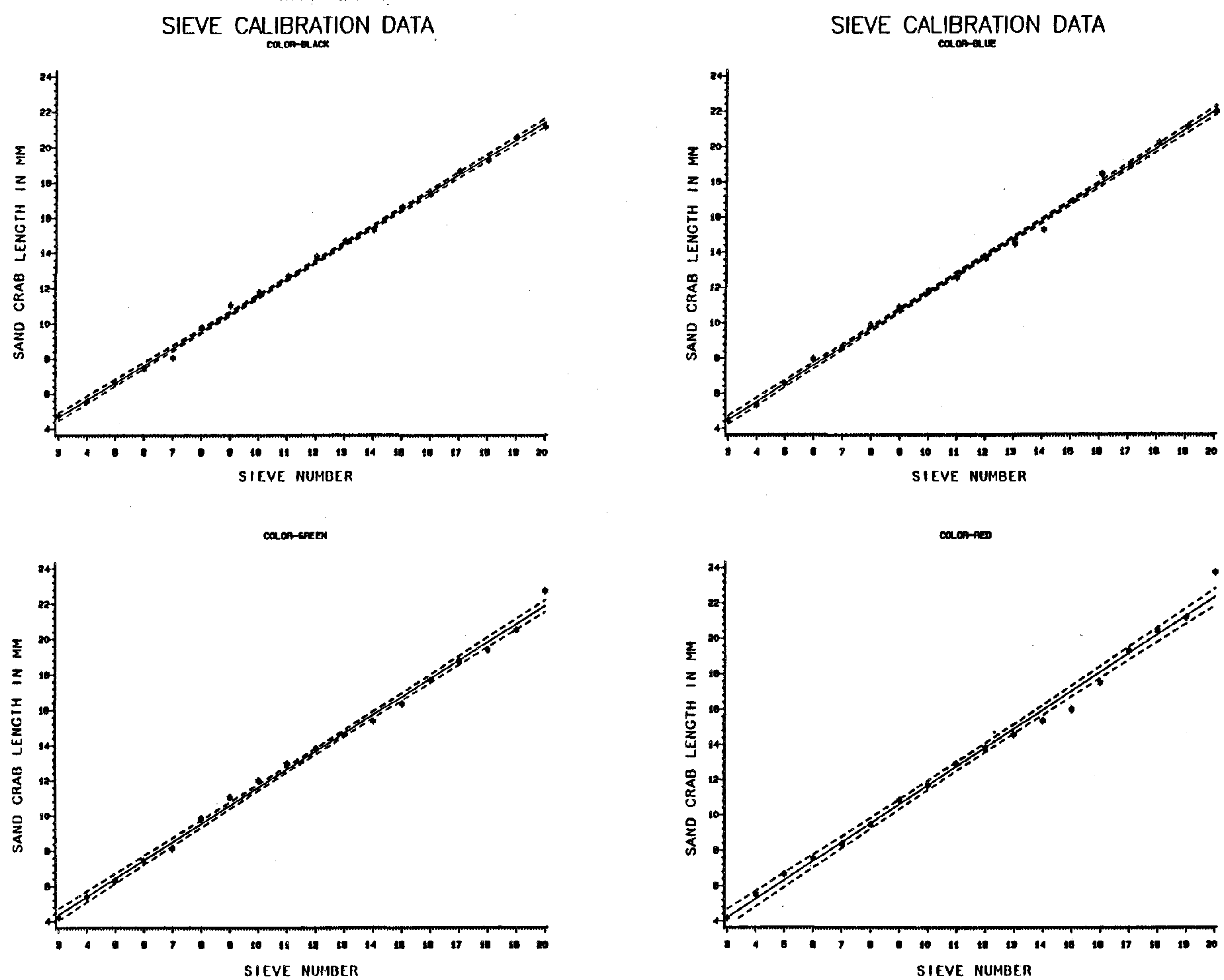


Figure A-2. Plots of the linear regressions between sand crab size (mm) and sieve size for the four color-coded sieve sets.

APPENDIX B

FIELD PROTOCOLS

B.1 Sand Crab Survey 1 (11-15 June 1983)

1) Note beach characteristics on field sheet. Make a note of your beginning/ending study site landmarks on the first survey.
Beach length and wave height are estimated; wave frequency is timed. Wave height is based on the trough to crest height when the waves break.

   The start and end points of the sampling area should be 30-100 meters away from any obstacle (pier, creek etc.) and 100 m away from the source of any bright lights.

2) WAIT UNTIL THE SUN HAS SET AND THE TIDE IS EBBING - The earliest possible sampling time will be estimated at the lab and provided on your field sheet. The field leader will wait for the sand crab patch width to contract to less than 6 meters or until 1.5 hours have elapsed since the earliest possible sampling time.

   (Note: If your have lots of time between your arrival and the Beach walk described in Step 3, you should place the sample location stakes at the positions liste on the Randomly Selected Sites: Positioning sheet. See below for techniques.)

3) BEACH WALK - Walk the length of the study area, one person above the patch area, the other below it, recording the locations and sizes of patches of sand crabs and rock/pebble patches on graph paper. Try to keep to the scale provided but don't attempt excessive detailing which might consume time.

   NOTE: You are taking meter-long strides to keep track of where you are on the beach.

   RANDOMLY SELECTED SITES: POSITIONING
   Carry your site stakes while you are walking. On your way back to the starting point place these stakes at the 9 preselected sampling sites as noted on your field sheets. Use the "Paces from 500" column to get the number of paces to count off from the end position.
   If one of the sites falls on a cobble stretch, replace it with the first number from the list of additional sites. All unacceptable sites are replaced as they occur. The new site numbers are listed in the "New Site" column of the "Positioning" sheet.
   When your have 9 acceptable sampling sites, reorder them, serially from zero on the Positioning sheet and transfer this list to the "Randomly Selected Sites: Description" sheet.

4) SAMPLE SITE- Go to sample site and describe it for sand crab patch length, width and portion of patch sampled - edge, middle, between patch, giving distances from the patch edges. If the sand crabs form a continuous band, state so and describe the band for 5 meters on either side of the tow.

5) START SAMPLING ANIMALS
Start 1/2 meter below the low edge of patch or in area exposed by a withdrawn wave if there is no patch or if there is no lower edge to the patch. Note: if animals sporatically occur down to wave edge, try to define the point where 90% of the animals are higher on the beach and use that boundary as your lower edge.

Tow towards the berm for the length of the net.

Pull the sled as quickly as you can without pulling the sled out of the sand. The sand will clog the mouth of the sampler when the tow is complete.

If the band is wider than the bag length, a second tow must be taken. This tow will start at the position where the first tow ended (plant your sled in the sand to mark the spot after the first tow) at least 2 meters up or down the beach from that tow line. Measure and record the distance of the second tow.

<u>Never</u> walk on the area you are about to sample and minimize the amount of light shone on this area.

Rinse sand out of the bag and take bage with you.
Leave stake at sampling site.

6) TAKE CHEMISTRY SAMPLES THREE PREDETERMINED TOW SITES ONLY
These sites will be noted on your "Sampling" field sheets. (The nine tow sites have been divided into three groups of three - three "triads". There is one chemistry site in each of these triads.)

A) Sand samples- taken from mid-tow area, one meter away from tow line.
Use specimen cups to take <u>FOUR</u> sand samples (as cores).
Cap and label outside of cups and caps with:
Beach name
Date
Site letter
Sample type
place sample in ice chest

Use glass bottle for <u>ONE</u> sand sample. Label as above.
These samples will not be taken on the first survey.

B) Wave-wash samples - these samples will be taken after you have processed the animal samples. Directions will be given in this protocol.

7) Describe each sample site area for 1) beach width (estimated) 2) beach slope (measured with level line) - if beach has two distinct slopes measure both of them 3) cobble on the wet sand, in the wave break and in knee-deep water (outgoing wave) and 4) temperature of water in knee-deep water (outgoing wave).

8) Proceed to animal processing area. Get sieves and jars from truck - while you are at the truck put on dry ice those chemistry samples which require freezing.

PROCESS ANIMALS THROUGH SIEVES 20 - 3
Each site is processed separately.
There are no buckets 1 and 2.
Stack buckets sequentially, #20 (largest holes) on the top.
Sieve animals.
Fill in zero counts on Sand Crab Tally Sheet - preserved
Fill in counts for buckets 11-20.

Animals from all buckets will be preserved separately by bucket in glass jars and returned to the laboratory. Use labels prepared in lab. Prepare the 10% Formalin solution at your processing area by pouring half of the Formalin (in the one gallon carboy) into the 5 gallon carboy then filling the 5 gallon carboy with sea water.

Using the "Sand crab tally sheet" keep track of the number of individuals preserved from buckets 11-20. We want to end up with at least 300 of these individuals preserved from the entire beach; at least one hundred from each of the three-site triads.
If not enough animals were sampled, return to site areas (i.e., triad) that provide low numbers and dig for more animals. Screen these animals through buck #11 and preserve each triad area separately from the towed samples.

LIVE ANIMALS
From each three-site triad area we want 30 females (approximately ten per tow site) with bright orange eggs from buckets 11-15 brought back alive. Go to the first area, find a patch of large animals, gently shovel them out, screen the shovelful through buckets 16 (top) and 11 (bottom). Select for smaller individuals.

When you have 30 undamaged females with orange eggs, place them in a wet laundry bag and fill out the red I.D. tag with Beach, Triad Area and Sample Time. Gently stow this bag in one of the "Live" containers provided for this useage and this useage only. Proceed to next triad area and find thrity more females as above.
Do same for third triad area.

10) TAKE WAVE WASH SAMPLES AND PROCESS THEM

Seston sample taking:

1) Fill the large, rectangular opaque bottle with ocean water from slack waer that is approx. one foot deep.

2) Allow sand in large bottle to settle for 30 seconds before carefully decanting water into smaller "triad bottle". Fill to overflowing.

3) Rinse large bottle and repeat procedure for each of next tow triads.

4) Fill large bottle from anywhere along the study beach.

5) Smaller bottles will be filtered in the field. Large bottle will be chilled and not filtered.

Chlorophyll sample taking:

1) Fill two scintillation vials marked "Sampl 1 (A, F or H)" and "Samp 2 (A, F or H)" to the top from slack water approx. one foot in depth. Cap the vials.

2) Both samples from each triad will be combined to be filtered as one.

3) The chlorophyll/phaeophytin sample will be filtered after the seston sample.

SESTON Filtering in the Field:

1) Use a preweighed GFC Filter in a numbered petri dish for the seston filtering.

2) Remove the top piece of the filter holder.

3) Wet the glass frit with distilled water.

4) Note the number on the petri dish in the log and remove the GFC filter to the wetted frit with the flat bladed Millipore forceps. <u>Do not touch the filter with your hands!</u>

5) Be careful to center the filter, apply vacuum and clamp or screw on the top part of the filter holder.

6) Filter the contents of bottle #1 with vacuum less than 15 inces Hg. Bottle #1 holds 200 ml. and the filtering apparatus does not. BE CAREFUL when pouring the sample into the filter holder. Swirl the contents prior to pouring the last of the sample water into the filter holder.

7) Turn pump off and break the vacuum. Reestablish setup.

8) Add 2.5-5.0 ml. distilled water to rinse the filter, briefly apply suction to remove excess water. Repeat.

9) With the suction on, remove the filter funnel and rinse the edge of the filter with a few drops of distilled water. Suck off excess water.

10) Break the vacuum and remove the filter with the flat bladed Millipore forceps. Put filter in numbered petri dish it came from.

11) Petri dish goes into a Ziploc bag and onto dry ice.

NOTE: You have only one spare preweighed filter.

IMPORTANT: The vacuum system does not have a water trap to protect the vacuum pumps. Empty the flasks after each filtering. <u>Save the last flask - it will be used for the chlorophyll filter rinse.</u>

CHLOROPHYLL/PHAEOPHYTIN FILTERING IN THE FIELD

1) Each ch. sample consists of 2 scintillation vials of sea water (approx. 50 ml.) labelled "Sampl 1 (A, H or F)" and "Samp 2 (A, H or F)".

2) Remove the filter funnel and wet the glass frit (distilled water).

3) MILLIPORE AA membrane filters will be used for the chl. samples. Each filter is between two blue wax papers. Remove the white membrane filter and center it on the wetted glass frit. The blue wax paper will curl up as it is wetted and can be removed. Be sure that there is no blue waxed paper when you are trying to filter.

4) While applying suction, replace and clamp the filtering funnel.

5) Filter water from both scintillation bottles (1 & 2) from the chemistry triad using a vacuum less than 15 inches of Hg.

6) Rinse the funnel with 2-5 ml. of the FILTERED SEA WATER FROM THE SESTON PROCEDURE or do not rinse at all. DO NOT use distilled water.

7) Suction off excess water. Remove the filter funnel and break the vacuum.

8) Remove the filter to the appropriate prelabelled scintillation vial which contains 10 ml. of acetone. Secure the cap, shake the vial and place the vial in the dry ice cooler.

IMPORTANT: As much as is practical, keep the sample in reduced light throughout its handling.

11) Return to truck with the samples first.

Fill a "live" carboy with seawater to be brought back to lab.

Rinse the gear to at least remove excess sand. If there is fresh water available, use it.

Stow the rest of the gear and come home.

KEEP THE LIVE ANIMALS AS FAR AWAY FROM THE PRESERVED SAMPLES AND THE PRESERVATIVE AS POSSIBLE.

B.2 Sand Crab Survey 2 (30 June-3 July 1983)

1) Note departure time under "Survey Duration". Note beach characteristics on field sheet. Use the beginning/ending study site landmarks as defined on the first survey.
   Wave height is estimated; wave frequency is timed. Wave height is based on the trough to crest height when the waves break.

   (The start and end points of the sampling area should be 30-100 meters away from any obstacle (pier, creek etc.) and 100 m away from the source of any bright lights.)

2) WAIT UNTIL THE SUN HAS SET - the earliest possible sampling time will be estimated at the lab and provided on your field sheet. The field leader can wait for the sand crab patch width to contract to less than 6 meters or until 1.5 hours have elapsed since the earliest possible sampling time.

3) BEACH WALK - Walk the length of the study area, one person above the patch area, the other below it, recording the locations and sizes of patches of sand crabs and rock/pebble patches.

   NOTE: You are taking meter-long strides to keep track of where you are on the beach.)

   Each new patch begins a new line on the BEACHWALK sheet.

   RANDOMLY SELECTED SITES: POSITIONING
   Carry your site stakes while you are walking. Mark the patches as you encounter them on your beachwalk if there are only a few patches on your beach.
   When you are through with your beachwalk tally up the number of patches and interpatches in your study area.
   <u>If there are five or more patches on the beach</u>, use your random number table to select four patches out of the total available and then two non-cobble interpatches out of the total available for sampling.
   <u>If there are four patches</u>, sample all four and randomly select two interpatch areas for sampling.
   <u>If there are less than four patches</u>, refer to the Contingency Flow Diagram for what to do.
   To use the random number table: make a blind stab at the table to select your first number-the digits at the right end of the block are the ones you are interested in. Work your way down the column, keeping the numbers that fall between one and the maximum allowable (as defined either by the number of patches or the number of interpatches.) For example: there are 25 patches on the beach, your finger ends up on "47448", 48 is too large, the next number is "92717", and 17 is acceptable, next is "92312", and 12 is acceptable, as is 05 from "63105" and 11 from "66711".

4) SAMPLE SITE- Go to sample site and if the patch has changed dimensions noticeably since the mapping, pace the length of the patch (or interpatch). Using the random number table and the length (number of paces as your maximum number), select the position in the patch (or interpatch) to be towed. You must be at least one pace away from the edge of your patch (or interpatch). Describe the patch (or interpatch) for length, width and portion of patch (or interpatch) sampled - in paces from the edge. If the sand crabs form a continuous band, state so and describe the band for 5 meters on either side of the tow.

5) START SAMPLING ANIMALS
Start 1/2 meter below the low edge of patch or in area exposed by a withdrawn wave if there is no patch or if there is no lower edge to the patch. Note: if animals sporatically occur down to wave edge, try to define the point where 90% of the animals are higher on the beach and use that boundary as your lower edge.

Tow towards the berm for the length of the net.

Pull the sled as quickly as you can without pulling the sled out of the sand and without jerking the sled. The sand will clog the mouth of the sampler when the tow is complete. Pace off the length of the tow and record it to the nearest 1/2 meter.

If the band is wider than the bag length, a second tow must be taken. This tow will start at the position where the first tow ended (plant your sled in the sand to mark the spot after the first tow) at least 2 meters up or down the beach from that tow line. Measure and record the distance of the second tow.

Tie off the open end of the sand crab net and stake it high on the beach, where it won't get washed away.

<u>Never</u> walk on the area you are about to sample and minimize the amount of light shone on this area.

Take the sand chemistry samples

A) Sand samples- taken from mid-tow area, 1/2 meter away from tow line.
Use specimen cups to take <u>FOUR</u> sand samples (as cores). The sample containers should be prelabelled for you, if not:
Cap and label outside of cups and caps with:
Beach code number
Date
Site letter
Sample type
place sample in ice chest

Use glass scintillation bottle for ONE sand sample. Label as above.

B) Wave-wash samples - these samples will be taken after you have processed the animal samples. Directions will be given later in this protocol.

6) IF YOU ARE SAMPLING A PATCH: Fill two laundry bags with sand from the patch you just sampled-you are after more animals. Shovel equal amounts of sand from low, mid and high areas of the patch.
Rinse the bag and check. If there are approximately 200 sand crabs (including at least 40 larger animals) from both bags combined, you're okay. If you need more animals, shovel more sand. Keep a record of the number of sand bags you filled to get the extra animals.

GO ON TO NEXT SAMPLE SITE AND TAKE YOUR NEXT TOW and extra crabs and sand samples. Time is of the essence--we would like all six tows taken as close in time as is possible.

7) After you have sampled all six sites for animals and sand, return to each to describe each sample site area for 1) beach width (estimated) 2) beach slope (measured with level line) - if beach has two distinct slopes measure both of them 3) cobble on the wet sand, in the wave break and in knee-deep water (outgoing wave) and 4) temperature of water in knee-deep water (outgoing wave).

Take the wave-wash samples at each site.
Fill one brown plastic bottle and two scintillation vials with water from a "settling" container. The settling container is a graduated cylinder. Fill the cylinder during slack water - after the wave has come in and before it goes out. Count to 30 seconds for settling before pouring contents into seston and chlorophyll containers. Be careful to avoid getting any sand in the receptacles. The plastic bottle is for "seston", the two vials are for chlorophyll. Label the containers appropriately (if the containers haven't been prelabelled).

Clean the sand out of the sand crab net bag. If the sand is too coarse to go through the netting, the sample contents should be sieved through Sieve # 5 (and therefore eliminate Sieves # 3 and 4).

8) Proceed to animal processing area with your animals, chemistry samples and sampling gear.
Get sieves and jars from truck - while you are at the truck put on dry ice those chemistry samples which require freezing.

PROCESS ANIMALS THROUGH SIEVES 20 - 3

Each site is processed separately.

There are no buckets 1 and 2.

Stack buckets sequentially, #20 (largest holes) on the top.

Sieve animals.

Fill in "p" for present and "0" for zero counts on Sand Crab Tally Sheet - Preserved for all size categories.

Keep approximate track of the total number in each patch sample.

Remember: if you had to use Sieve # 5 to clean the sand out of the sample, you are not going to have crab samples from Sieves # 3 and 4.

Animals from all buckets will be preserved separately by bucket in glass jars and returned to the laboratory. Use labels prepared in lab. Return unused labels to the lab. Prepare the 10% Formalin solution at your processing area by pouring half of the Formalin (in the one gallon carboy) into the 5 gallon carboy then filling the 5 gallon carboy with sea water.

Using the "Sand crab tally sheet" keep track of the number of individuals preserved. We want to end up with at least 200 of these individuals preserved from each patch sampled.

9) Return to truck with the samples first.

Fill a "live" carboy with seawater to be brought back to lab.

Rinse the gear to at least remove excess sand. If there is fresh water available, use it.

Stow the rest of the gear and come home.

KEEP THE LIVE ANIMALS AS FAR AWAY FROM THE PRESERVED SAMPLES AND THE PRESERVATIVE AS POSSIBLE.

10) Record the time you return to MEC on Page 1 of the field sheet under "Survey duration".

B.3 Sand Crab Survey 3 (2-5 August 1983)

1) Note departure time under "Survey Duration". Note beach characteristics on field sheet. Use the beginning/ending study site landmarks as defined on the first survey. Wave height is estimated; wave frequency is timed. Wave height is based on the trough to crest height when the wave first breaks.

(The start and end points of the sampling area should be 30-100 meters away from any obstacle (pier, creek etc.) and 100 m away from the source of any bright lights.)

2) WAIT UNTIL THE SUN HAS SET - the earliest possible sampling time will be estimated at the lab and provided on your field sheet. The field leader can wait for the sand crab patch width to contract to less than 6 meters or until 1.5 hours have elapsed since the earliest possible sampling time.

3) BEACH WALK - Walk the length of the study area, one person above the patch area, the other below it, recording the locations and sizes of patches of sand crabs and rock/pebble patches.

NOTE: You are taking meter-long strides to keep track of where you are on the beach.)

Each new patch begins a new line on the BEACHWALK sheet.

RANDOMLY SELECTED SITES: POSITIONING
Carry your site stakes while you are walking. Mark the patches as you encounter them on your beachwalk if there are only a few patches on your beach.
When you are through with your beachwalk tally up the number of patches and interpatches in your study area.
<u>If there are five or more patches on the beach</u>, use your random number table to select four patches out of the total available and then two non-cobble interpatches out of the total available for sampling.
<u>If there are four patches</u>, sample all four and randomly select two interpatch areas for sampling.
<u>If there are less than four patches</u>, refer to the Contingency Flow Diagram for what to do.
To use the random number table: make a blind stab at the table to select your first number-the digits at the right end of the block are the ones you are interested in. Work your way down the column, keeping the numbers that fall between one and the maximum allowable (as defined either by the number of patches or the number of interpatches.) For example: there are 25 patches on the beach, your finger ends up on "47448", 48 is too large, the next number is "92717", and 17 is acceptable, next is "92312", and 12 is acceptable, as is 05 from "63105" and 11 from "66711".

4) SAMPLE SITE- Go to sample site and if the patch has changed dimensions noticeably since the mapping, pace the length of the patch (or interpatch). Using the random number table and the length (number of paces as your maximum number), select the position in the patch (or interpatch) to be towed. You must be at least one pace away from the edge of your patch (or interpatch). Describe the patch (or interpatch) for length, width and portion of patch (or interpatch) sampled - in paces from the edge. If the sand crabs form a continuous band, state so and describe the band for 5 meters on either side of the tow.

5) START SAMPLING ANIMALS
You will be taking animals three different ways:
 1) in a sled tow
 2) shovelled into a small mesh laundry bag
 3) shovelled into a large mesh laundry bag

CATEORY 1 SLED TOWS
Start 1/2 meter below the low edge of patch or in area exposed by a withdrawn wave if there is no patch or if there is no lower edge to the patch. Note: if animals sporatically occur down to wave edge, try to define the point where 90% of the animals are higher on the beach and use that boundary as your lower edge.

Tow towards the berm for the length of the net.

Pull the sled as quickly as you can without pulling the sled out of the sand and without jerking the sled. The sand will clog the mouth of the sampler when the tow is complete. Pace off the length of the tow and record it to the nearest 1/2 meter.

If the patch is <u>much</u> wider than the bag length, a second tow must be taken. This tow will start at the position where the first tow ended (plant your sled in the sand to mark the spot after the first tow) at least 2 meters up or down the beach from that tow line. Measure and record the distance of the second tow.
If you missed only a small portion of the patch with your tow, you can use your wider shovel to collect the portion that a second tow would take to complete the patch sample. <u>Be careful</u> to scoop out the same width, depth and length that the sled would have taken. Measure and record this distance.

Tie off the open end of the sand crab net and stake it high on the beach, where it won't get washed away.

<u>Never</u> walk on the area you are about to sample and minimize the amount of light shone on this area.

Take the sand chemistry samples

A) Sand samples- taken from mid-tow area, 1/2 meter away from tow line.
Use specimen cups to take FOUR sand samples (as cores).

The sample containers should be prelabelled for you, saying:
Survey ID #
Beach Code #
Site letter
Sample type

Use a spare specimen cup to take water from a core hole and transfer this water to a prelabelled specimen cup. Fill this cup between waves, if your hole gets filled by a wave before you have taken the entire sample, wait for the wave to depart, dig a new hole and add what additional sediment water you need. (This water will be used for a salinity measurement.)
Keep the core hole no deeper than the depth of the cup (about three inches).

Use glass scintillation bottle for ONE sand sample. Label as above.

Place samples in the ice chest.

B) Wave-wash samples - these samples will be taken after you have processed the animal samples. Directions will be given later in this protocol.

6) IF YOU ARE SAMPLING A PATCH OR BAND:

DO NOT TRY FOR THESE ANIMALS IF THERE ARE NONE THERE!!!!!!!

CATEGORY 2:
(Small laundry bag - animals for population structure)
Fill a small mesh laundry bag with sand from the patch you just sampled-you are after more animals. Shovel equal amounts of sand from low, mid and high ares of the patch.
Rinse the bag and check. If there are approximately 200 sand crabs both bags combined, you're okay. If you need more animals, shovel more sand.
If you are on a coarse sand beach, use your #5 5-gallon bucket instead of the laundry bag to clean the sand from the sample. You still want around 200 animals.
Store the animals in a small mesh laundry bag. Make sure the bag is labelled with beach, site and category 2.

CATEGORY 3:
(Large mesh laundry bag - adult females for tissue studies)

You may take these samples when you do the water chemistry if you are afraid of not being able to complete the sled tows during the favorable tidal cycle you are working in.

Fill the large mesh bag with sand from the patch area you are sampling-you are after adult females, sieve sizes 8-10, 11-14 ang 15-20; within each of these three size categories you want 20 females with orange eggs and 20 females without eggs. (Realistically, most beaches probably will not yield a full complement of females.)
Rinse the bag and check. If it looks like you are close, you're okay. If you need more animals, shovel more sand. Transfer these animals to a small mesh laundry bag for the trip home.

Make sure your laundry bags are labelled with beach, site and category (2 or 3).

Pace yourself. You should by now have a good feeling for how long it takes to sample the whole beach. Do not spend time you don't have on a site that isn't producing enough animals.

GO ON TO NEXT SAMPLE SITE AND REPEAT PROCEDURES 4 - 6. Time is of the essence--we would like all six tows taken as close in time as is possible.

7) After you have sampled all six sites for animals and sand, return to each to describe each sample site area for 1) beach width (estimated) 2) beach slope (measured with level line) - if beach has two distinct slopes measure both of them 3) cobble on the wet sand, in the wave break and in knee-deep water (outgoing wave) and 4) temperature of water in knee-deep water (outgoing wave).

Take the wave-wash samples at each site.
Fill one brown plastic bottle and two scintillation vials with water from a "settling" container. The settling container is a graduated cylinder. Fill the cylinder during slack water - after the wave has come in and before it goes out. Count to 30 seconds for settling before pouring contents into seston and chlorophyll containers. Be careful to avoid getting any sand in the receptacles. The plastic bottle is for "seston", the two vials are for chlorophyll. Label the containers appropriately (if the containers haven't been prelabelled).

Clean the sand out of the sand crab net bag. <u>If the sand is too coarse to go through the netting, the sample contents should be sieved through Sieve # 5 (and therefore eliminate Sieves # 3 and 4).</u>

8) Proceed to animal processing area with your animals, chemistry samples and sampling gear.
Get sieves and jars from truck - while you are at the truck put on (not in) dry ice those chemistry samples which

require freezing.

PROCESS CATEGORY 1 ANIMALS THROUGH SIEVES 20 - 3

Each site is processed separately.
There are no buckets 1 and 2.
Stack buckets sequentially, #20 (largest holes) on the top.
Sieve animals.

Remember: if you had to use Sieve # 5 to clean the sand out of the sample, you are not going to have crab samples from Sieves # 3 and 4.

Keep approximate track of the total number in each sieve size on the Sand Crab Tally Sheet-Preserved.
(Line out #3 & 4 on the tally sheet if you used a #5 to clean out the sand.)
Animals from all buckets will be preserved separately by bucket in glass jars and returned to the laboratory. Use labels prepared in lab. Return unused labels to the lab.
Prepare the 10% Formalin solution at your processing area by pouring half of the Formalin (in the one gallon carboy) into the 5 gallon carboy then filling the 5 gallon carboy with sea water.

9) PROCESS CATEGORY 3 ANIMALS THROUGH SIEVES 15, 11 and 8

Do not keep animals smaller than 8.
Tally the animals in sieves 15, 11 and 8 separately. Within each size category tally females with bright orange eggs and females with no eggs separately. (We do not want females with burnt orange or grey eggs.) Keep track of your tally on the Sand Crab Tally Sheet - Live sheet.
If it looks like a little more shovelling from a site will get you the 20 females with (or without) eggs in a size category from a patch area - go for them.

YOU DO NOT PROCESS CATEGORY 2 ANIMALS.

10) Return to truck with the samples first.
Fill a "live" carboy with seawater to be brought back to lab.
Rinse the gear to at least remove excess sand. If there is fresh water available, use it.
Stow the rest of the gear and come home.

KEEP THE LIVE ANIMALS AS FAR AWAY FROM THE PRESERVED SAMPLES AND THE PRESERVATIVE AS POSSIBLE.

Do not put the live animals in water. Instead, put some damp sand in each laundry bag and put the laundry bags in a sieve.

10) Record the time you return to MEC on Page 1 of the field sheet under "Survey duration".

APPENDIX C

LABORATORY PROTOCOLS

C.1 Sex/Fecundity Analyses

1. In the wet laboratory, transfer sand crab sled or shovel sample to screen to pour off formalin. If the sample has more than 150 crabs, split the sample using the large Folsom splitter.
2. Rinse sand crabs with tap water.
3. Transfer crabs to sorting dish.
4. Return to dry laboratory.
5. Examine crabs for sex, fecundity and egg condition using the disecting microscope or, for very large animals, the illuminating magnifier. Females may be recognized by the presence of a gonopore on the third legs, pleopods, and egg masses. Males are recognized by absence of above features. If a female has an egg mass, classifiy the female by the color and condition of the egg mass as follows: egg mass with bright orange eggs, egg mass with burnt orange eggs (two eyespots should be visible through egg capsule), egg mass with gray eggs, egg mass with empty egg cases, and egg mass with a few bright or burnt orange eggs but mainly with spent egg cases.
6. Fill in the laboratory raw data sheet.
7. Return crabs to storage jar and reformalize. Label top of jar with survey ID number, beach location, tow ID, sieve size and number of jars for this sample.

C.2 Parasites, Egg Mass Volume, Egg Diameter, and Gut Content Analyses

1. Randomly select females with bright orange eggs from a sample

in the following manner:

a. when more than 10 sieves have females with bright orange eggs, use a random numbers table to decide which 10 sieves provide the randomly selected females;

b. when exactly 10 sieves have females with bright orange eggs, randomly select one such female from each of the sieves;

c. when fewer than 10 sieves have females with bright orange eggs, randomly select an equal number of females from the array available; if it is not possible to select an equal number of females with bright orange eggs from each sieve, then randomly select which sieves will provide more or fewer animals;

d. when less than 10 females with bright orange eggs are available from all the sieves of a sled sample from a patch, randomly select females with bright orange eggs, when available, from the shovel samples.

2. Examine legs and egg mass area for parasites. Record observations under the following categories: 1 = parasites on abdominal legs; 2 = parasites on egg mass. Note type of parasites: a = protozoan; b = nematode; c = crustacean.
3. Remove egg mass.
4. Place female in jar labeled on lid with survey, beach, tow, sieve size, animal number. Add formalin.
5. Place egg mass in vial labeled on lid with survey, beach, tow, sieve size, animal number. Add formalin.
6. Determine volume displaced by egg mass. Pour egg mass from

vial onto screen, blot excess fluid from beneath the screeen, place egg mass into pre-filled calibrated vial, and remove displaced water with micropipette. Record the amount of water removed from the vial with a micropipette to the nearest 0.0005 ml. Record observations for each egg mass by sieve size and animal number.

7. Randomly select two egg masses from each patch/beach. Place portion of egg mass or loose eggs in a depression slide with water. Measure the diameter of 10 eggs, including egg membranes to nearest .005 mm using an ocular micrometer on a compound microscope. Record observations for each egg mass by sieve size and animal number.
8. Note color and pattern of color (i.e., uniform or mottled) for female sand crab. Record observations for each animal by sieve size and animal number.
9. Dissect fore- and hindgut from sand crab. Place on separate slides and scan with dissecting scope. Determine % fullness of guts (i.e., 0, $< 50\%$, $> 50\%$). Record observations for each animal by sieve size and animal number.
10. If gut almost empty, then wash contents with water onto slide and examine with compound microscope. If gut $> 50\%$ full, then thin contents with water and examine a subsample of the contents with the compound microscope. Record the percent contribution (i.e., 0, $< 50\%$, $> 50\%$) of the constituents (e.g ., sand, phytoplankton, zooplankton, detritus) of the fore- and hindgut.
11. Return dissected female crabs to their jars and reformalize.

C.3 Sediment Grain Size Analysis

A. Equipment - for determination of median grain size, silt/clay fraction, coarse fraction, skewness, and dispersion of sediments.

1. 8 oz. numbered plastic deflocculent bottles
2. 0.025N (38.25g per 15 liters deionized water) sodium hexametaphate (deflocculent)
3. 63 micron sieve
4. Stainless steel evaporating dish
5. Preweighed and numbered Coors dishes
6. Numbered 1000ml graduated cylinders
7. Watchglasses to cover graduated cylinders
8. 3" sections of pipe (used to weigh down 1000 ml graduated cylinders in water bath)
9. Plunging device (for agitating silt and clay solution)
10. 25 ml Lowy Automatic Pipette with markings at 7,8,10 and 20 cm
11. Preweighed and numbered 50ml beakers
12. 24° C water bath
13. Drying Oven ($110^{\circ} + 20^{\circ}$ C)
14. Eleven U.S.A. Standard Testing Sieves (A.S.T.M. E-11 specification) and bottom catch plate; Sieve numbers 10, 14, 18, 25, 35, 45, 60, 80, 120, 170, 230
15. Sieve shaker
16. Sartorius milligram balance

B. Initial Treatment

1. Thaw frozen samples.
2. Mix wet sample thoroughly in its container or transfer to a suitable large container to mix. Immediately (while still homogeneous) weigh 30-50 gm wet sediment into 8 oz. deflocculent bottles.
3. Record on data sheet Sample ID, analyzed by: date, sieve size for sand/silt-clay separation, deflocculent bottle number, sample color and sample composition.
4. To sediment in 8 oz. bottles, add 150 ml of sodium hexametaphosphate (deflocculent), shake well, and let stand 8 hours.

C. Separate fine particles (silt & clay) from sand

1. Place 63 micron screen in evaporating dish in order to catch all wash water.
2. Shake sample, let settle 10-15 seconds and decant suspended fine particles through sieve into a collecting pan. Add deionized water to sample remaining in the bottle.
3. If necessary, wash fine particles through sieve with deionized water into a collecting pan.
4. Repeat steps 5 and 6 until most fine particles removed.
5. Transfer remaining sample from bottle to sieve using squirt bottle with deionized water.
6. Using light finger pressure and squirt bottle, wash remaining fine particles through sieve.
7. Periodically wash the bottom of the sieve to remove adhering particles.

8. Wash sand remaining in the sieve with deionized water to remove excess sodium hexametaphosphate and salts.
9. Carefully concentrate sand against bottom lip of sieve with squirt bottle. Scrape and wash sand into numbered Coors dish and record sand dish number on data sheet.

D. Prepare Sand

1. Let sand settle and decant most overlying water (not particles).
2. Dry sand in over at 70° C.

E. Prepare Silt & Clay

1. Transfer silt-clay solution from collecting pan to a numbered 1000 ml graduated cylinder with a funnel and fill to 1000 ml with deionized water.
2. Record cylinder number and silt/clay beaker number on data sheet.
3. Agitate silt-clay solution with plunger for one minute.
4. 15 seconds after stopping agitation, take a 25 ml aliquot from a depth of 20 cm with pipette.
5. Cover the top of the cylinder with a watchglass and set the cylinder aside until such time as it is decided that the silt/clay fraction of the sample is no longer needed.
6. Transfer 25 ml aliquot to a 50 ml numbered beaker.
7. Rinse pipette before reuse.
8. Dry silt-clay solution in oven.
9. Allow silt-clay and sand fractions to come to room

temperature in dessicators and weigh on balance.

10. Determine percent sand and percent silt and clay contained in the total sample weight.

F. Sieve Analysis for Sand

1. Transfer sand from Coors dish to top sieve in sieve stack.
2. Gently shake sieve stack and break-up aggregates on top 1-3 sieves.
3. Place sieve stack in sieve shaker and shake for 15 minutes.
4. Starting with top sieve, invert each sieve on a large piece of paper and rap sieve firmly on table top to remove all sand.
5. Examine particles on successive sieves and the bottom catch plate and make notes in comments section of data sheet if shell, aggregates, twigs, metal, etc., are present.
6. Initially tare out the empty weight of plastic weighing dish (dish wt. to = 0.001 gm).
7. Transfer sand to tare plastic dish on balance; record cumulative weight with each successive sieve.
8. The difference in the successive cumulative weights is the contribution of each phi size.

C.4 Sediment Moisture Content and Salinity Analyses

A. Moisture Content

1. Invert moisture/salinity specimen cup for 60 seconds to redistribute any water that may have settled.

2. Using a cut-off syringe remove approximately 100 ml of sediment and place into a pre-weighed large Coors evaporating dish "A".
3. Weigh the fresh sediment and dish to the nearest .01 mg and record weight "B" using Sartorius electronic top loading balance. Readability + or - .01 g.
4. Dry the sample at 80° C for 8 hours.
5. Remove the sample to cool for a few minutes.
6. Reweigh dry sediments and record weight "C".
7. Calculate moisture content:

   fresh sediment - dry sediment/fresh sediment X 100 or

   A - B - C/ A - B X 100

B. Sediment Salinity Determination

1. Using distilled water:
2. Rehydrate dried sediments from moisture content determinations with twice the amount of water evaporated from the sediment (A - B - C = amount of evaporated water; 1 mg of water = 1 ml).
3. Mix the sediments for at least 60 seconds to dissolve salts.
4. Decant off the fluid into a small beaker.
5. Measure and record the TOC, salinity (%), and conductivity with a Yellow Springs Instrument model 3311 salinometer.
6. Compare measured sediment salinities to the calibration curve to determine the salinity of the interstitial water. The calibration curve is developed by comparing salinities and conductivities measured with the above method to

salinities and conductivities of interstitial water collected in the field.

C.5 Sediment Total Organic Carbon Analyses

A. Equipment: The MEC chemistry lab uses an Oceanography International model 524-B total organic carbon system for the determination of total organic carbon in sediments. This system utilizes a Horiba model PIR 2000 infarared gas analyzer and an ampule sealing unit manufactured by Oceanography International. The method used is that recommeded by the manufacturers with modifications.

B. Calibration Procedure

1. Dry Potassium Biphthalate at 120° C for 2 hours and allow to cool in a dessicator.
2. Weigh out an appropriate amount to micrograms and make up a stock solution (.15939 g/25 ml = 3μgC/μ 1). This solution should be used the same day it is prepared.
3. Amounts of the standard solution covering the range of carbon expected in the samples are dispensed into precombusted ampules with a 10-100 microliter Eppendorf pipette.
4. 0.2 ml of a 10% v/v Phosphoric acid solution is added to the ampules containing the standards and added to empty ampules for reagent blank determinations.
5. Add 2.0 ml water to the ampules (washing down the sides).

6. The following is done in groups of eight ampules:
   a. Add 0.2 g Potassium Persulfate.
   b. Add 2.0 ml water (washing the granules Persulfate down the sides of the ampule).
   c. Purge for 8 min. with O_2 and seal.
7. The standards and blanks are oxidized with a batch of samples and used to calibrate only that beach.

C. Sample Procedure

1. Dry 20-50 g subsample at 70° C for at least 12 hours.
2. Grind samples to a homogeneous powder.
3. Dry powder for 8 hours then cool in a dessicator.
4. Weigh precombusted ampules to the nearest 0.00001 g.
5. Add sample (5-50 mg) to the preweighed ampules.
6. Reweigh the ampules containing the samples.
7. Add 1 ml Phosphoric acid (10% v/v) each to the sample ampules and the empty reagent blank ampules.
8. Add 2.0 ml of water to samples and blanks.
9. Allow to stand for at least 30 minutes.
10. The following is done in groups of eight samples:
    a. Add 0.2 g Potassium Persulfate to each sample.
    b. Add 2.0 ml water to wash down the sides of the ampule.
    c. Purge for 8 minutes and seal.
11. Convert organic material to CO_2 by placing the sealed ampules in an 130° C autoclave for at least four hours.
12. Measure carbon content from the amount (moles) of CO_2 liberated.

C.6 Wave Wash Seston Weight and Organic Content Analyses

A. Equipment for determining the amount of seston in a sample of water and its carbon content. The proceedure follows standard analysis procedures as described in Strickland and Parsons with modifications.

1. Numbered petri dishes
2. 2.5 cm GFC filters
3. 2.5 cm filter holder apparatus
4. Flat-bladed forceps
5. Squeeze bottle with distilled water
6. Mettler electronic micronbalance to 0.00001 gm
7. Drying oven
8. Muffle furnace

B. Procedure

1. Combust 2.5 cm GFC filters at 450-500° C for 4 hours to burn off organic contaminants.
2. Soak filters in distilled water for 5 minutes to remove inorganic binders.
3. Dry filters on aluminum foil (shiny side) for 1 hour at 70° C and cool in a dessicator.
4. Weigh the filter to nearest 0.00001 gm and place in a numbered petri dish.
5. Filter the sample through the preweighed filter.
6. Rinse the funnel and filter with 2-5 ml of distilled water. Disconnect from the vacuum source between rinses to allow

the water to cover the filter for a few seconds before reapplying suction to remove excess water.

7. Dry the filter at 70° C for 1 hour and cool in a dessicator (filter can be dried in the petri dish).
8. Weigh the dried filter containing sample material to the nearest 0.00001 gm. The difference in weights from step 8 and step 4 is the seston.
9. Place filter on a combusted metal rack in a muffle furnace set at 450-500 ° C for 24 hours.
10. Cool filter in a dessicator and weigh to the nearest 0.00001 gm. The difference from step 10 and step 8 is the amount of carbon.
11. Filter blanks should be handled as described above omitting step 5 (filtering the sample). Blanks should be run with each batch of filters.

C.7 Chlorophyll-a/Phaeophytin Analyses

A. Water Samples

1. Screen water samples through 380μ NITEX to remove large planktonic organisms.
2. Water samples in 125 ml plastic screw-cap bottles, kept cold and in dark
3. Filter samples (50 ml for inshore samples) onto Millipore AA filters.
4. Place filter in scintillation vial, covered with 100% acetone (90% acetone used in August survey) (several ml),

cap, shake, place in freezer to extract in dark.

5. After extraction, filter and acetone transfer to grinding tube, ground with additional 90% acetone, slurry filter through glass fiber filter to remove debris.
6. Bring volume of cleared extract to 10 ml.
7. Read fluorescence al extract on Turner III.
8. Acidify sample (2 drops 10% HCl) and read again.
9. Calculate chlorophyll and phaeopigment concentrations.

B. Sand Samples

1. Collect samples by pushing a plastic syringe (with the end cut off and bevelled) into sand to a set depth, extruded sample into a scintillation vial or other container with stopper, kept cold and in the dark.
2. Add 100% acetone to cover sand, cap.
3. Shake vigorously, place in freezer to extract, shake several times during extraction.
4. Separate sand from extract by screening.
5. Rinse sand several times with small volume of 90% acetone.
6. Bring volume to 10 ml with 90% acetone extract and acidified extract.
7. Read Turner III as for water samples.
8. Calculate pigment concentrations on a per-area basis.

C. Calculations

1. µg chlorophyll-a/liter for wave wash samples =

   $C\ (R_B - R_A)\ F_D/$ volume filtered;

μg chlorphyll-a/cm^2 for sand samples =

$C\ (R_B - R_A)\ F_D /$ surface area sand (cm^2)

where R_B = fluorescence before acidification and

R_A = fluorescence after acidification.

2. μg phaeophytin/liter for wave wash samples =

$C\ (\tau R_A - R_B)\ F_D /$ volume filtered;

μg phaeophytin/cm^2 for sand samples =

$C\ (\tau R_A - R_B)\ F_D /$ surface area sand (cm^2)

where C = instrument specific calibration constant and

τ = "acidification ratio" (also instrument specific) and

F_D = silt factor

APPENDIX D

DATA ANALYSES

APPENDIX D

This appendix documents the analytical techniques that were used in the evaluation of three of the examined measures of sand crab populations: weighted mean abundance, size modes, and clutch size. Methods used in multiple regression analysis are also presented.

D.1 Weighted Mean Abundance

This section documents the equations used to calculate the mean abundance per beach by stratified random sampling and those used to test for a beach effect. The equations for beach abundance, beach variance and the degrees of freedom per beach are from Cochran (1963) and are noted by equation number and page.

The steps involved in the computations are:

1. Sum the number of crabs per tow over sieve sizes 5-20.

2. Log transform (x+1) the number of crabs per tow.

3. Determine the mean, variance and number of tows in each stratum. There are two strata per beach on patchy beaches. All patches form one stratum; all interpatches the second. Banded beaches (where sand crabs align themselves longshore with virtually no break) form only one stratum.

4. Compute the number of possible 1/4 m wide sled tows in the length of beach covered by each stratum.

5. Compute the number of possible 1/4 m wide sled tows on the habitable (< 80% cobble) portions of each beach.

6. Perform steps 6a through 6c for each beach.

6a. Calculating the mean abundance per (eq. 5.1, p.89):

$$\bar{y}_e = \frac{\sum_{h=1}^{2} N_h \bar{y}_h}{N}$$

where $\bar{y}_e$ = the mean abundance per beach

N_h = the number of possible sled tows per stratum

y_h = the mean number of crabs per tow in stratum h

$N = N_1 + N_2$

6b. Calculate the variance per beach (Eq. 5.11, p.93):

$$s^2(\bar{y}_e) = \frac{1}{N^2}\left(\sum_{h=1}^{2} N_h(N_h - n_h)\frac{s_h^2}{n_h}\right)$$

where $s^2(\bar{y}_e)$ = the variance of the mean abundance per beach

n_h = the actual number of sled tows in stratum h

s_h^2 = the variance of the number of crabs per tow in stratum h

6c. Calculate the degrees of freedom per beach (Eq. 5.15, p.95):

$$n_e = \frac{(\Sigma\, g_h s_h^2)}{\Sigma\, \frac{g_h^2 s_h^4}{n_h - 1}} \quad ; \quad g_h = \frac{N_h(N_h - n_h)}{n_h}$$

where n_e = the degrees of freedom per beach

7. Calculate the mean abundance per survey from the abundance per beach:

$$\bar{\bar{y}}_s = \frac{\sum_{e=1}^{M} \bar{y}_e}{M}$$

where M = the number of beaches

8. Calculate the between beach mean square:

$$\text{B.B. mean square} = \frac{\sum_{e=1}^{M}(n_e+1) * (\bar{y}_e - \bar{\bar{y}}_s)^2}{M - 1}$$

9. Calculate the within beach mean square

$$\text{W.B. mean square} = \frac{\sum_{e=1}^{M} s^2(\bar{y}_e)}{M}$$

10. Calculate the within beach degrees of freedom:

$WBdf = \Sigma n_e$

11. Calculate the F value for the BBdf and WBdf:

$$F \text{ value} = \frac{\text{B.B. mean square}}{\text{W.B. mean square}}$$

An example of the calculations for the 45 km S beach on the July survey follows, step by step as numbered above.

1. Number of crabs per tow:

	TOW					
	A	B	C	D	E	F
Patch or Interpatch	P	I	P	I	P	P
Sieve						
20	0	0	0	0	0	0
19	0	0	0	0	0	0
18	0	0	0	1	0	0
17	1	0	1	0	3	0
16	1	0	1	0	2	0
15	2	0	1	0	4	0
14	1	0	2	0	9	1
13	4	0	3	0	15	6
12	9	1	13	1	55	24
11	71	0	90	1	129	126
10	88	5	73	2	88	111
9	32	7	68	0	27	77
8	16	2	33	2	7	24
7	36	7	34	4	12	28
6	33	35	180	32	81	125
5	93	62	219	15	58	224
Total sand crabs/tow	387	119	718	58	490	746

2. LOG (crabs/tow +1): 2.59 2.08 2.86 1.77 2.96 2.87

3. Strata means, variances and sizes:

	Patch	Interpatch
$\bar{y}_h$ = LOG MEAN	2.75	1.93
s_h^2 = VARIANCE	0.018	0.048
n_h = TOWS	4	2
STRATUM SIZE	271 m	175.5 m

4. Possible number of 0.25 m wide sled tows/stratum:
N_h = 1084 702

5. Possible number of 0.25 m wide sled tows/habitable beach:
N = 1084 + 702 = 1786

6a. Mean abundance per beach:

$$\bar{y}_{45km\ S} = (2.75 * (1084/1786)) + (1.93 * (702/1786))$$
$$= 2.43 \text{ sand crabs/tow (log mean)}$$

6b. Variance per beach:

$$s^2_{45km\ S} = \frac{((1084) * (1084 - 4) * (0.018 / 4))}{(1786 * 1786)} + \frac{((702) * (702 - 2) * (0.048 / 2))}{(1786 * 1786)}$$
$$= 0.005$$

6c. Degrees of freedom per beach:

$$g_{patch} = \frac{1084 * (1084 - 4)}{4} = 292680$$

$$g_{interpatch} = \frac{702 * (702 - 2)}{2} = 245700$$

$$n_{45\ km\ S} = \frac{((292680 * .0017) + (245700 * .0037))^2}{((292680^2 * .0017^2)/(4-1)) + ((245700^2 * .0037^2)/(2-1))}$$
$$= 2.2$$

Thus the beach at 45 km S has a mean number of sand crabs per tow of 2.43, a variance of 0.005 and degrees of freedom of 2.2. These values calculated in the same manner for all other beaches (July survey) are shown below.

BEACH	DENSITY	VARIANCE	DEGREES OF FREEDOM
115 km N	2.79	0.009	5.0
100 km N	2.37	0.037	5.0
79 km N	0.13	0.000	3.0
15.5 km N	0.52	0.037	5.0
12 km N	2.14	0.017	5.0
6.5 km N	2.46	0.039	5.0
1.5 km N	0.60	0.071	4.0
0.4 km N	1.79	0.021	5.0
1.5 km S	1.66	0.072	1.2
6.5 km S	2.45	0.050	5.0
12 km S	1.69	0.040	1.0
18 km S	1.20	0.026	1.0
25 km S	2.82	0.004	5.0
45 km S	2.43	0.005	2.2
65 km S	0.81	0.252	1.0
Σ	25.87	0.681	53.4
M	15	15	

7. Mean abundance per survey:

$$\bar{y}_s = 25.87 / 15 = 1.72$$

8. Between beach mean square:

BB mean square = 3.80

9. Within beach mean square:

WB mean square = 0.681 / 15 = 0.045

D.2 Size Modes

The mean of the maximum size mode of males and mean of the minimum size mode of females with eggs were determined using a method from Wenner (1982). The cumulative percent of females or males were plotted on normal probability paper against sieve size for each sled tow with at least five female or male sand crabs. (Figure D-1). Size modes were determined by drawing straight lines to best fit the data points (Cassie, 1954). This method is subjective; however, the subjectivity is lessened by taking into account natural breaks in the data, such as any sharp increases in the slope of the overall curve, and the horizontal or vertical trend between points. The minimum size mode of females with eggs was considered to be composed of all data points for the smallest sieve sizes connected by a straight line. Similarly, the maximum size mode of males was considered to be composed of all data points for the larger sieve sizes connected by a straight line.

Once these modes were identified, a two-step process was applied in order to determine their means. The mean of the minimum size mode of females with eggs was determined by first expanding the scale of the mode to 100% then identifying the median value on this expanded scale. The scale expansion was accomplished by first determining the midpoint between the highest cumulative percentage point in the minimum mode and the lowest point in the next larger mode. This midpoint value was set at 100% and the scale of the minimum mode then expanded by multiplying each value by the factor: 100%/midpoint%.

The scale expansion for determining the mean maximum mode of males was accomplished by determining the midpoint between the lowest cumulative percentage point in the maximum mode and the highest point in the next lower mode, then applying the following equation to each value contained in the maximum mode:

Expanded cumulative % =

(original cumulative % - midpoint %) (100%/(100% - midpoint %))

The 50% midpoint of the expanded scales were considered the mean size of the modes.

D.3 Clutch Size

Clutch size was estimated from the measured displaced volume of the egg mass and diameter of eggs using the following equation:

$$N = V/M$$

where:

N = number of eggs/egg mass, or clutch size,

V = volume of egg mass (1 ml = 1000 mm^3), and

M = mean volume of eggs in the egg mass (mm^3).

The clutch size of egg masses from females with orange eggs was compared among beach sites. Before this could be done, the relationships between size of the females and the diameter of their eggs and the volume of their egg masses were determined. The mean diameter of 10 eggs per examined egg mass was plotted against size (sieve size) of the female sand crabs. The diameter of the eggs and the size of the animal was unrelated (Figure D-2). In contrast a positive relationship was found between the volume of the egg masses and size of the female sand crabs. Clutch size was log transformed prior to statistical analysis to help linearize the relationship between animal size and clutch size (Figure D-3).

The mean volume of eggs in an egg mass was computed from the mean diameter of all measured eggs based on the assumption that eggs are spherical (after Efford, 1969). The following equation derived from the equation for a sphere was used:

$$\text{mean volume of eggs in the egg mass} = 4/3\pi r^3 = 0.5236\ d^3$$

where d = diameter (mm).

Differences among beach sites were statistically compared using Student-Newman-Keuls (SNK) tests on least square means (LSMEANS) after the Analysis of Covariance (ANCOVA) demonstrated that the relationship (slope) between animal size and clutch size was not different ($p > 0.05$) among beach site groupings (i.e., near, north, and south of SONGS). It should be noted that SNK was performed on the LSMEANS, which are estimated by the regression using the covariate, with the understanding that groups formed at an alpha level was unknown but thought to be close to 0.05.

During a quality control examination of all egg masses of bright-orange eggs that were included in the analysis of clutch size, it was observed that egg masses sometimes differed in the relative proportion of spent egg cases among bright-orange eggs. These spent egg cases were empty and therefore were of far less volume than the eggs. These observations were considered of potential importance, therefore, each egg mass was given a qualitative designation according to its relative amount of spent egg cases. The designations were as follows: no spent egg cases, very few spent egg cases (eggs far out-numbered spent egg cases), few spent egg cases (spent egg cases apparent but not as abundant as eggs), and several spent egg cases (spent egg cases as numerous as eggs). Results of the "laboratory observation" showed that of the examined egg masses, 38% of them from the "north" sites (115 km N and 100 km N) and 64% of them from the "near" sites (12 km N to 12 km S) had spent egg cases. In contrast, only 2% of the examined egg masses from the "south" sites (18 km S to 65 km S) had spent egg cases. A contingency analysis by Chi-square (Zar, 1974: p. 59) on the three beach site groups (North, Near, and South) versus the spent condition (several plus few*, very few, none) indicated that the occurrence of spent egg cases in clutches was not independent of beach site group ($X^2 = 234.77$, $p < .01$).

To control for some of the bias associated with comparing egg masses with different amounts of spent egg cases, egg masses with greater than 50% egg cases in spent condition were not included in the clutch size analyses. Even with this restriction, 19% of the egg masses from the "north" sites and 57% of the egg masses from the "near" sites had some spent egg cases.

D.4 Multiple Regression

Attributes of sand crab populations that exhibited a locality effect relative to SONGS were subjected to multiple regression analysis. A backward elimination technique (STEPWISE procedure; SAS,

* The groups "several" and "few" had to be pooled to meet restrictions of the analysis.

1982) was used to reduce the number of environmental variables included in the model. The full set of 18-19 environmental variables was included in the first step (Step 0) of the backwards-elimination procedure if there were 21 or more observations for the dependent variable. A subset of the full array of environmental variables was selected for inclusion in the backward procedure when there were less than 20 observations for the dependent variable. The subset was selected to include variables from each category of environmental measurements available; ie., sediment characteristics, temperature, and potential food. The subset never included more than (n-2) independent variables, where n is the number of observations of the biological variable.

Environmental variables were ultimately included or excluded during the stepwise process on the basis of their contribution to the regression relationship. The SAS procedure stopped eliminating variables when the significance ($P > F$) of each of the retained independent variables was less than .10. As the less correlated variables are eliminated in the backward procedure, the R^2 (square of the multiple correlation coefficient) decreases slightly but the adjusted R^2 increases to a maximum value; if additional environmental variables are eliminated after the maximum adjusted R^2 is reached, the loss of correlation causes the adjusted R^2 to decrease. The adjusted R^2 depends on the number of independent variables as well as the correlations. The maximum value of the adjusted R^2 was used to define the "optimum" regression result. The adjusted R^2 (multiple correlation coefficient) as well as the number of environmental variables were examined to determine the most "parsimonious" result.

In all cases where the last step of the SAS procedure coincided with the maximum adjusted R^2, we accepted it as the most "optimal" and "parsimonious" result. Nine of the 14 regressions that are presented herein stopped by the rule of maximum adjusted R^2. If the backward variable-elimination procedure had not stopped at the maximum adjusted R^2 (= "optimum" result), the elimination steps after the optimum result were examined. A more parsimonious step (i.e., fewer independent variables) was selected to ease interpretation if the adjusted R^2 was reduced less than .05 from that of the "optimum" result (eg., adjusted from R^2 = .79 to R^2 = .74). In the case where three closely allied biological variables were analyzed (i.e., % of all females, % females > 10 mm to 13 mm, and % females > 13 mm), the adjusted R^2 of the three analyses were consulted to arrive at a parsimonious interpretation.

The "parsimonious" result was further evaluated to asses the fit of the model. Cook's D statistics, which is a measure of influence (Cook, 1977, 1979; SAS, 1982), were examined for each beach site to determine whether there were observations having undue influence on the regression result. A high Cook's D for a particular beach site indicates either that the relationship between the environmental and biological variables is different for this beach, or that the environmental variables are outliers, or both.

If there was a beach site(s) with a significant (as compared to F-values; Draper and Smith, 1981, p. 170) Cook's D, then the observations for that beach site were deleted and the regression was re-run and the results with and without the influential observations were compared. Cabrillo Beach had significant Cook's D in the preliminary regression runs, for it had extreme values for several environmental variables (see section 3.1), which exhibited aberrent relationships with the biological measures. To improve the evaluation of relationships between sand crabs and their habitats at other beach sites, Cabrillo

Beach was excluded from all final regression analyses. Other beach sites with significant Cook's D values were determined for each regression of the different biological variables on a case by case basis. To provide comparisons, both the parsimonious regression results with all beach sites except Cabrillo Beach (regardless of Cook's D values) and the regression results with only beach sites with non-significant Cook's D values are presented in the main body of this report. This occurred in only one case (see Table 3-9).

To determine whether another regression technique might produce disparate models, results using a forward selection procedure in multiple regressions were compared to those of the backward elimination procedure. Application of both procudures does not necessarily guarantee exactly the same solutions. However, if results of both techniques are similar, then this serves to increase confidence in the multiple regression results. The two procedures agreed fairly well in choice of environmental variables especially when we looked at outputs from each with equal numbers of independent variables. Out of 14 regressions, 8 had changes in none or one independent variable and three had changes in two variables (Table D-1). Thus the results of the backward elimination technique were considered reasonable.

Two additional analyses were performed using mutiple regression. The first investigated the influence of sites near SONGS on the regression equations. Using the independent variables selected in the original regression, new regressions were run without information from two of the three beach sites within 1.5 km of SONGS (sites 1.5 N, 0.4 N, and 1.5 S) to determine how well the environmental variables at other sites predicted the biology near SONGS. The Cook's D statistic, which is a measure of influence, was compared between the near-SONGS site and the other sites on each run. If the Cook's D was higher than expected (as determined from the F-statistic; Draper and Smith, 1981, p. 170) at the beach site near SONGS, then this indicated that the multiple regression model poorly predicted the biolgical characteristic near SONGS because the site in question was having an undue influence on (i.e., forcing) the regression model. The results are presented in Table 3-10 of the main body of this report.

The second set was run to further investigate if there were identifiable trends in the biolgical data within 15.5 km of SONGS. Distance from SONGS was included as an independent variable to examine its contribution as a predictor of biology. The forward selection procedure was used in this set of multiple regressions because of the reduced number of beach sites (resulting in fewer observations) and the added independent variable. If distance from SONGS outperformed other environmental variables and was included in the final regression equation, it would indicate that there was a trend in biology with distance from SONGS and noted in the main text.

Multiple regression analyses were performed on untransformed data. Plots of the data and regression residuals were examined to make this decision. In addition, for those plots that indicated a non-linear relationship between the population measure and an environmental variable, the relationships were reanalyzed using transformations of environmental variables; the reanalysis did not substantially improve the relationship. The shape of the plot determined the type of transformation tried (Daniel and Wood, 1971).

Included at the end of this Appendix are support packages for each regression model that include the following information: the variables included in the first step (step 0) of the backward elimination procedure, variables retained in the final regression result, parameter estimates (= regression coefficients, slopes) for the final regression result, standard errors of the parameter estimates, ANOVA tables for the final regressions including the probability that the R^2 value would occur by chance (probability of significance), Cook's D values for each beach site in the final regression result, the actual and predicted values for each beach site (beach site = ID variable) in the final regression result, residual values, and plots of the residuals versus distance from SONGS.

Table D-1. Comparison of variables selected using backward elimination and forward selection procedures of multiple regression.

Variable	Backward Elimination Independent Variables	Forward Selection Independent Variables
weighted mean abundance of sand crabs of all sizes in June (recruitment/colonization)	seston, sediment chlorophyll, sediment phaeophytin, grain size dispersion, temperature, weighted cobble coverage on sand	seston, sediment chlorophyll, sediment phaeophytin, grain size dispersion, temperature, cobble on sand
weighted mean abundance of sand crabs 6-9 mm in June, July, and August (recruitment)	sediment chlorophyll, sediment carbon, % coarse sand, beach slope, cobble on sand, temperature	sediment chlorophyll, sediment carbon, % coarse sand, beach slope, cobble on sand, temperature
% of all females with eggs or spent egg cases in July and August	water chlorophyll, temperature, seston, sediment phaeophytin, grain size dispersion	water chlorophyll, temperature, cobble in water, moisture, water phaeophytin
% of females > 13 mm with eggs or spent egg cases in July and August	water chlorophyll, grain size dispersion, beach slope, weighted cobble coverage on sand, cobble in water	water chlorophyll, grain size dispersion, beach slope, weighted cobble coverage on sand, moisture
% of females > 10 mm and < 13 mm with eggs or spent egg cases in July and August	water chlorophyll, % coarse sand, median grain size, grain size skewness, temperature, weighted cobble coverage on sand	water chlorophyll, water phaeophytin, sediment phaeophytin, sediment carbon, moisture, grain size dispersion
% of all females with eggs in July and August	seston, sediment chlorophyll, sediment phaeophytin, temperature, grain size dispersion	seston, sediment chlorophyll, sediment phaeophytin, temperature, % silt/clay
% of females > 13 mm with eggs in July and August	seston, % silt/clay, grain size dispersion, temperature, sediment phaeophytin	seston, % silt/clay, grain size dispersion, temperature, beach slope
% of females > 10 mm and < 13 mm with eggs in July and August	sediment chlorophyll, sediment phaeophytin, water chlorophyll, temperature, % silt/clay	sediment chlorophyll, sediment phaeophytin, water chlorophyll, temperature, moisture
% of all females with spent egg cases in August	July water chlorophyll, sediment carbon, cobble on sand, weighted cobble coverage on sand, July water phaeophytin, median grain size	July water chlorophyll, sediment carbon, cobble on sand, weighted cobble coverage on sand, seston, sediment phaeophytin
% of females > 13 mm with spent egg cases in August	July water chlorophyll, July water phaeophytin, sediment phaeophytin, cobble on sand, sediment carbon	July water chlorophyll, July water phaeophytin, sediment phaeophytin, cobble on sand, grain size dispersion, median grain size
% of females > 10 mm and < 13 mm with spent egg cases in August	sediment carbon, median grain size, cobble on sand, July water chlorophyll, July water phaeophytin	sediment carbon, median grain size, cobble on sand, sediment phaeophytin, weighted cobble coverage on sand
clutch size in July and August	beach slope, median grain size, % silt/clay, moisture, cobble on sand	beach slope, sediment phaeophytin, temperature, water chlorophyll, cobble in water
% of spent females 8-13 mm producing another clutch of eggs in August	water phaeophytin, median grain size	water phaeophytin, median grain size, temperature
phosphoglucomutase activity in August	water phaeophytin, sediment phaeophytin, grain size dispersion	water phaeophytin, sediment phaeophytin, grain size dispersion

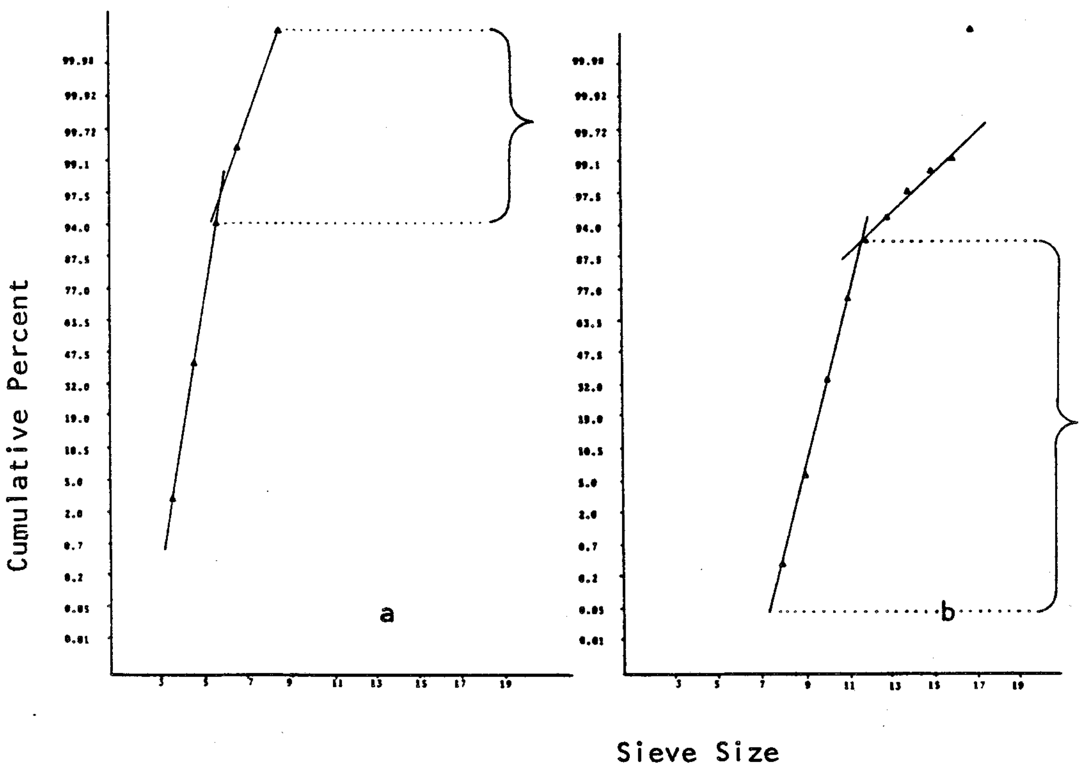


Figure D-1. The cumulative percentage of males (a) and females with eggs (b) plotted against sieve size. Straight lines indicate the size modes. Brackets indicate the maximum size mode of males (a) and minimum size mode of females with eggs (b). Data is from the July survey, site "E" at the beach site 45 km south of SONGS.

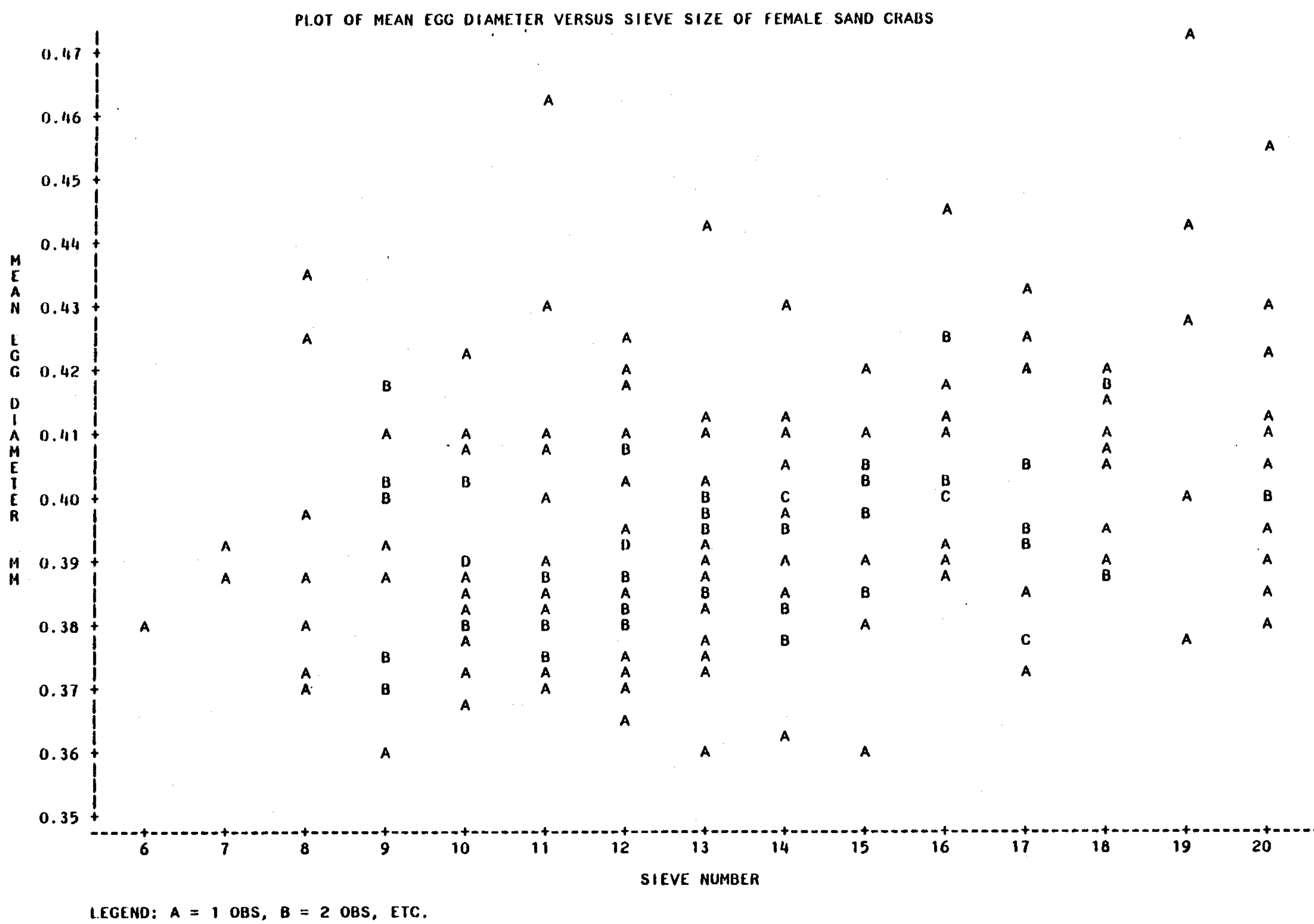
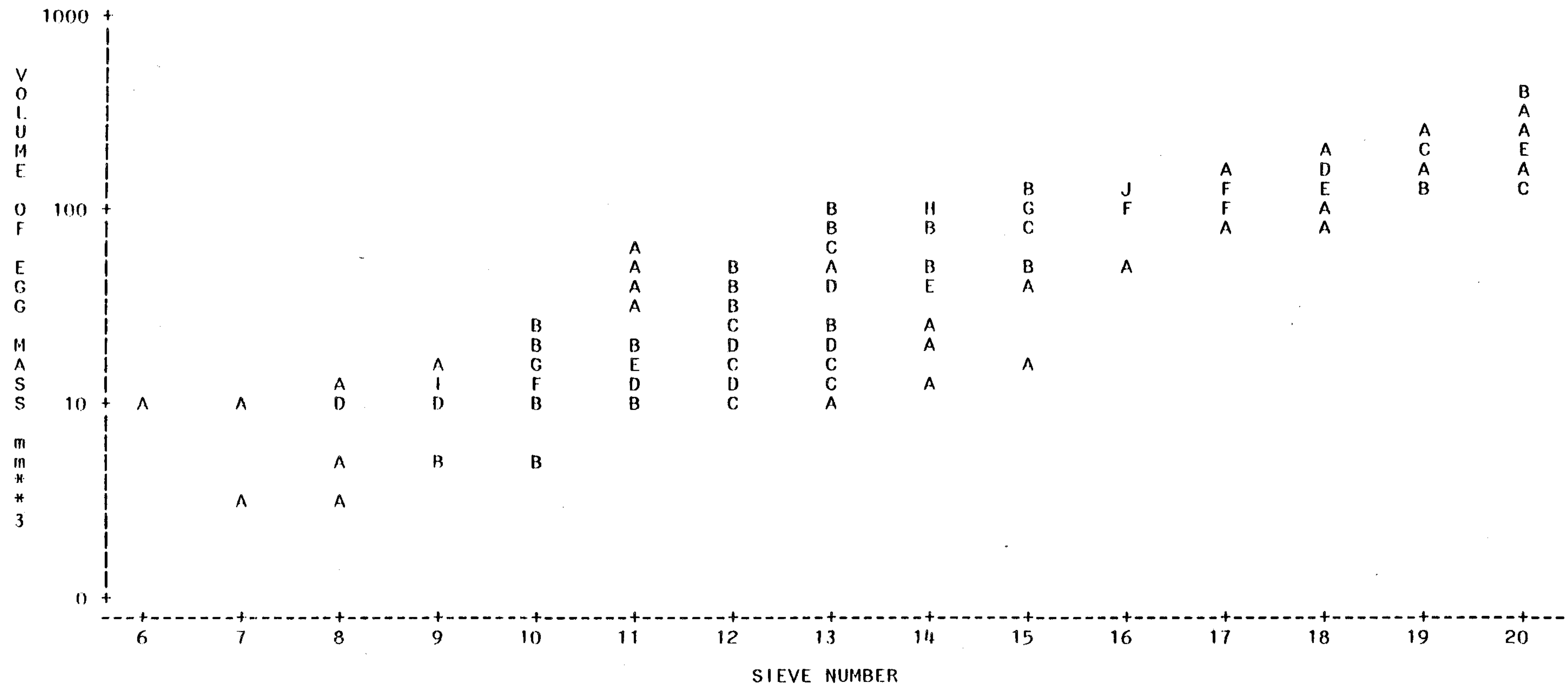


Figure D-2. Plot of the relationship between mean egg diameter of external eggs and size (sieve size) of female sand crabs.

PLOT OF VOLUME OF EGG MASS (LOG SCALE) VERSUS SIZE OF FEMALE SAND CRABS



LEGEND: A = 1 OBS,   B = 2 OBS, ETC.
NOTE: 15 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

Figure D-3. Relationship between volume of the egg mass and size (sieve size) of female sand crabs.

SUPPORT PACKAGES FOR MULTIPLE REGRESSION MODELS

STEPWISE REGRESSION, UNTRANSFORMED WEIGHTED MEAN ABUNDANCE, ALL SIZES JUNE ONLY

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE WEIGHTED MEAN ABUNDANCE

STEP 0 ALL VARIABLES ENTERED R SQUARE = 0.78208962 C(P) = 13.00000000 ADJ. R SQUARE = -1.8328

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	12	870480.92422740	72540.07701895	0.30	0.9076
ERROR	1	242538.47987901	242538.47987901		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	4013.23490288				
SESTON	-5.19487989	18.91263705	18299.00584845	0.08	0.8293
SEDCHLOR	-1424.94359613	2018.84833288	120828.28519694	0.50	0.6087
SEDPHAEO	4304.82782951	7064.75192795	90053.04270963	0.37	0.6516
WATCHLOR	-28.84696484	527.31552360	725.83814535	0.00	0.9652
WATPHAEO	267.76573113	1423.55114945	8581.13013745	0.04	0.8816
GSMEDIAN	207.54317253	841.12185159	14766.57318372	0.06	0.8460
GSDISP	-400.73918546	1725.20535770	13086.47491757	0.05	0.8547
MOISTURE	-1308.13697512	8506.57448685	5735.58441013	0.02	0.9029
COBSAND	5.42220362	166.94412421	255.85270917	0.00	0.9793
COBWAT	-1.15005932	6.40301895	7824.40929649	0.03	0.8869
TEMP	-183.76057378	339.89811551	70890.46323639	0.29	0.6845
WTCOBBLE	-16.86199314	81.94789326	10268.87533826	0.04	0.8708

STEP 1 VARIABLE COBSAND REMOVED R SQUARE = 0.78185975 C(P) = 11.00105490 ADJ. R SQUARE = -0.4179

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	11	870225.07151822	79111.37013802	0.65	0.7416
ERROR	2	242794.33258819	121397.16629409		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3834.18470981				
SESTON	-4.74327433	9.06991702	33201.55368341	0.27	0.6532
SEDCHLOR	-1403.86766875	1352.50221118	130793.12800945	1.08	0.4083
SEDPHAEO	4268.17433249	4933.98727653	90844.11501056	0.75	0.4782
WATCHLOR	-42.32441227	230.20006438	4103.73718956	0.03	0.8711
WATPHAEO	235.24563367	715.91031109	13107.94037090	0.11	0.7737
GSMEDIAN	222.42201838	499.07473284	24111.98353168	0.20	0.6994
GSDISP	-369.07933972	1007.04662030	16306.05364529	0.13	0.7491
MOISTURE	-1136.99191321	4724.53519991	7030.80613346	0.06	0.8322
COBWAT	-1.15780676	4.52686103	7941.20467948	0.07	0.8220
TEMP	-176.87214249	187.91477436	107548.79995596	0.89	0.4459
WTCOBBLE	-14.45423718	24.70969795	41539.76447926	0.34	0.6178

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

STEPWISE REGRESSION, UNTRANSFORMED WEIGHTED MEAN ABUNDANCE, ALL SIZES JUNE ONLY

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE WEIGHTED MEAN ABUNDANCE

STEP 2 VARIABLE WATCHLOR REMOVED R SQUARE = 0.77817272 C(P) = 9.01797484 ADJ. R SQUARE = 0.0387

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	10	866121.33432866	86612.13343287	1.05	0.5470
ERROR	3	246898.06977775	82299.35659258		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3745.46351114				
SESTON	-5.84741731	5.59641415	89847.27835802	1.09	0.3729
SEDCHLOR	-1468.94413500	1074.79751347	153728.25344331	1.87	0.2651
SEDPHAEO	4589.98614765	3798.27254352	120184.07946459	1.46	0.3134
WATPHAEO	294.09949637	527.25242507	25606.35898346	0.31	0.6159
GSMEDIAN	177.40792900	358.07921618	20201.53004756	0.25	0.6543
GSDISP	-409.36624114	809.30413245	21057.02314058	0.26	0.6478
MOISTURE	-1443.25201548	3640.23357295	12936.66356223	0.16	0.7183
COBWAT	-0.83725750	3.43975250	4875.96007868	0.06	0.8234
TEMP	-168.35560727	149.94868714	103744.78520635	1.26	0.3433
WTCOBBLE	-16.76591119	17.51447493	75414.78867147	0.92	0.4091

STEP 3 VARIABLE COBWAT REMOVED R SQUARE = 0.77379188 C(P) = 7.03807870 ADJ. R SQUARE = 0.2648

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	9	861245.37424997	95693.93047222	1.52	0.3636
ERROR	4	251774.02985643	62943.50746411		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3760.12732321				
SESTON	-5.98326724	4.86986141	95015.51738167	1.51	0.2866
SEDCHLOR	-1556.43223496	885.83029259	194316.78576815	3.09	0.1537
SEDPHAEO	4883.53953515	3149.83037753	151302.47127717	2.40	0.1960
WATPHAEO	358.50025771	398.84156608	50854.46133770	0.81	0.4195
GSMEDIAN	195.80762901	306.09540192	25757.07518101	0.41	0.5572
GSDISP	-465.82558867	678.07213347	29706.11304902	0.47	0.5298
MOISTURE	-1815.71690823	2888.57918588	24870.16464633	0.40	0.5637
TEMP	-166.48513788	130.96307488	101719.48518724	1.62	0.2725
WTCOBBLE	-18.63553910	13.76545928	115359.52248665	1.83	0.2472

STEPWISE REGRESSION, UNTRANSFORMED WEIGHTED MEAN ABUNDANCE, ALL SIZES JUNE ONLY

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE WEIGHTED MEAN ABUNDANCE

STEP 4 VARIABLE MOISTURE REMOVED R SQUARE = 0.75144711 C(P) = 5.14061981 ADJ. R SQUARE = 0.3538

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	836375.20960365	104546.90120046	1.89	0.2505
ERROR	5	276644.19450276	55328.83890055		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3429.96429768				
SESTON	-6.39748456	4.52380656	110652.69525636	2.00	0.2164
SEDCHLOR	-1256.18081048	699.43292071	178469.38481804	3.23	0.1324
SEDPHAEO	3804.40927480	2475.97516800	130627.14966980	2.36	0.1850
WATPHAEO	221.04706367	312.72688729	27643.34618807	0.50	0.5112
GSMEDIAN	131.72840921	270.60049089	13111.52751288	0.24	0.6470
GSDISP	-477.92959222	635.47872492	31295.17389532	0.57	0.4859
TEMP	-156.54704044	121.88805952	91268.08821839	1.65	0.2553
WTCOBBLE	-13.03821017	9.84195381	97101.26010860	1.75	0.2426

STEP 5 VARIABLE GSMEDIAN REMOVED R SQUARE = 0.73966696 C(P) = 3.19467939 ADJ. R SQUARE = 0.4359

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	823263.68209077	117609.09744154	2.44	0.1491
ERROR	6	289755.72201564	48292.62033594		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	4249.29789142				
SESTON	-7.39478097	3.76815151	185983.61600503	3.85	0.0974
SEDCHLOR	-1208.38415062	646.97696973	168466.35073639	3.49	0.1110
SEDPHAEO	3774.43041780	2312.47217088	128656.16083236	2.66	0.1538
WATPHAEO	230.21485617	291.63584074	30093.01288618	0.62	0.4599
GSDISP	-666.54607045	470.57682326	96890.24371847	2.01	0.2064
TEMP	-184.09782863	100.85448521	160911.71705856	3.33	0.1177
WTCOBBLE	-13.50775897	9.15061220	105231.81837788	2.18	0.1904

STEPWISE REGRESSION, UNTRANSFORMED WEIGHTED MEAN ABUNDANCE, ALL SIZES JUNE ONLY

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE WEIGHTED MEAN ABUNDANCE

STEP 6 VARIABLE WATPHAEO REMOVED R SQUARE = 0.71262969 C(P) = 1.31875460 ADJ. R SQUARE = 0.4663

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	6	793170.66920458	132195.11153410	2.89	0.0953
ERROR	7	319848.73490182	45692.67641455		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3795.98749389				
SESTON	-7.58378295	3.65790824	196405.10530795	4.30	0.0768
SEDCHLOR	-1007.58757285	578.63978294	138546.52069085	3.03	0.1252
SEDPHAEO	3141.66361929	2109.90059833	101307.58729858	2.22	0.1801
GSDISP	-637.68053506	456.35023269	89218.79754672	1.95	0.2050
TEMP	-156.92795642	92.21248326	132332.89104501	2.90	0.1326
WTCOBBLE	-7.96958942	5.71444988	88872.95832068	1.95	0.2058

STEP 7 VARIABLE WTCOBBLE REMOVED R SQUARE = 0.63278116 C(P) = -0.31481712 ADJ. R SQUARE = 0.4033

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	704297.71088391	140859.54217678	2.76	0.0976
ERROR	8	408721.69322250	51090.21165281		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3259.03012716				
SESTON	-7.37254526	3.86461047	185934.99816488	3.64	0.0929
SEDCHLOR	-752.57946844	580.51060715	85866.17444810	1.68	0.2310
SEDPHAEO	2083.08518801	2081.67086888	51159.65818398	1.00	0.3463
GSDISP	-773.14751535	471.49395038	137375.78317917	2.69	0.1397
TEMP	-121.45542722	93.72425296	85796.10631457	1.68	0.2312

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

STEPWISE REGRESSION, UNTRANSFORMED WEIGHTED MEAN ABUNDANCE, ALL SIZES JUNE ONLY

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE WEIGHTED MEAN ABUNDANCE

STEP 8 VARIABLE SEDPHAEO REMOVED R SQUARE = 0.58681641 C(P) = -2.10388293 ADJ. R SQUARE = 0.4032

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	653138.05269993	163284.51317498	3.20	0.0682
ERROR	9	459881.35140648	51097.92793405		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	3478.53140491				
SESTON	-5.98895573	3.60908017	140705.94151213	2.75	0.1314
SEDCHLOR	-192.29231183	153.29888471	80398.72108935	1.57	0.2413
GSDISP	-979.12925609	424.22027094	272207.76527270	5.33	0.0464
TEMP	-122.39798743	93.72659681	87141.72381064	1.71	0.2240

STEP 9 VARIABLE SEDCHLOR REMOVED R SQUARE = 0.51458162 C(P) = -3.77239441 ADJ. R SQUARE = 0.3690

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	572739.33161058	190913.11053686	3.53	0.0562
ERROR	10	540280.07249582	54028.00724958		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	2250.65031060				
SESTON	-5.22481021	3.65786516	110231.21746971	2.04	0.1837
GSDISP	-661.88147752	350.21143085	192982.87419750	3.57	0.0881
TEMP	-73.85783594	87.77856959	38250.32306485	0.71	0.4198

STEP 10 VARIABLE TEMP REMOVED R SQUARE = 0.48021536 C(P) = -5.61468615 ADJ. R SQUARE = 0.3857

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	534489.00854574	267244.50427287	5.08	0.0274
ERROR	11	578530.39556067	52593.67232370		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	865.52947533				
SESTON	-5.07192585	3.60452877	104131.54093450	1.98	0.1870
GSDISP	-614.52869025	341.04086861	170767.40212271	3.25	0.0990

STEPWISE REGRESSION, UNTRANSFORMED WEIGHTED MEAN ABUNDANCE, ALL SIZES JUNE ONLY

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE WEIGHTED MEAN ABUNDANCE

STEP 11 VARIABLE SESTON REMOVED R SQUARE = 0.38665765 C(P) = -7.18534586
ADJ. R SQUARE = 0.3355

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	430357.46761124	430357.46761124	7.56	0.0176
ERROR	12	682661.93649517	56888.49470793		
TOTAL	13	1113019.40410641			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	900.42484731				
GSDISP	-850.01843707	309.04797001	430357.46761123	7.56	0.0176

ALL VARIABLES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

MARINE ECOLOGICAL CONSULTANTS
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MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: DENSITY WEIGHTED MEAN ABUNDANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	12	870481	72540.077	0.299	0.9076
ERROR	1	242538	242538		
C TOTAL	13	1113019			

ROOT MSE	492.482	R-SQUARE	0.7821
DEP MEAN	228.101	ADJ R-SQ	-1.8328
C.V.	215.9055		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	4013.235	8000.463	0.502	0.7040	INTERCEPT
SESTON	1	-5.194880	18.912637	-0.275	0.8293	SESTON (MG/LITER)
SEDCHLOR	1	-1424.944	2018.848	-0.706	0.6087	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	4304.828	7064.752	0.609	0.6516	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-28.846965	527.316	-0.055	0.9652	Water chlorophyll (microgram/liter)
WATPHAEO	1	267.766	1423.551	0.188	0.8816	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	207.543	841.122	0.247	0.8460	Median grain size
GSDISP	1	-400.739	1725.205	-0.232	0.8547	Grain size dispersion
MOISTURE	1	-1308.137	8506.574	-0.154	0.9029	
COBSAND	1	5.422204	166.944	0.032	0.9793	PERCENT OF COBBLE IN SAND
COBWAT	1	-1.150059	6.403019	-0.180	0.8869	PERCENT OF COBBLE IN WATER
TEMP	1	-183.761	339.898	-0.541	0.6845	WATER TEMPERATURE
WTCOBBLE	1	-16.861993	81.947893	-0.206	0.8708	

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	16.000	54.244	490.995	-38.244	38.244	-1.000	| *| |	12.679
2	-15.5	10.167	-24.510	491.260	34.676	34.676	1.000	| |* |	15.439
3	-100	360.720	640.496	405.294	-279.776	279.776	-1.000	| *| |	0.161
4	65	555.273	509.181	490.320	46.092	46.092	1.000	| |* |	8.705
5	45	235.140	312.652	486.344	-77.512	77.512	-1.000	| *| |	3.028
6	25	944.326	757.580	455.702	186.746	186.746	1.000	| |* |	0.458
7	-6.5	81.167	51.845	491.608	29.322	29.322	1.000	| |* |	21.623
8	-115	626.833	342.058	401.798	284.775	284.775	1.000	| |* |	0.153
9	-0.4	0.833333	-58.789	488.860	59.623	59.623	1.000	| |* |	5.171
10	-1.5	56.000	96.869	490.783	-40.869	40.869	-1.000	| *| |	11.093
11	1.5	2.500	49.582	490.226	-47.082	47.082	-1.000	| *| |	8.339
12	12	11.833	133.075	477.325	-121.242	121.242	-1.000	| *| |	1.192
13	18	216.973	318.375	481.930	-101.402	101.402	-1.000	| *| |	1.738
14	6.5	75.645	10.750	488.188	64.894	64.894	1.000	| |* |	4.353

SUM OF RESIDUALS 8.27995E-11
SUM OF SQUARED RESIDUALS 242538.5

DURBIN-WATSON D 1.979
1ST ORDER AUTOCORRELATION -0.001

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: DENSITY WEIGHTED MEAN ABUNDANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	793171	132195	2.893	0.0953
ERROR	7	319849	45692.676		
C TOTAL	13	1113019			

ROOT MSE	213.758	R-SQUARE	0.7126
DEP MEAN	228.101	ADJ R-SQ	0.4663
C.V.	93.7123		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	3795.987	1841.677	2.061	0.0782	INTERCEPT
SESTON	1	-7.583783	3.657908	-2.073	0.0768	SESTON (MG/LITER)
SEDCHLOR	1	-1007.588	578.640	-1.741	0.1252	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	3141.664	2109.901	1.489	0.1801	Sediment phaeophytin (microgram/cm2)
GSDISP	1	-637.681	456.350	-1.397	0.2050	Grain size dispersion
TEMP	1	-156.928	92.212483	-1.702	0.1326	WATER TEMPERATURE
WTCOBBLE	1	-7.969589	5.714450	-1.395	0.2058	

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	16.000	-6.804	153.054	22.804	149.222	0.153	| | |	0.004
2	-15.5	10.167	69.469	87.237	-59.302	195.147	-0.304	| | |	0.003
3	-100	360.720	662.579	159.172	-301.859	142.678	-2.116	| ****| |	0.796
4	65	555.273	554.252	192.201	1.021	93.549	0.011	| | |	0.000
5	45	235.140	268.595	158.024	-33.454	143.948	-0.232	| | |	0.009
6	25	944.326	643.518	156.437	300.808	145.672	2.065	| |**** |	0.703
7	-6.5	81.167	-18.710	180.455	99.876	114.580	0.872	| |* |	0.269
8	-115	626.833	355.078	130.936	271.755	168.963	1.608	| |*** |	0.222
9	-0.4	0.833333	-27.582	186.233	28.415	104.928	0.271	| | |	0.033
10	-1.5	56.000	26.691	129.331	29.309	170.194	0.172	| | |	0.002
11	1.5	2.500	183.436	160.373	-180.936	141.326	-1.280	| **| |	0.302
12	12	11.833	42.558	84.450	-30.725	196.369	-0.156	| | |	0.001
13	18	216.973	329.584	99.836	-112.611	189.012	-0.596	| *| |	0.014
14	6.5	75.645	110.746	182.085	-35.101	111.971	-0.313	| | |	0.037

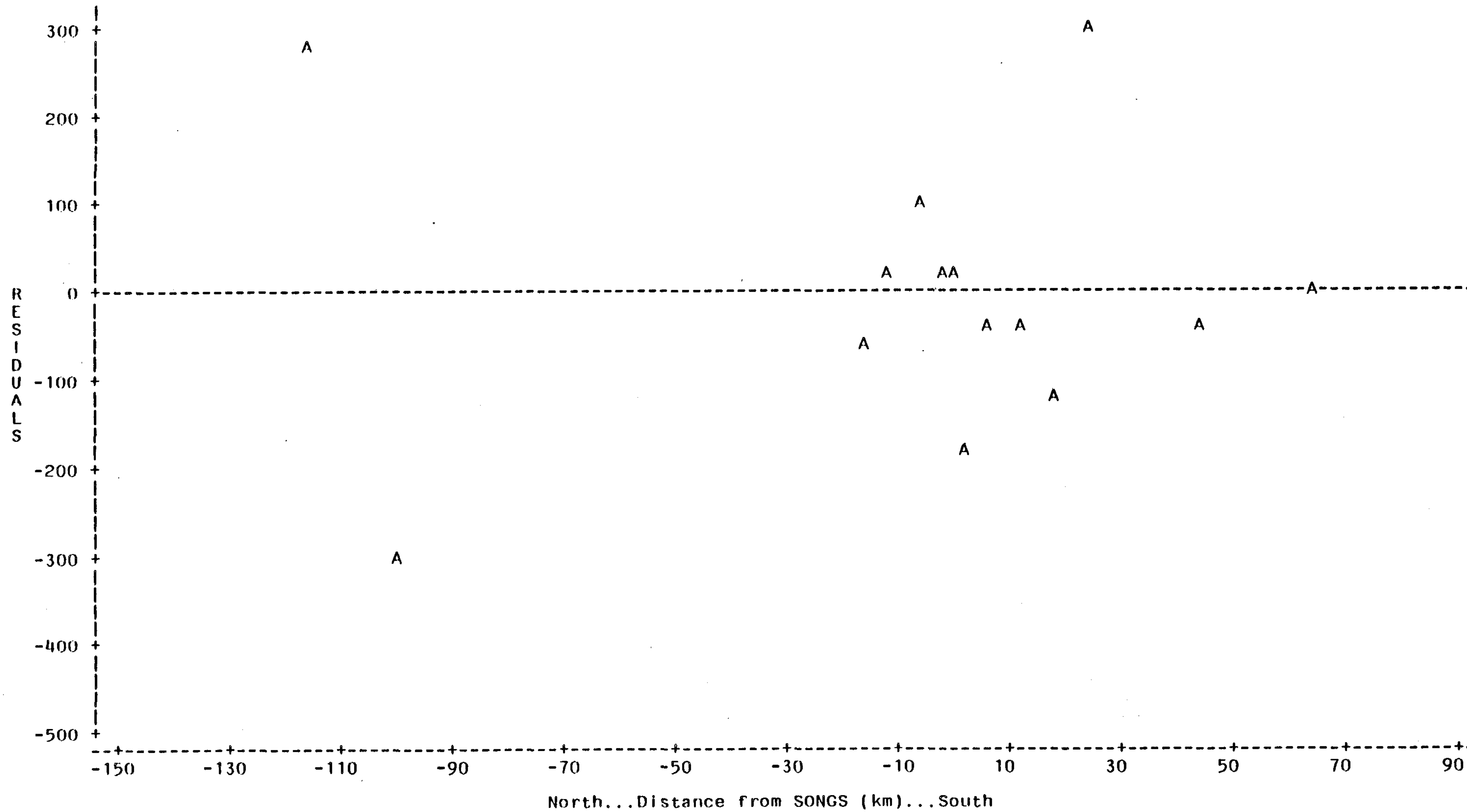
SUM OF RESIDUALS 2.45954E-11
SUM OF SQUARED RESIDUALS 319848.7

DURBIN-WATSON D 1.497
1ST ORDER AUTOCORRELATION 0.249

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR WEIGHTED MEAN ABUNDANCE

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: DENS567 WEIGHTED MEAN ABUNDANCE OF SAND CRABS 6-9 mm

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	19	819041	43107.407	2.343	0.0355
ERROR	19	349600	18399.977		
C TOTAL	38	1168640			

ROOT MSE	135.647	R-SQUARE	0.7008
DEP MEAN	156.637	ADJ R-SQ	0.4017
C.V.	86.59914		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	2392.976	786.655	3.042	0.0067	INTERCEPT
SESTON	1	-5.003527	2.666318	-1.877	0.0760	SESTON (MG/LITER)
SEDCHLOR	1	-111.110	75.922789	-1.463	0.1597	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	254.040	282.073	0.901	0.3791	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-2.466548	28.162295	-0.088	0.9311	Water chlorophyll (microgram/liter)
WATPHAEO	1	-101.324	63.707624	-1.590	0.1282	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	-178.752	158.945	-1.125	0.2748	Median grain size
GSDISP	1	465.138	322.281	1.443	0.1652	Grain size dispersion
MOISTURE	1	89.291662	1232.762	0.072	0.9430	
COBSAND	1	-7.045771	6.071776	-1.160	0.2603	PERCENT OF COBBLE IN SAND
COBWAT	1	0.716338	1.122250	0.638	0.5309	PERCENT OF COBBLE IN WATER
TEMP	1	-96.496729	31.630100	-3.051	0.0066	WATER TEMPERATURE
WTCOBBLE	1	0.931426	2.520802	0.369	0.7158	
WATCARB	1	5.893876	6.324500	0.932	0.3631	WATER CARBON (MG/LITER)
SEDCARB	1	10906.690	6074.459	1.795	0.0885	Sediment carbon (mg/gram)
LT4PHI	1	-37.026009	62.484446	-0.593	0.5605	% silt/clay
GT1PHI	1	-15.294956	5.918333	-2.584	0.0182	% coarse sand
GSSKEW	1	61.884924	96.637979	0.640	0.5296	Grain size skewness
BSLOPE	1	-1071.456	623.751	-1.718	0.1021	BEACH SLOPE (DROP/HORDIST)
DISTANCE	1	-0.086316	0.428591	-0.201	0.8425	North...Distance from SONGS (km)...South

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	15.833	24.912	104.060	-9.078	87.014	-0.104	| | |	0.001
2	-15.5	10.000	.	.	.	.	.		.
3	-100	140.946	303.136	89.742	-162.190	101.717	-1.595	| ***| |	0.099
4	65	516.905	362.009	86.287	154.896	104.664	1.480	| |** |	0.074
5	45	200.362	304.925	112.731	-104.563	75.443	-1.386	| **| |	0.214
6	25	730.215	582.403	101.744	147.812	89.711	1.648	| |*** |	0.175
7	-6.5	71.167	170.055	75.271	-98.888	112.846	-0.876	| *| |	0.017

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
8	-115	388.000	350.698	105.280	37.302	85.534	0.436	| | |	0.014
9	-0.4	0.666667	18.012	122.489	-17.345	58.279	-0.298	| | |	0.020
10	-1.5	54.600	132.627	94.931	-78.027	96.892	-0.805	| *| |	0.031
11	1.5	1.250	-53.753	102.465	55.003	88.887	0.619	| |* |	0.025
12	12	9.833	129.548	109.728	-119.714	79.748	-1.501	| ***| |	0.213
13	18	89.488	.	.	.	.	.		.
14	6.5	52.306	-9.512	117.159	61.818	68.366	0.904	| |* |	0.120
15	-12	137.833	90.338	89.603	47.495	101.839	0.466	| | |	0.008
16	-15.5	4.000	149.190	53.904	-145.190	124.476	-1.166	| **| |	0.013
17	-100	254.833	215.111	70.085	39.722	116.138	0.342	| | |	0.002
18	65	30.152	75.330	127.720	-45.177	45.689	-0.989	| *| |	0.382
19	45	200.861	286.016	58.223	-85.156	122.515	-0.695	| *| |	0.005
20	25	442.277	308.016	79.049	134.261	110.233	1.218	| |** |	0.038
21	-6.5	357.500	326.577	75.287	30.923	112.836	0.274	| | |	0.002
22	-115	361.833	289.214	75.874	72.619	112.441	0.646	| |* |	0.009
23	-0.4	65.333	135.521	73.515	-70.188	113.998	-0.616	| *| |	0.008
24	-1.5	8.625	47.499	101.138	-38.874	90.394	-0.430	| | |	0.012
25	1.5	33.363	100.261	63.863	-66.898	119.673	-0.559	| *| |	0.004
26	12	43.191	-54.337	90.439	97.528	101.098	0.965	| |* |	0.037
27	18	126.654	315.809	96.331	-189.155	95.501	-1.981	| ***| |	0.200
28	6.5	480.888	264.272	83.854	216.616	106.623	2.032	| |**** |	0.128
29	-12	44.093	-67.618	95.429	111.711	96.402	1.159	| |** |	0.066
30	-15.5	3.167	-45.854	84.138	49.020	106.399	0.461	| | |	0.007
31	-100	28.819	-13.423	113.875	42.242	73.705	0.573	| |* |	0.039
32	65	32.831	6.538	129.574	26.294	40.131	0.655	| |* |	0.224
33	45	104.733	164.869	124.466	-60.136	53.928	-1.115	| **| |	0.331
34	-450	239.167	243.990	131.895	-4.823	31.680	-0.152	| | |	0.020
35	25	188.656	236.381	99.920	-47.725	91.739	-0.520	| *| |	0.016
36	-6.5	153.833	214.251	73.531	-60.417	113.987	-0.530	| *| |	0.006
37	-115	21.500	.	.	.	.	.		.
38	-0.4	320.759	180.709	117.759	140.050	67.326	2.080	| |**** |	0.662
39	-1.5	4.667	126.739	85.770	-122.072	105.088	-1.162	| **| |	0.045
40	1.5	46.167	-21.723	74.115	67.890	113.609	0.598	| |* |	0.008
41	12	34.333	42.070	83.153	-7.737	107.170	-0.072	| | |	0.000
42	18	0	.	.	.	.	.		.
43	6.5	178.200	178.049	127.687	0.150867	45.781	0.003	| | |	0.000

SUM OF RESIDUALS 1.54493E-10
SUM OF SQUARED RESIDUALS 349599.6

DURBIN-WATSON D 3.138
1ST ORDER AUTOCORRELATION -0.517

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: DLNS567   WEIGHTED MEAN ABUNDANCE OF SAND CRABS 6-9 mm

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	690700	115117	7.708	0.0001
ERROR	32	477940	14935.625		
C TOTAL	38	1168640			

ROOT MSE	122.211	R-SQUARE	0.5910
DEP MEAN	156.637	ADJ R-SQ	0.5143
C.V.	78.02192		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	1757.834	404.030	4.351	0.0001	INTERCEPT
SEDCHLOR	1	-67.593478	20.645662	-3.274	0.0026	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDCARB	1	9912.343	3739.830	2.650	0.0124	Sediment carbon (mg/gram)
GT1PHI	1	-8.194428	1.524203	-5.376	0.0001	% coarse sand
BSLOPE	1	-686.918	418.259	-1.642	0.1103	BEACH SLOPE (DROP/HORDIST)
COBSAND	1	-5.390086	3.054694	-1.765	0.0872	PERCENT OF COBBLE IN SAND
TEMP	1	-73.122410	20.553423	-3.558	0.0012	WATER TEMPERATURE

<table>
<tr><th>OBS</th><th>ID</th><th>ACTUAL</th><th>PREDICT VALUE</th><th>STD ERR PREDICT</th><th>RESIDUAL</th><th>STD ERR RESIDUAL</th><th>STUDENT RESIDUAL</th><th>-2-1-0 1 2</th><th>COOK'S D</th></tr>
<tr><td>1</td><td>-12</td><td>15.833</td><td>78.855</td><td>46.871</td><td>-63.022</td><td>112.866</td><td>-0.558</td><td>| *| |</td><td>0.008</td></tr>
<tr><td>2</td><td>-15.5</td><td>10.000</td><td>.</td><td>.</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>3</td><td>-100</td><td>140.946</td><td>297.212</td><td>57.565</td><td>-156.266</td><td>107.805</td><td>-1.450</td><td>| **| |</td><td>0.086</td></tr>
<tr><td>4</td><td>65</td><td>516.905</td><td>409.234</td><td>57.281</td><td>107.671</td><td>107.956</td><td>0.997</td><td>| |* |</td><td>0.040</td></tr>
<tr><td>5</td><td>45</td><td>200.362</td><td>397.148</td><td>55.994</td><td>-196.786</td><td>108.629</td><td>-1.812</td><td>| ***| |</td><td>0.125</td></tr>
<tr><td>6</td><td>25</td><td>730.215</td><td>464.676</td><td>60.850</td><td>265.539</td><td>105.986</td><td>2.505</td><td>| |*****|</td><td>0.296</td></tr>
<tr><td>7</td><td>-6.5</td><td>71.167</td><td>178.501</td><td>28.936</td><td>-107.334</td><td>118.736</td><td>-0.904</td><td>| *| |</td><td>0.007</td></tr>
<tr><td>8</td><td>-115</td><td>388.000</td><td>353.517</td><td>55.417</td><td>34.483</td><td>108.925</td><td>0.317</td><td>| | |</td><td>0.004</td></tr>
<tr><td>9</td><td>-0.4</td><td>0.666667</td><td>96.050</td><td>50.208</td><td>-95.383</td><td>111.422</td><td>-0.856</td><td>| *| |</td><td>0.021</td></tr>
<tr><td>10</td><td>-1.5</td><td>54.600</td><td>187.436</td><td>39.939</td><td>-132.836</td><td>115.501</td><td>-1.150</td><td>| **| |</td><td>0.023</td></tr>
<tr><td>11</td><td>1.5</td><td>1.250</td><td>-111.132</td><td>60.411</td><td>112.382</td><td>106.236</td><td>1.058</td><td>| |** |</td><td>0.052</td></tr>
<tr><td>12</td><td>12</td><td>9.833</td><td>102.107</td><td>36.806</td><td>-92.274</td><td>116.537</td><td>-0.792</td><td>| *| |</td><td>0.009</td></tr>
<tr><td>13</td><td>18</td><td>89.488</td><td>.</td><td>.</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>14</td><td>6.5</td><td>52.306</td><td>70.105</td><td>44.345</td><td>-17.799</td><td>113.882</td><td>-0.156</td><td>| | |</td><td>0.001</td></tr>
<tr><td>15</td><td>-12</td><td>137.833</td><td>140.710</td><td>29.301</td><td>-2.877</td><td>118.647</td><td>-0.024</td><td>| | |</td><td>0.000</td></tr>
<tr><td>16</td><td>-15.5</td><td>4.000</td><td>134.050</td><td>26.141</td><td>-130.050</td><td>119.383</td><td>-1.089</td><td>| **| |</td><td>0.008</td></tr>
<tr><td>17</td><td>-100</td><td>254.833</td><td>209.961</td><td>41.722</td><td>44.872</td><td>114.869</td><td>0.391</td><td>| | |</td><td>0.003</td></tr>
<tr><td>18</td><td>65</td><td>30.152</td><td>113.205</td><td>83.323</td><td>-83.053</td><td>89.403</td><td>-0.929</td><td>| *| |</td><td>0.107</td></tr>
<tr><td>19</td><td>45</td><td>200.861</td><td>209.158</td><td>37.639</td><td>-8.297</td><td>116.271</td><td>-0.071</td><td>| | |</td><td>0.000</td></tr>
<tr><td>20</td><td>25</td><td>442.277</td><td>287.832</td><td>42.434</td><td>154.444</td><td>114.608</td><td>1.348</td><td>| |** |</td><td>0.036</td></tr>
</table>

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
21	-6.5	357.500	344.579	42.459	12.921	114.599	0.113	|	0.000
22	-115	361.833	259.856	42.795	101.977	114.474	0.891	|*	0.016
23	-0.4	65.333	117.929	31.532	-52.596	118.073	-0.445	|	0.002
24	-1.5	8.625	60.731	46.955	-52.106	112.831	-0.462	|	0.005
25	1.5	33.363	33.533	40.077	-.170437	115.453	-0.001	|	0.000
26	12	43.191	20.652	34.932	22.539	117.113	0.192	|	0.000
27	18	126.654	256.344	48.095	-129.689	112.350	-1.154	**|	0.035
28	6.5	480.888	227.532	40.510	253.356	115.302	2.197	|****	0.085
29	-12	44.093	16.885	44.675	27.208	113.753	0.239	|	0.001
30	-15.5	3.167	-83.005	50.199	86.171	111.426	0.773	|*	0.017
31	-100	28.819	99.974	60.117	-71.155	106.403	-0.669	*|	0.020
32	65	32.831	-14.517	109.031	47.348	55.208	0.858	|*	0.410
33	45	104.733	111.421	48.365	-6.688	112.234	-0.060	|	0.000
34	-450	239.167	166.121	74.841	73.046	96.615	0.756	|*	0.049
35	25	188.656	298.977	39.718	-110.321	115.577	-0.955	*|	0.015
36	-6.5	153.833	205.780	34.170	-51.947	117.337	-0.443	|	0.002
37	-115	21.500	.	.	.	.	.		.
38	-0.4	320.759	49.765	68.085	270.994	101.489	2.670	|*****	0.458
39	-1.5	4.667	101.303	28.357	-96.636	118.876	-0.813	*|	0.005
40	1.5	46.167	6.623	33.129	39.544	117.635	0.336	|	0.001
41	12	34.333	18.388	40.853	15.946	115.181	0.138	|	0.000
42	18	0	.	.	.	.	.		.
43	6.5	178.200	191.356	89.213	-13.156	83.526	-0.158	|	0.004

SUM OF RESIDUALS 8.28386E-11
SUM OF SQUARED RESIDUALS 477940

DURBIN-WATSON D 3.345
1ST ORDER AUTOCORRELATION -0.569

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
21	-6.5	357.500	344.579	42.459	12.921	114.599	0.113	|	0.000
22	-115	361.833	259.856	42.795	101.977	114.474	0.891	|*	0.016
23	-0.4	65.333	117.929	31.532	-52.596	118.073	-0.445	|	0.002
24	-1.5	8.625	60.731	46.955	-52.106	112.831	-0.462	|	0.005
25	1.5	33.363	33.533	40.077	-.170437	115.453	-0.001	|	0.000
26	12	43.191	20.652	34.932	22.539	117.113	0.192	|	0.000
27	18	126.654	256.344	48.095	-129.689	112.350	-1.154	**|	0.035
28	6.5	480.888	227.532	40.510	253.356	115.302	2.197	|****	0.085
29	-12	44.093	16.885	44.675	27.208	113.753	0.239	|	0.001
30	-15.5	3.167	-83.005	50.199	86.171	111.426	0.773	|*	0.017
31	-100	28.819	99.974	60.117	-71.155	106.403	-0.669	*|	0.020
32	65	32.831	-14.517	109.031	47.348	55.208	0.858	|*	0.410
33	45	104.733	111.421	48.365	-6.688	112.234	-0.060	|	0.000
34	-450	239.167	166.121	74.841	73.046	96.615	0.756	|*	0.049
35	25	188.656	298.977	39.718	-110.321	115.577	-0.955	*|	0.015
36	-6.5	153.833	205.780	34.170	-51.947	117.337	-0.443	|	0.002
37	-115	21.500	.	.	.	.	.		.
38	-0.4	320.759	49.765	68.085	270.994	101.489	2.670	|*****	0.458
39	-1.5	4.667	101.303	28.357	-96.636	118.876	-0.813	*|	0.005
40	1.5	46.167	6.623	33.129	39.544	117.635	0.336	|	0.001
41	12	34.333	18.388	40.853	15.946	115.181	0.138	|	0.000
42	18	0	.	.	.	.	.		.
43	6.5	178.200	191.356	89.213	-13.156	83.526	-0.158	|	0.004

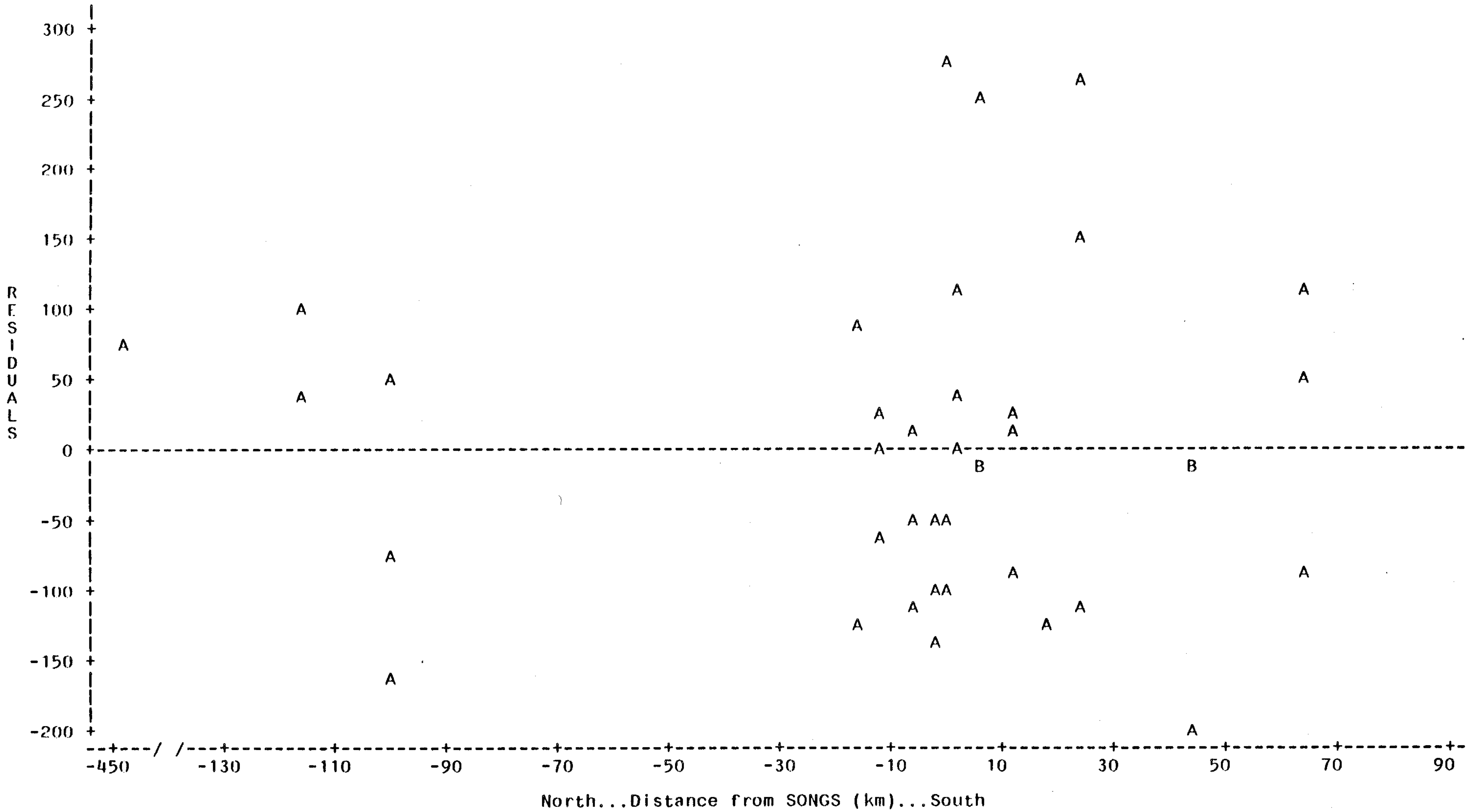
SUM OF RESIDUALS 8.28386E-11
SUM OF SQUARED RESIDUALS 477940

DURBIN-WATSON D 3.345
1ST ORDER AUTOCORRELATION -0.569

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

RESIDUAL PLOT FOR WEIGHTED MEAN ABUNDANCE OF SAND CRABS 6-9 MM
PLOT OF RESID*DISTANCE LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 4 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: PERCTES PERCENT OF ALL FEMALES WITH EGGS OR SPENT EGG CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	19	22952.152	1208.008	2.693	0.0923
ERROR	7	3140.567	448.652		
C TOTAL	26	26092.719			

ROOT MSE	21.181417	R-SQUARE	0.8796
DEP MEAN	34.181144	ADJ R-SQ	0.5529
C.V.	61.96813		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-589.226	274.855	-2.144	0.0692	INTERCEPT
SESTON	1	-0.566294	0.732719	-0.773	0.4649	SESTON (MG/LITER)
SEDCHLOR	1	-2.939558	13.826676	-0.213	0.8377	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	28.823342	53.486865	0.539	0.6067	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-11.221357	5.912834	-1.898	0.0995	Water chlorophyll (microgram/liter)
WATPHAEO	1	7.901043	15.358786	0.514	0.6228	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	53.739851	48.408881	1.110	0.3036	Median grain size
GSDISP	1	1.781991	104.563	0.017	0.9869	Grain size dispersion
MOISTURE	1	-81.503346	1059.711	-0.077	0.9408	
COBSAND	1	1.088505	1.514883	0.719	0.4957	PERCENT OF COBBLE IN SAND
COBWAT	1	0.228173	0.270955	0.842	0.4276	PERCENT OF COBBLE IN WATER
TEMP	1	26.399306	17.472171	1.511	0.1746	WATER TEMPERATURE
WTCOBBLE	1	-0.210572	0.605589	-0.348	0.7383	
WATCARB	1	1.184771	2.918971	0.406	0.6969	WATER CARBON (MG/LITER)
SEDCARB	1	-1164.494	1713.064	-0.680	0.5185	Sediment carbon (mg/gram)
LT4PHI	1	22.091172	28.432568	0.777	0.4626	% silt/clay
GT1PHI	1	1.291015	1.824839	0.707	0.5021	% coarse sand
GSSKEW	1	-47.638677	50.771405	-0.938	0.3793	Grain size skewness
BSLOPE	1	35.970150	117.297	0.307	0.7680	BEACH SLOPE (DROP/HORDIST)
DISTANCE	1	-0.132142	0.088585	-1.492	0.1794	North...Distance from SONGS (km)...South

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	2.005	-.433642	19.097	2.438	9.162	0.266	| | |	0.015
2	-15.5	0	18.374	15.464	-18.374	14.474	-1.269	| **| |	0.092
3	-100	6.891	32.865	14.577	-25.974	15.368	-1.690	| ***| |	0.129
4	65	21.116	20.197	21.070	0.918848	2.172	0.423	| | |	0.842
5	45	79.837	51.484	11.782	28.354	17.602	1.611	| |*** |	0.058
6	25	22.534	37.552	15.384	-15.018	14.560	-1.031	| **| |	0.059
7	-6.5	3.732	4.644	17.666	-.912346	11.686	-0.078	| | |	0.001

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
8	-115	2.837	-1.677	15.133	4.514	14.821	0.305	| | |	0.005
9	-0.4	3.635	10.542	18.181	-6.907	10.868	-0.636	| *| |	0.057
10	-1.5	3.731	-6.752	20.279	10.484	6.117	1.714	| |*** |	1.614
11	1.5	2.867	13.989	16.081	-11.122	13.786	-0.807	| *| |	0.044
12	12	14.604	16.937	19.692	-2.333	7.801	-0.299	| | |	0.028
13	18	41.996	35.689	18.519	6.307	10.281	0.614	| |* |	0.061
14	6.5	3.413	-7.833	16.538	11.247	13.234	0.850	| |* |	0.056
15	-12	34.879	31.173	18.714	3.706	9.921	0.374	| | |	0.025
16	-15.5	77.875	65.200	19.704	12.675	7.773	1.631	| |*** |	0.854
17	-100	92.404	87.924	20.400	4.480	5.700	0.786	| |* |	0.396
18	65	87.479	89.738	20.982	-2.259	2.899	-0.779	| *| |	1.590
19	45	85.592	94.040	20.682	-8.449	4.574	-1.847	| ***| |	3.488
20	-450	36.454	31.153	20.897	5.301	3.460	1.532	| |*** |	4.281
21	25	88.797	85.248	20.459	3.549	5.487	0.647	| |* |	0.291
22	-6.5	26.424	19.073	15.768	7.352	14.143	0.520	| |* |	0.017
23	-115	.	.	.	.	.	.		.
24	-0.4	46.141	54.046	20.399	-7.905	5.705	-1.385	| **| |	1.227
25	-1.5	16.667	23.597	17.738	-6.931	11.576	-0.599	| *| |	0.042
26	1.5	40.137	46.885	14.197	-6.748	15.719	-0.429	| | |	0.008
27	12	50.845	41.254	17.047	9.591	12.573	0.763	| |* |	0.053
28	18	.	.	.	.	.	.		.
29	6.5	29.997	27.982	21.030	2.015	2.527	0.797	| |* |	2.201

SUM OF RESIDUALS -2.56541E-11
SUM OF SQUARED RESIDUALS 3140.567

DURBIN-WATSON D 1.924
1ST ORDER AUTOCORRELATION 0.023

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: PERCTES PERCENT OF ALL FEMALES WITH EGGS OR SPENT EGG CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	19005.352	3801.070	11.263	0.0001
ERROR	21	7087.367	337.494		
C TOTAL	26	26092.719			

ROOT MSE	18.371000	R-SQUARE	0.7284
DEP MEAN	34.181144	ADJ R-SQ	0.6637
C.V.	53.74601		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-392.002	101.511	-3.862	0.0009	INTERCEPT
SEDPHAEO	1	35.632344	11.799159	3.020	0.0065	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-11.909235	3.577212	-3.329	0.0032	Water chlorophyll (microgram/liter)
SESTON	1	-0.795856	0.344973	-2.307	0.0313	SESTON (MG/LITER)
GSDISP	1	63.660138	28.914741	2.202	0.0390	Grain size dispersion
TEMP	1	20.455922	4.894924	4.179	0.0004	WATER TEMPERATURE

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	2.005	0.105165	13.953	1.899	11.951	0.159	|	0.006
2	-15.5	0	22.079	5.034	-22.079	17.668	-1.250	**|	0.021
3	-100	6.891	28.108	7.619	-21.217	16.716	-1.269	**|	0.056
4	65	21.116	42.333	6.292	-21.218	17.260	-1.229	**|	0.033
5	45	79.837	50.280	5.683	29.557	17.470	1.692	|***	0.050
6	25	22.534	37.914	6.840	-15.379	17.050	-0.902	*|	0.022
7	-6.5	3.732	11.306	7.490	-7.574	16.775	-0.452	|	0.007
8	-115	2.837	15.733	6.408	-12.895	17.217	-0.749	*|	0.013
9	-0.4	3.635	9.906	5.057	-6.272	17.661	-0.355	|	0.002
10	-1.5	3.731	-5.554	7.121	9.286	16.935	0.548	|*	0.009
11	1.5	2.867	16.251	6.030	-13.384	17.353	-0.771	*|	0.012
12	12	14.604	28.413	3.674	-13.809	18.000	-0.767	*|	0.004
13	18	41.996	29.888	10.616	12.108	14.993	0.808	|*	0.055
14	6.5	3.413	-16.226	10.240	19.640	15.252	1.288	|**	0.125
15	-12	34.879	44.742	6.504	-9.863	17.181	-0.574	*|	0.008
16	-15.5	77.875	65.591	9.872	12.284	15.493	0.793	|*	0.043
17	-100	92.404	76.920	11.578	15.484	14.264	1.086	|**	0.129
18	65	87.479	94.852	14.622	-7.372	11.122	-0.663	*|	0.127
19	45	85.592	90.027	11.944	-4.435	13.958	-0.318	|	0.012
20	-450	36.454	22.151	11.977	14.304	13.930	1.027	|**	0.130
21	25	88.797	47.481	8.264	41.316	16.407	2.518	|*****	0.268

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
22	-6.5	26.424	39.733	5.407	-13.309	17.557	-0.758	| *| |	0.009
23	-115	.	.	.	.	.	.		.
24	-0.4	46.141	55.050	9.584	-8.909	15.673	-0.568	| *| |	0.020
25	-1.5	16.667	26.237	7.671	-9.570	16.693	-0.573	| *| |	0.012
26	1.5	40.137	35.234	6.442	4.903	17.204	0.285	| | |	0.002
27	12	50.845	45.884	7.587	4.961	16.731	0.296	| | |	0.003
28	18	.	.	.	.	.	.		.
29	6.5	29.997	8.455	8.144	21.542	16.467	1.308	| |** |	0.070

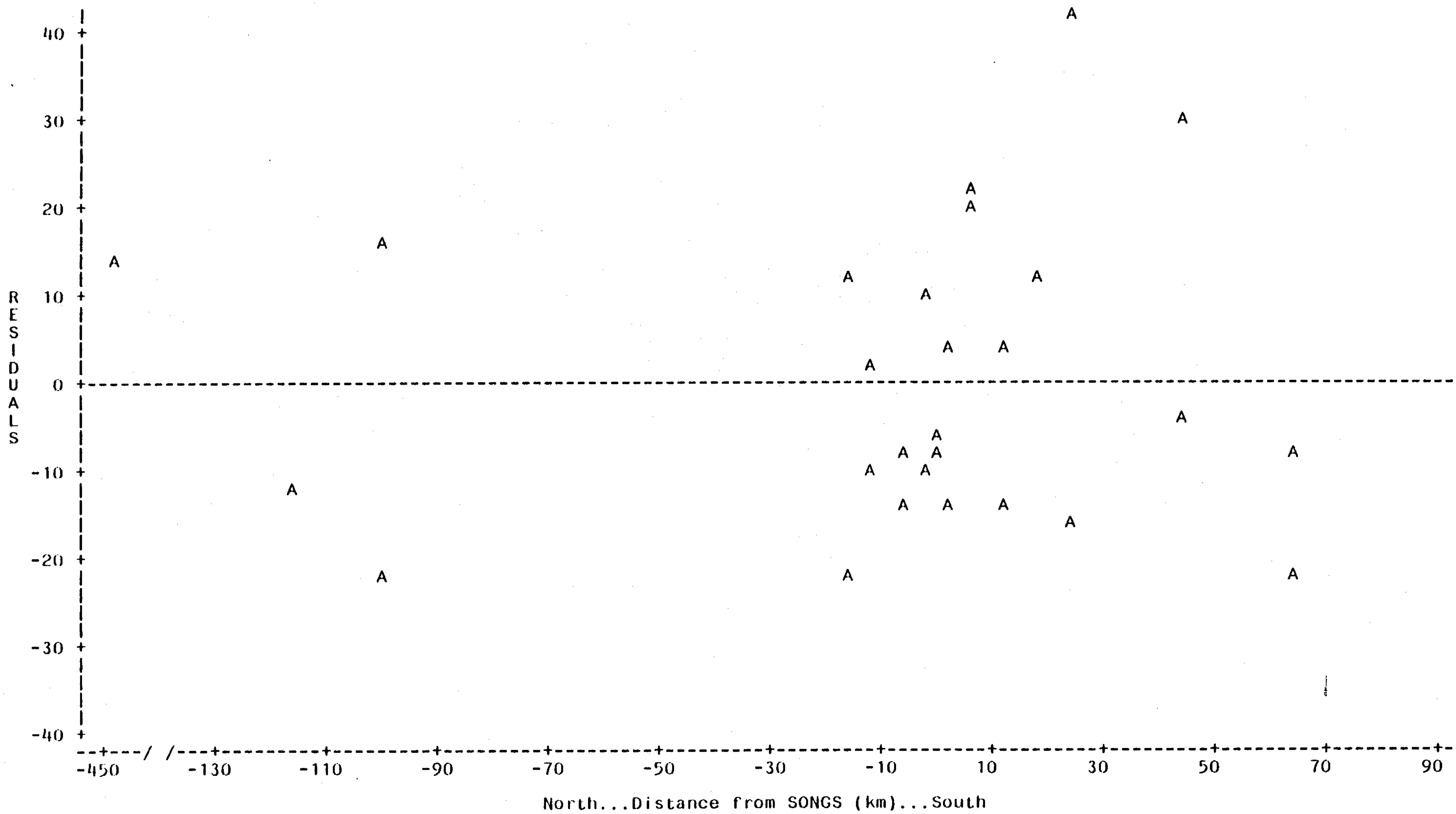
SUM OF RESIDUALS -1.02283E-11
SUM OF SQUARED RESIDUALS 7087.367

DURBIN-WATSON D 1.982
1ST ORDER AUTOCORRELATION -0.000

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR PERCENT OF ALL FEMALES WITH EGGS OR SPENT EGG CASES

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: TOTGE13 FEMALES > 13MM WITH EGGS OR SPENT EGG CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	19	14908.460	784.656	1.156	0.5630
ERROR	2	1357.328	678.664		
C TOTAL	21	16265.788			

ROOT MSE	26.051185	R-SQUARE	0.9166
DEP MEAN	72.990508	ADJ R-SQ	0.1238
C.V.	35.6912		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-97.519001	560.859	-0.174	0.8780	INTERCEPT
SESTON	1	-2.270852	1.793326	-1.266	0.3329	SESTON (MG/LITER)
SEDCHLOR	1	-8.796494	20.985720	-0.419	0.7158	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	72.381561	93.246311	0.776	0.5188	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-20.141313	11.172801	-1.803	0.2132	Water chlorophyll (microgram/liter)
WATPHAEO	1	-26.603847	31.652456	-0.840	0.4891	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	-46.340065	114.435	-0.405	0.7247	Median grain size
GSDISP	1	343.255	350.329	0.980	0.4305	Grain size dispersion
MOISTURE	1	-1683.257	2480.766	-0.679	0.5674	
COBSAND	1	1.410454	3.510978	0.402	0.7267	PERCENT OF COBBLE IN SAND
COBWAT	1	0.907625	0.875715	1.036	0.4089	PERCENT OF COBBLE IN WATER
TEMP	1	22.019593	42.307714	0.520	0.6546	WATER TEMPERATURE
WTCOBBLE	1	-2.322296	2.161418	-1.074	0.3950	
WATCARB	1	7.921721	5.805672	1.364	0.3057	WATER CARBON (MG/LITER)
SEDCARB	1	-2414.340	3625.121	-0.666	0.5739	Sediment carbon (mg/gram)
LT4PHI	1	40.174258	52.002686	0.773	0.5206	% silt/clay
GT1PHI	1	-4.378819	5.242596	-0.835	0.4915	% coarse sand
GSSKEW	1	10.948821	119.863	0.091	0.9355	Grain size skewness
BSLOPE	1	-745.561	462.634	-1.612	0.2484	BEACH SLOPE (DROP/HORDIST)
DISTANCE	1	-0.104930	0.146541	-0.716	0.5483	North...Distance from SONGS (km)...South

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	100.000	95.067	25.748	4.933	3.964	1.245	| |** |	3.268
2	-15.5	.	66.130	41.474	.	.	.		.
3	-100	19.403	25.262	22.410	-5.859	13.284	-0.441	| | |	0.028
4	65	78.346	79.342	25.991	-.995453	1.772	-0.562	| *| |	3.393
5	45	98.052	90.378	25.216	7.674	6.544	1.173	| |** |	1.021
6	25	66.915	54.828	23.532	12.087	11.176	1.082	| |** |	0.259
7	-6.5	72.727	57.428	23.171	15.299	11.906	1.285	| |** |	0.313

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
8	-115	16.579	30.293	19.307	-13.714	17.490	-0.784	| *| |	0.037
9	-0.4	.	66.730	75.356	.	.	.		.
10	-1.5	.	-127.351	104.393	.	.	.		.
11	1.5	28.571	31.194	24.552	-2.622	8.711	-0.301	| | |	0.036
12	12	41.667	43.083	26.019	-1.417	1.293	-1.096	| **| |	24.293
13	18	94.313	103.256	25.258	-8.943	6.381	-1.402	| **| |	1.539
14	6.5	37.500	37.633	25.814	-.133333	3.504	-0.038	| | |	0.004
15	-12	.	-13.820	84.876	.	.	.		.
16	-15.5	100.000	99.353	26.011	0.647232	1.449	0.447	| | |	3.215
17	-100	95.476	92.586	25.970	2.891	2.049	1.411	| |** |	15.993
18	65	97.101	97.566	25.953	-.464227	2.262	-0.205	| | |	0.277
19	45	98.408	101.711	25.940	-3.303	2.404	-1.374	| **| |	10.988
20	-450	91.931	87.376	25.850	4.555	3.231	1.410	| |** |	6.358
21	25	93.504	99.092	25.746	-5.588	3.973	-1.407	| **| |	4.155
22	-6.5	63.953	76.212	23.469	-12.258	11.308	-1.084	| **| |	0.253
23	-115	33.333	.	.	.	.	.		.
24	-0.4	100.000	100.529	26.026	-.528950	1.150	-0.460	| | |	5.418
25	-1.5	.	46.718	51.186	.	.	.		.
26	1.5	74.096	81.633	24.879	-7.537	7.727	-0.975	| *| |	0.493
27	12	72.340	55.065	22.314	17.275	13.445	1.285	| |** |	0.227
28	18	.	.	.	.	.	.		.
29	6.5	64.907	66.904	25.994	-1.997	1.731	-1.153	| **| |	14.995

SUM OF RESIDUALS 3.28271E-12
SUM OF SQUARED RESIDUALS 1357.328

DURBIN-WATSON D 1.558
1ST ORDER AUTOCORRELATION -0.013

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: TOTGE13 FEMALES > 13MM WITH EGGS OR SPENT EGG CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	11746.088	2349.218	8.316	0.0005
ERROR	16	4519.700	282.481		
C TOTAL	21	16265.788			

ROOT MSE	16.807179	R-SQUARE	0.7221
DEP MEAN	72.990508	ADJ R-SQ	0.6353
C.V.	23.02653		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	94.057352	18.842084	4.992	0.0001	INTERCEPT
WATCHLOR	1	-5.285196	3.009598	-1.756	0.0982	Water chlorophyll (microgram/liter)
GSDISP	1	61.162807	25.752435	2.375	0.0304	Grain size dispersion
BSLOPE	1	-509.264	94.969160	-5.362	0.0001	BEACH SLOPE (DROP/HORDIST)
COBWAT	1	0.240955	0.135897	1.773	0.0953	PERCENT OF COBBLE IN WATER
WTCOBBLE	1	-0.639824	0.345464	-1.852	0.0826	

<table>
<tr><th>OBS</th><th>ID</th><th>ACTUAL</th><th>PREDICT VALUE</th><th>STD ERR PREDICT</th><th>RESIDUAL</th><th>STD ERR RESIDUAL</th><th>STUDENT RESIDUAL</th><th>-2-1-0 1 2</th><th>COOK'S D</th></tr>
<tr><td>1</td><td>-12</td><td>100.000</td><td>96.968</td><td>8.894</td><td>3.032</td><td>14.261</td><td>0.213</td><td>| | |</td><td>0.003</td></tr>
<tr><td>2</td><td>-15.5</td><td>.</td><td>62.269</td><td>5.305</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>3</td><td>-100</td><td>19.403</td><td>29.208</td><td>8.578</td><td>-9.805</td><td>14.453</td><td>-0.678</td><td>| *| |</td><td>0.027</td></tr>
<tr><td>4</td><td>65</td><td>78.346</td><td>82.449</td><td>8.710</td><td>-4.103</td><td>14.374</td><td>-0.285</td><td>| | |</td><td>0.005</td></tr>
<tr><td>5</td><td>45</td><td>98.052</td><td>83.217</td><td>6.154</td><td>14.835</td><td>15.640</td><td>0.949</td><td>| |* |</td><td>0.023</td></tr>
<tr><td>6</td><td>25</td><td>66.915</td><td>79.742</td><td>6.561</td><td>-12.827</td><td>15.474</td><td>-0.829</td><td>| *| |</td><td>0.021</td></tr>
<tr><td>7</td><td>-6.5</td><td>72.727</td><td>49.654</td><td>6.439</td><td>23.073</td><td>15.525</td><td>1.486</td><td>| |** |</td><td>0.063</td></tr>
<tr><td>8</td><td>-115</td><td>16.579</td><td>25.878</td><td>9.262</td><td>-9.299</td><td>14.025</td><td>-0.663</td><td>| *| |</td><td>0.032</td></tr>
<tr><td>9</td><td>-0.4</td><td>.</td><td>96.918</td><td>8.993</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>10</td><td>-1.5</td><td>.</td><td>2.009</td><td>18.404</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>11</td><td>1.5</td><td>28.571</td><td>42.221</td><td>8.209</td><td>-13.650</td><td>14.666</td><td>-0.931</td><td>| *| |</td><td>0.045</td></tr>
<tr><td>12</td><td>12</td><td>41.667</td><td>56.870</td><td>5.073</td><td>-15.203</td><td>16.023</td><td>-0.949</td><td>| *| |</td><td>0.015</td></tr>
<tr><td>13</td><td>18</td><td>94.313</td><td>91.557</td><td>10.919</td><td>2.756</td><td>12.778</td><td>0.216</td><td>| | |</td><td>0.006</td></tr>
<tr><td>14</td><td>6.5</td><td>37.500</td><td>37.438</td><td>10.730</td><td>0.061570</td><td>12.937</td><td>0.005</td><td>| | |</td><td>0.000</td></tr>
<tr><td>15</td><td>-12</td><td>.</td><td>28.760</td><td>15.361</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>16</td><td>-15.5</td><td>100.000</td><td>69.017</td><td>9.039</td><td>30.983</td><td>14.169</td><td>2.187</td><td>| |****|</td><td>0.324</td></tr>
<tr><td>17</td><td>-100</td><td>95.476</td><td>74.558</td><td>5.662</td><td>20.918</td><td>15.825</td><td>1.322</td><td>| |** |</td><td>0.037</td></tr>
<tr><td>18</td><td>65</td><td>97.101</td><td>101.242</td><td>8.818</td><td>-4.140</td><td>14.308</td><td>-0.289</td><td>| | |</td><td>0.005</td></tr>
<tr><td>19</td><td>45</td><td>98.408</td><td>92.445</td><td>7.371</td><td>5.963</td><td>15.105</td><td>0.395</td><td>| | |</td><td>0.006</td></tr>
<tr><td>20</td><td>-450</td><td>91.931</td><td>85.406</td><td>11.324</td><td>6.525</td><td>12.420</td><td>0.525</td><td>| |* |</td><td>0.038</td></tr>
<tr><td>21</td><td>25</td><td>93.504</td><td>90.005</td><td>7.360</td><td>3.499</td><td>15.110</td><td>0.232</td><td>| | |</td><td>0.002</td></tr>
</table>

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
22	-6.5	63.953	96.656	7.145	-32.703	15.213	-2.150	| ****| |	0.170
23	-115	33.333	.	.	.	.	.		.
24	-0.4	100.000	102.100	16.271	-2.100	4.213	-0.498	| | |	0.618
25	-1.5	.	72.000	8.729	.	.	.		.
26	1.5	74.096	87.517	8.549	-13.421	14.471	-0.927	| *| |	0.050
27	12	72.340	59.682	6.640	12.659	15.440	0.820	| |* |	0.021
28	18	.	79.821	6.277	.	.	.		.
29	6.5	64.907	71.961	8.338	-7.054	14.593	-0.483	| | |	0.013

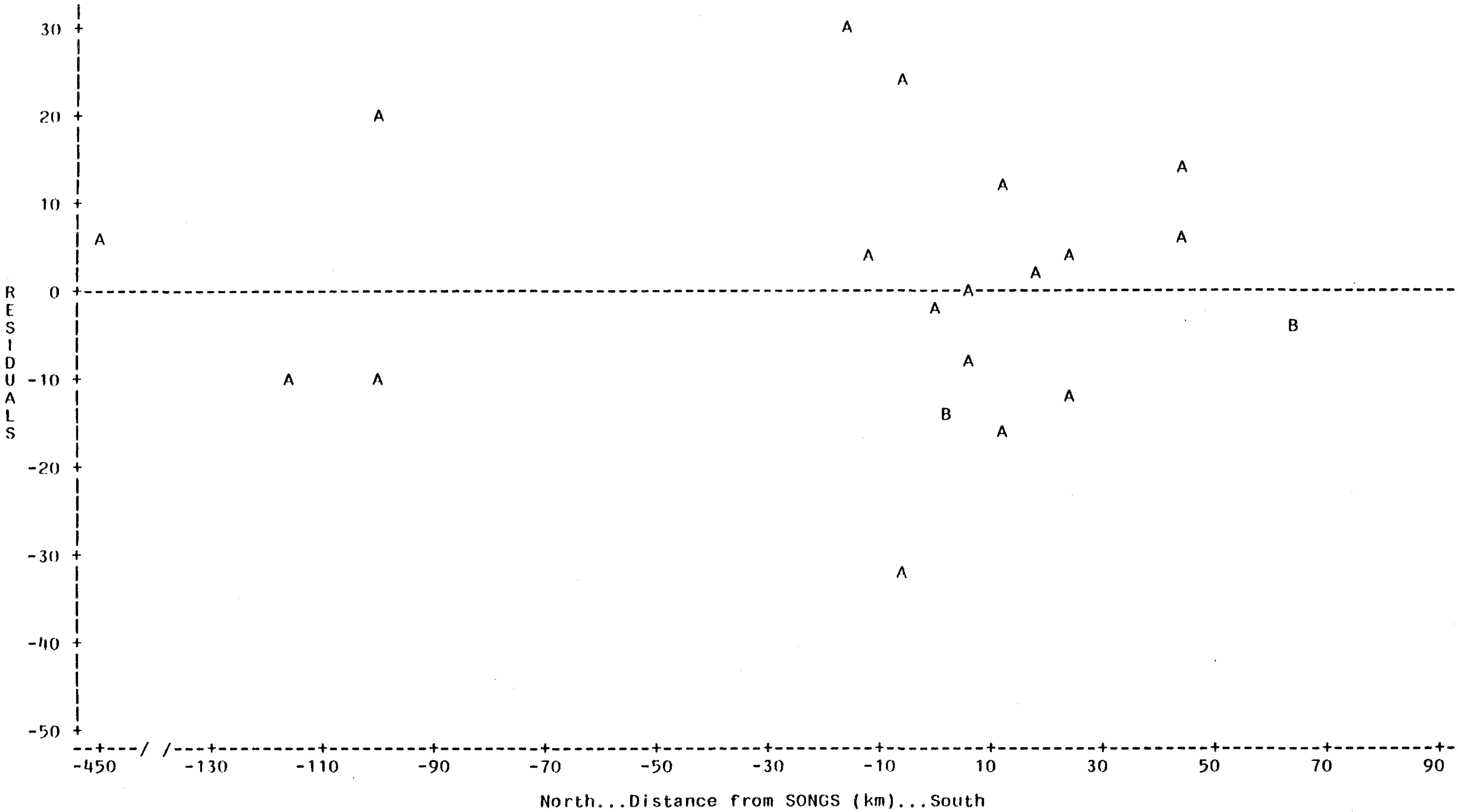
SUM OF RESIDUALS 1.54543E-12
SUM OF SQUARED RESIDUALS 4519.7

DURBIN-WATSON D 2.188
1ST ORDER AUTOCORRELATION -0.079

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR FEMALES > 13MM WITH EGGS OR SPENT EGG CASES

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 7 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: TOT1013 FEMALES 10 TO 13MM WITH EGGS OR SPENT EGG CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	19	24529.586	1291.031	2.464	0.1131
ERROR	7	3667.176	523.882		
C TOTAL	26	28196.762			

ROOT MSE	22.888474	R-SQUARE	0.8699
DEP MEAN	34.904947	ADJ R-SQ	0.5169
C.V.	65.57373		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-498.968	297.006	-1.680	0.1368	INTERCEPT
SESTON	1	-0.467942	0.791770	-0.591	0.5731	SESTON (MG/LITER)
SEDCHLOR	1	-5.618408	14.940999	-0.376	0.7180	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	38.946764	57.797491	0.674	0.5220	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-15.789641	6.389362	-2.471	0.0428	Water chlorophyll (microgram/liter)
WATPHAEO	1	-3.687001	16.596585	-0.222	0.8305	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	39.113815	52.310261	0.748	0.4790	Median grain size
GSDISP	1	-22.882091	112.990	-0.203	0.8453	Grain size dispersion
MOISTURE	1	-351.008	1145.116	-0.307	0.7681	
COBSAND	1	0.399501	1.636970	0.244	0.8142	PERCENT OF COBBLE IN SAND
COBWAT	1	0.227819	0.292792	0.778	0.4620	PERCENT OF COBBLE IN WATER
TEMP	1	26.357829	18.880292	1.396	0.2054	WATER TEMPERATURE
WTCOBBLE	1	0.410501	0.654394	0.627	0.5504	
WATCARB	1	0.932744	3.154217	0.296	0.7760	WATER CARBON (MG/LITER)
SEDCARB	1	-1255.212	1851.123	-0.678	0.5195	Sediment carbon (mg/gram)
LT4PHI	1	29.348019	30.724012	0.955	0.3713	% silt/clay
GT1PHI	1	1.339584	1.971906	0.679	0.5188	% coarse sand
GSSKEW	1	-45.566871	54.863187	-0.831	0.4336	Grain size skewness
BSLOPE	1	34.492625	126.750	0.272	0.7934	BEACH SLOPE (DROP/HORDIST)
DISTANCE	1	-0.015383	0.095724	-0.161	0.8769	North...Distance from SONGS (km)...South

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	11.688	4.875	20.637	6.813	9.900	0.688	| |* |	0.103
2	-15.5	0	21.668	16.711	-21.668	15.641	-1.385	| **| |	0.110
3	-100	1.066	20.173	15.751	-19.107	16.607	-1.151	| **| |	0.060
4	65	16.667	15.724	22.768	0.942584	2.347	0.402	| | |	0.758
5	45	88.025	55.552	12.731	32.472	19.021	1.707	| |*** |	0.065
6	25	8.848	27.935	16.624	-19.087	15.733	-1.213	| **| |	0.082
7	-6.5	0.931677	5.535	19.090	-4.603	12.628	-0.364	| | |	0.015

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
8	-115	0.147493	-4.199	16.352	4.347	16.015	0.271	| | |	0.004
9	-0.4	17.778	21.273	19.646	-3.495	11.744	-0.298	| | |	0.012
10	-1.5	26.667	19.088	21.913	7.579	6.610	1.147	| |** |	0.722
11	1.5	2.381	20.773	17.377	-18.392	14.897	-1.235	| **| |	0.104
12	12	27.273	29.990	21.279	-2.717	8.430	-0.322	| | |	0.033
13	18	24.834	13.731	20.011	11.103	11.110	0.999	| |* |	0.162
14	6.5	0.531915	-10.254	17.871	10.786	14.300	0.754	| |* |	0.044
15	-12	52.041	39.497	20.222	12.544	10.721	1.170	| |** |	0.244
16	-15.5	85.714	72.286	21.292	13.429	8.400	1.599	| |*** |	0.821
17	-100	53.659	52.709	22.044	0.949285	6.159	0.154	| | |	0.015
18	65	89.520	91.818	22.673	-2.298	3.133	-0.734	| *| |	1.409
19	45	97.332	105.515	22.348	-8.182	4.942	-1.656	| ***| |	2.802
20	-450	0	-4.653	22.581	4.653	3.739	1.244	| |** |	2.824
21	125	89.076	86.127	22.107	2.949	5.929	0.497	| | |	0.172
22	-6.5	28.119	27.299	17.039	0.819714	15.283	0.054	| | |	0.000
23	-115	75.000	.	.	.	.	.		.
24	-0.4	69.733	76.756	22.043	-7.024	6.165	-1.139	| **| |	0.830
25	-1.5	35.294	33.096	19.168	2.198	12.509	0.176	| | |	0.004
26	1.5	38.782	50.777	15.341	-11.995	16.986	-0.706	| *| |	0.020
27	12	57.955	52.558	18.420	5.396	13.586	0.397	| | |	0.015
28	18	.	.	.	.	.	.		.
29	6.5	18.372	16.783	22.725	1.589	2.731	0.582	| |* |	1.172

SUM OF RESIDUALS -2.04612E-11
SUM OF SQUARED RESIDUALS 3667.176

DURBIN-WATSON D 2.053
1ST ORDER AUTOCORRELATION -0.030

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: TOT1013 FEMALES 10 TO 13MM WITH EGGS OR SPENT EGG CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	21951.782	3658.630	11.717	0.0001
ERROR	20	6244.980	312.249		
C TOTAL	26	28196.762			

ROOT MSE	17.670568	R-SQUARE	0.7785
DEP MEAN	34.904947	ADJ R-SQ	0.7121
C.V.	50.62483		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-463.474	125.911	-3.681	0.0015	INTERCEPT
WATCHLOR	1	-17.531197	3.418265	-5.129	0.0001	Water chlorophyll (microgram/liter)
GT1PHI	1	1.334234	0.695835	1.917	0.0696	% coarse sand
GSMEDIAN	1	49.483011	18.500322	2.675	0.0146	Median grain size
GSSKEW	1	-40.475711	12.474963	-3.245	0.0041	Grain size skewness
TEMP	1	21.948785	5.603788	3.917	0.0009	WATER TEMPERATURE
WTCOBBLE	1	0.519149	0.255883	2.029	0.0560	

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0	0 1 2	COOK'S D
1	-12	11.688	11.509	5.053	0.179505	16.933	0.011			0.000
2	-15.5	0	9.026	5.714	-9.026	16.721	-0.540	*		0.005
3	-100	1.066	23.700	7.013	-22.633	16.219	-1.395	**		0.052
4	65	16.667	18.540	17.194	-1.873	4.077	-0.459			0.536
5	45	88.025	49.472	6.013	38.552	16.616	2.320		****	0.101
6	25	8.848	41.469	8.139	-32.621	15.685	-2.080	****		0.166
7	-6.5	0.931677	22.101	7.977	-21.169	15.768	-1.343	**		0.066
8	-115	0.147493	6.826	8.530	-6.678	15.475	-0.432			0.008
9	-0.4	17.778	17.270	5.552	0.507368	16.776	0.030			0.000
10	-1.5	26.667	16.643	10.694	10.023	14.067	0.713		*	0.042
11	1.5	2.381	12.767	6.296	-10.386	16.511	-0.629	*		0.008
12	12	27.273	18.660	6.708	8.613	16.348	0.527		*	0.007
13	18	24.834	27.353	11.972	-2.518	12.997	-0.194			0.005
14	6.5	0.531915	-30.514	10.034	31.046	14.545	2.134		****	0.310
15	-12	52.041	50.795	5.836	1.246	16.679	0.075			0.000
16	-15.5	85.714	65.402	10.236	20.312	14.404	1.410		**	0.143
17	-100	53.659	52.976	11.906	0.682117	13.058	0.052			0.000
18	65	89.520	78.611	9.341	10.909	15.000	0.727		*	0.029
19	45	97.332	95.682	8.578	1.650	15.449	0.107			0.001
20	-450	0	-.769991	10.201	0.769991	14.429	0.053			0.000

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
21	25	89.076	79.130	9.696	9.946	14.773	0.673	| |* |	0.028
22	-6.5	28.119	43.943	5.835	-15.824	16.679	-0.949	| *| |	0.016
23	-115	75.000	.	.	.	.	.		.
24	-0.4	69.733	82.061	14.796	-12.328	9.661	-1.276	| **| |	0.546
25	-1.5	35.294	24.791	6.798	10.503	16.310	0.644	| |* |	0.010
26	1.5	38.782	50.449	5.795	-11.667	16.693	-0.699	| *| |	0.008
27	12	57.955	51.347	6.622	6.607	16.383	0.403	| | |	0.004
28	18	.	.	.	.	.	.		.
29	6.5	18.372	23.196	7.350	-4.823	16.069	-0.300	| | |	0.003

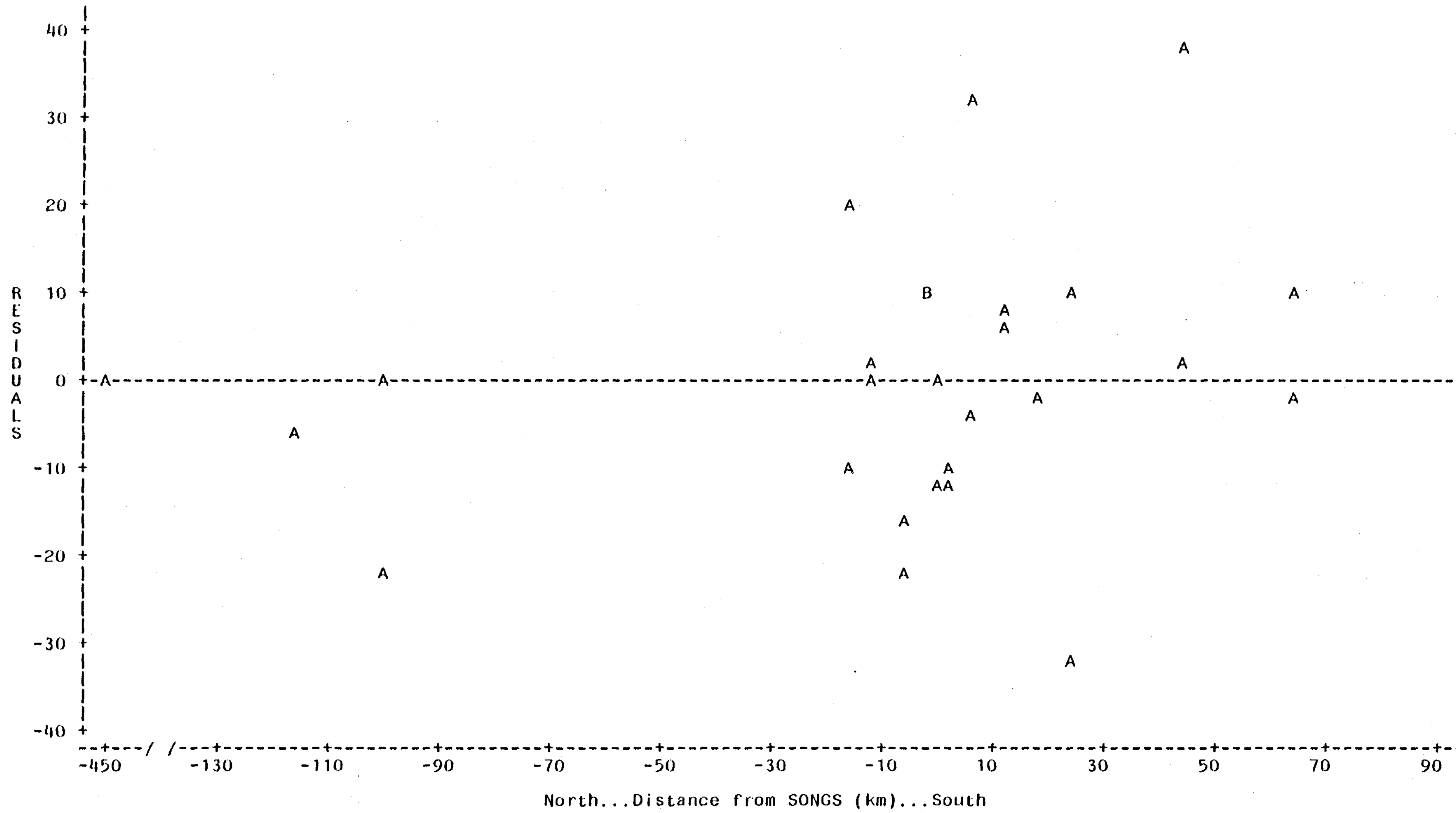
SUM OF RESIDUALS -1.27400E-11
SUM OF SQUARED RESIDUALS 6244.98

DURBIN-WATSON D 2.279
1ST ORDER AUTOCORRELATION -0.151

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR FEMALES 10 TO 13MM WITH EGGS OR SPENT EGG CASES

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: PERALL   PERCENT OF ALL FEMALES WITH EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	19	23179.844	1219.992	2.973	0.0728
ERROR	7	2872.476	410.354		
C TOTAL	26	26052.320			

ROOT MSE	20.257191	R-SQUARE	0.8897
DEP MEAN	24.987332	ADJ R-SQ	0.5905
C.V.	81.06984		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-674.033	262.862	-2.564	0.0373	INTERCEPT
SESTON	1	-0.818263	0.700747	-1.168	0.2812	SESTON (MG/LITER)
SEDCHLOR	1	-7.709291	13.223365	-0.583	0.5782	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	45.684495	51.153029	0.893	0.4015	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-10.930086	5.654834	-1.933	0.0945	Water chlorophyll (microgram/liter)
WATPHAEO	1	-3.205379	14.688624	-0.218	0.8335	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	62.666026	46.296617	1.354	0.2179	Median grain size
GSDISP	1	-46.188181	100.001	-0.462	0.6582	Grain size dispersion
MOISTURE	1	-863.078	1013.472	-0.852	0.4226	
COBSAND	1	-0.483412	1.448783	-0.334	0.7484	PERCENT OF COBBLE IN SAND
COBWAT	1	0.502026	0.259132	1.937	0.0939	PERCENT OF COBBLE IN WATER
TEMP	1	35.545308	16.709793	2.127	0.0710	WATER TEMPERATURE
WTCOBBLE	1	0.320523	0.579165	0.553	0.5972	
WATCARB	1	0.388789	2.791605	0.139	0.8932	WATER CARBON (MG/LITER)
SEDCARB	1	155.168	1638.316	0.095	0.9272	Sediment carbon (mg/gram)
LT4PHI	1	53.138726	27.191947	1.954	0.0916	% silt/clay
GT1PHI	1	1.375457	1.745214	0.788	0.4565	% coarse sand
GSSKEW	1	-54.201050	48.556056	-1.116	0.3012	Grain size skewness
BSLOPE	1	18.447184	112.178	0.164	0.8740	BEACH SLOPE (DROP/HORDIST)
DISTANCE	1	-0.129665	0.084719	-1.531	0.1697	North...Distance from SONGS (km)...South

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	1.027	-8.787	18.264	9.814	8.762	1.120	| |** |	0.273
2	-15.5	0	17.411	14.790	-17.411	13.843	-1.258	| **| |	0.090
3	-100	2.487	22.879	13.941	-20.392	14.697	-1.387	| **| |	0.087
4	65	24.686	24.371	20.150	0.314613	2.078	0.151	| | |	0.108
5	45	80.507	50.723	11.268	29.783	16.834	1.769	| |*** |	0.070
6	25	21.508	36.323	14.713	-14.816	13.924	-1.064	| **| |	0.063
7	-6.5	0.625782	0.095210	16.895	0.530572	11.176	0.047	| | |	0.000

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
8	-115	1.023	1.220	14.472	-.196418	14.174	-0.014	| | |	0.000
9	-0.4	1.592	10.530	17.387	-8.938	10.394	-0.860	| *| |	0.103
10	-1.5	1.626	-7.347	19.394	8.973	5.850	1.534	| |*** |	1.292
11	1.5	0.425532	6.909	15.379	-6.484	13.185	-0.492	| | |	0.016
12	12	12.216	12.763	18.833	-.547570	7.461	-0.073	| | |	0.002
13	18	24.847	17.667	17.711	7.180	9.832	0.730	| |* |	0.086
14	6.5	0.535715	-2.798	15.817	3.334	12.656	0.263	| | |	0.005
15	-12	8.969	4.976	17.898	3.992	9.488	0.421	| | |	0.031
16	-15.5	65.278	55.736	18.844	9.542	7.434	1.284	| |** |	0.529
17	-100	77.980	73.545	19.510	4.434	5.451	0.813	| |* |	0.424
18	65	87.242	89.742	20.067	-2.500	2.773	-0.901	| *| |	2.128
19	45	82.377	90.653	19.779	-8.275	4.374	-1.892	| ***| |	3.659
20	-450	36.752	31.518	19.985	5.233	3.309	1.582	| |*** |	4.561
21	25	86.071	82.703	19.566	3.368	5.247	0.642	| |* |	0.286
22	-6.5	0.632911	-.326550	15.080	0.959462	13.526	0.071	| | |	0.000
23	-115	37.500	.	.	.	.	.		.
24	-0.4	20.842	28.076	19.508	-7.234	5.456	-1.326	| **| |	1.123
25	-1.5	13.953	12.064	16.964	1.890	11.071	0.171	| | |	0.003
26	1.5	1.626	17.600	13.577	-15.974	15.034	-1.063	| **| |	0.046
27	12	19.101	7.774	16.303	11.328	12.024	0.942	| |* |	0.082
28	18	0	.	.	.	.	.		.
29	6.5	0.729167	-1.364	20.112	2.093	2.417	0.866	| |* |	2.597

SUM OF RESIDUALS -2.69018E-11
SUM OF SQUARED RESIDUALS 2872.476

DURBIN-WATSON D 2.307
1ST ORDER AUTOCORRELATION -0.184

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: PERALL PERCENT OF ALL FEMALES WITH EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	17986.645	3597.329	9.366	0.0001
ERROR	21	8065.675	384.080		
C TOTAL	26	26052.320			

ROOT MSE	19.597953	R-SQUARE	0.6904
DEP MEAN	24.987332	ADJ R-SQ	0.6167
C.V.	78.43156		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-235.720	107.288	-2.197	0.0394	INTERCEPT
SESTON	1	-1.012391	0.364314	-2.779	0.0113	SESTON (MG/LITER)
SEDCHLOR	1	-15.378005	9.782806	-1.572	0.1309	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	106.767	34.024799	3.138	0.0050	Sediment phaeophytin (microgram/cm2)
GSDISP	1	57.958918	29.743843	1.949	0.0648	Grain size dispersion
TEMP	1	10.974844	4.964375	2.211	0.0383	WATER TEMPERATURE

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	1.027	-15.226	15.335	16.254	12.203	1.332	| |** |	0.467
2	-15.5	0	16.734	4.811	-16.734	18.998	-0.881	| *| |	0.008
3	-100	2.487	21.639	8.118	-19.151	17.837	-1.074	| **| |	0.040
4	65	24.686	21.400	10.452	3.286	16.578	0.198	| | |	0.003
5	45	80.507	51.307	6.424	29.200	18.515	1.577	| |*** |	0.050
6	25	21.508	38.582	6.604	-17.075	18.452	-0.925	| *| |	0.018
7	-6.5	0.625782	3.130	7.984	-2.504	17.898	-0.140	| | |	0.001
8	-115	1.023	8.147	6.817	-7.123	18.374	-0.388	| | |	0.003
9	-0.4	1.592	7.341	5.098	-5.750	18.923	-0.304	| | |	0.001
10	-1.5	1.626	-1.638	6.160	3.264	18.605	0.175	| | |	0.001
11	1.5	0.425532	16.088	5.001	-15.662	18.949	-0.827	| *| |	0.008
12	12	12.216	22.446	4.543	-10.230	19.064	-0.537	| *| |	0.003
13	18	24.847	41.957	7.820	-17.111	17.970	-0.952	| *| |	0.029
14	6.5	0.535715	8.525	7.495	-7.990	18.108	-0.441	| | |	0.006
15	-12	8.969	16.427	5.879	-7.458	18.696	-0.399	| | |	0.003
16	-15.5	65.278	31.363	9.733	33.915	17.010	1.994	| |*** |	0.217
17	-100	77.980	64.568	12.330	13.412	15.233	0.880	| |* |	0.085
18	65	87.242	88.465	18.156	-1.223	7.377	-0.166	| | |	0.028
19	45	82.377	98.231	17.272	-15.853	9.261	-1.712	| ***| |	1.699
20	-450	36.752	30.158	12.738	6.594	14.893	0.443	| | |	0.024
21	25	86.071	31.016	7.764	55.055	17.994	3.060	| |******|	0.290

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

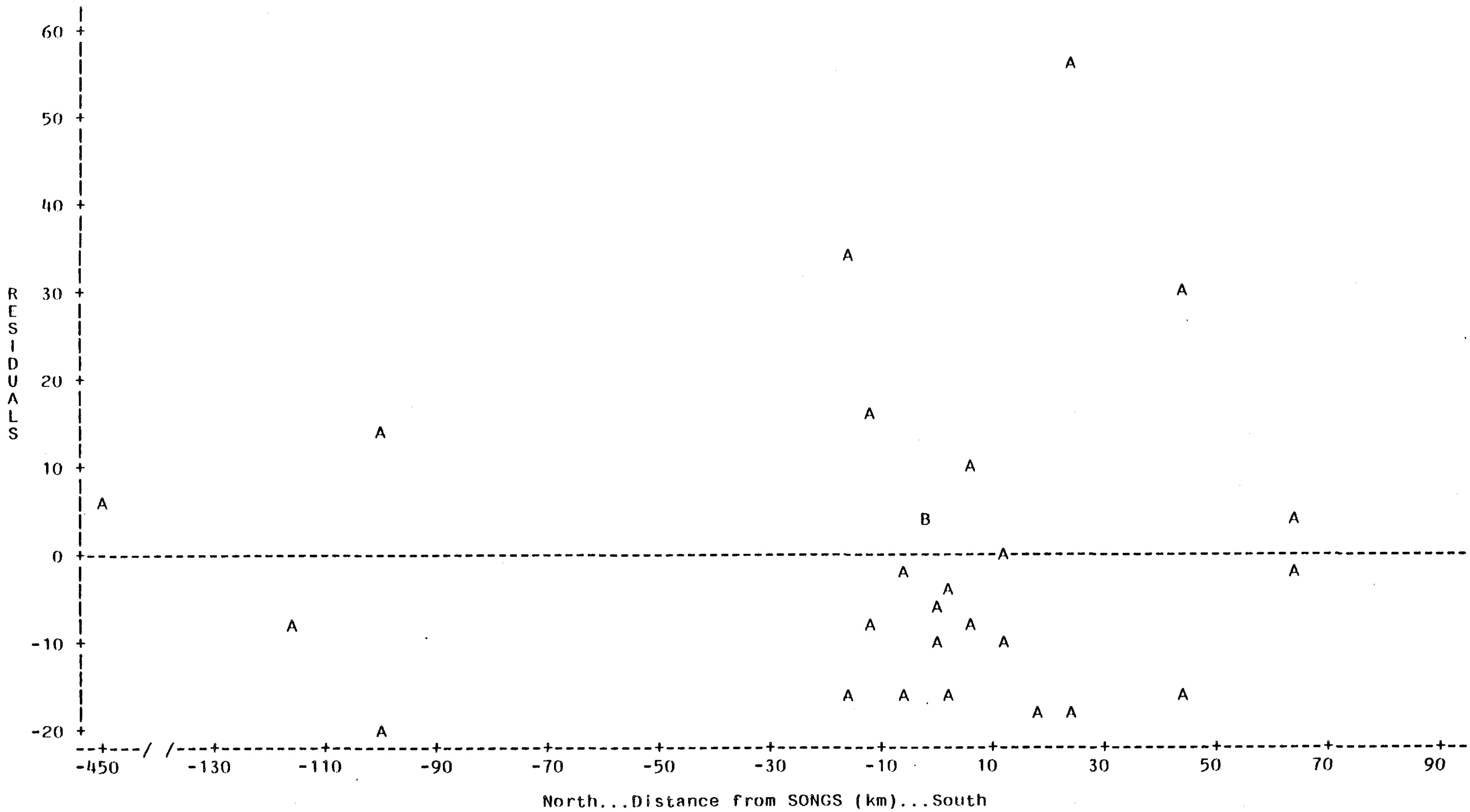
OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
22	-6.5	0.632911	16.761	4.425	-16.128	19.092	-0.845	| *| |	0.006
23	-115	37.500	.	.	.	.	.		.
24	-0.4	20.842	30.320	10.152	-9.478	16.764	-0.565	| *| |	0.020
25	-1.5	13.953	10.562	7.855	3.392	17.955	0.189	| | |	0.001
26	1.5	1.626	6.522	5.800	-4.896	18.720	-0.262	| | |	0.001
27	12	19.101	18.792	5.558	0.308705	18.793	0.016	| | |	0.000
28	18	0	.	.	.	.	.		.
29	6.5	0.729167	-8.958	8.264	9.687	17.770	0.545	| |* |	0.011

SUM OF RESIDUALS -4.20353E-12
SUM OF SQUARED RESIDUALS 8065.675

DURBIN-WATSON D 2.028
1ST ORDER AUTOCORRELATION -0.042

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR PERCENT OF ALL FEMALES WITH EGGS

PLOT OF RESID*DISTANCE LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: PERGE13 PERCENT OF FEMALES > 13MM WITH EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	19	31122.601	1638.032	2.743	0.3008
ERROR	2	1194.520	597.260		
C TOTAL	21	32317.121			

ROOT MSE	24.438901	R-SQUARE	0.9630
DEP MEAN	52.776272	ADJ R-SQ	0.6119
C.V.	46.30661		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-689.688	526.148	-1.311	0.3202	INTERCEPT
SESTON	1	-4.184180	1.682338	-2.487	0.1307	SESTON (MG/LITER)
SEDCHLOR	1	-19.903092	19.686934	-1.011	0.4184	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	134.920	87.475384	1.542	0.2629	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-17.704132	10.481327	-1.689	0.2333	Water chlorophyll (microgram/liter)
WATPHAEO	1	-60.682471	29.693515	-2.044	0.1777	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	-22.023792	107.352	-0.205	0.8564	Median grain size
GSDISP	1	336.881	328.647	1.025	0.4131	Grain size dispersion
MOISTURE	1	-2924.736	2327.234	-1.257	0.3357	
COBSAND	1	0.270313	3.293687	0.082	0.9421	PERCENT OF COBBLE IN SAND
COBWAT	1	1.208162	0.821518	1.471	0.2792	PERCENT OF COBBLE IN WATER
TEMP	1	55.108559	39.689329	1.388	0.2994	WATER TEMPERATURE
WICOBBLE	1	-1.093714	2.027650	-0.539	0.6436	
WATCARB	1	11.462377	5.446364	2.105	0.1700	WATER CARBON (MG/LITER)
SEDCARB	1	-2047.907	3400.766	-0.602	0.6082	Sediment carbon (mg/gram)
LT4PHI	1	101.055	48.784288	2.071	0.1741	% silt/clay
GT1PHI	1	-3.354626	4.918137	-0.682	0.5656	% coarse sand
GSSKEW	1	-11.461123	112.445	-0.102	0.9281	Grain size skewness
BSLOPE	1	-673.637	434.002	-1.552	0.2608	BEACH SLOPE (DROP/HORDIST)
DISTANCE	1	-0.175367	0.137472	-1.276	0.3302	North...Distance from SONGS (km)...South

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	33.333	28.973	24.154	4.360	3.718	1.173	| |** |	2.901
2	-15.5	.	58.137	38.907	.	.	.		.
3	-100	8.955	16.071	21.023	-7.116	12.462	-0.571	| *| |	0.046
4	65	76.772	77.913	24.382	-1.141	1.663	-0.687	| *| |	5.069
5	45	97.403	90.716	23.655	6.687	6.139	1.089	| |** |	0.881
6	25	66.169	53.946	22.076	12.223	10.484	1.166	| |** |	0.301
7	-6.5	36.364	22.729	21.737	13.634	11.169	1.221	| |** |	0.282

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
8	-115	5.000	15.905	18.112	-10.905	16.408	-0.665	| *| |	0.027
9	-0.4	.	29.099	70.692	.	.	.		.
10	-1.5	.	-143.484	97.932	.	.	.		.
11	1.5	7.143	10.701	23.032	-3.558	8.172	-0.435	| | |	0.075
12	12	33.333	34.549	24.409	-1.216	1.213	-1.002	| **| |	20.335
13	18	93.839	102.077	23.694	-8.238	5.986	-1.376	| **| |	1.484
14	6.5	25.000	24.668	24.217	0.332380	3.287	0.101	| | |	0.028
15	-12	.	-60.808	79.623	.	.	.		.
16	-15.5	100.000	99.575	24.401	0.424946	1.359	0.313	| | |	1.575
17	-100	77.738	75.058	24.363	2.680	1.922	1.395	| |** |	15.624
18	65	94.928	95.069	24.347	-.141484	2.122	-0.067	| | |	0.029
19	45	96.815	99.973	24.335	-3.158	2.255	-1.400	| **| |	11.412
20	-450	88.214	83.996	24.250	4.218	3.031	1.392	| |** |	6.196
21	25	88.986	94.150	24.153	-5.163	3.727	-1.385	| **| |	4.031
22	-6.5	4.651	17.042	22.017	-12.391	10.608	-1.168	| **| |	0.294
23	-115	0	.	.	.	.	.		.
24	-0.4	100.000	100.352	24.415	-.351990	1.079	-0.326	| | |	2.726
25	-1.5	.	-11.566	48.018	.	.	.		.
26	1.5	2.410	8.716	23.339	-6.307	7.249	-0.870	| *| |	0.392
27	12	23.404	6.544	20.933	16.860	12.613	1.337	| |** |	0.246
28	18	.	.	.	.	.	.		.
29	6.5	0.621118	2.355	24.385	-1.734	1.624	-1.067	| **| |	12.842

SUM OF RESIDUALS -1.81912E-11
SUM OF SQUARED RESIDUALS 1194.52

DURBIN-WATSON D 1.483
1ST ORDER AUTOCORRELATION 0.033

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: PERGE13 PERCENT OF FEMALES > 13MM WITH EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	23910.432	4782.086	9.101	0.0003
ERROR	16	8406.689	525.418		
C TOTAL	21	32317.121			

ROOT MSE	22.922000	R-SQUARE	0.7399
DEP MEAN	52.776272	ADJ R-SQ	0.6586
C.V.	43.4324		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-457.095	137.159	-3.333	0.0042	INTERCEPT
SESTON	1	-1.195488	0.443155	-2.698	0.0158	SESTON (MG/LITER)
SEDPHAEO	1	30.632880	16.243436	1.886	0.0776	Sediment phaeophytin (microgram/cm2)
GSDISP	1	135.119	35.980632	3.755	0.0017	Grain size dispersion
LT4PHI	1	54.162284	17.530542	3.090	0.0070	% silt/clay
TEMP	1	18.005153	6.123637	2.940	0.0096	WATER TEMPERATURE

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	33.333	27.746	19.306	5.587	12.357	0.452	| | |	0.083
2	-15.5	.	78.903	11.999	.	.	.		.
3	-100	8.955	20.531	10.672	-11.576	20.286	-0.571	| *| |	0.015
4	65	76.772	76.592	11.292	0.179555	19.948	0.009	| | |	0.000
5	45	97.403	71.295	7.166	26.108	21.773	1.199	| |** |	0.026
6	25	66.169	82.675	9.287	-16.506	20.956	-0.788	| *| |	0.020
7	-6.5	36.364	-2.833	10.895	39.197	20.167	1.944	| |*** |	0.184
8	-115	5.000	0.897665	10.504	4.102	20.373	0.201	| | |	0.002
9	-0.4	.	18.661	7.812	.	.	.		.
10	-1.5	.	14.310	8.444	.	.	.		.
11	1.5	7.143	32.870	8.490	-25.727	21.292	-1.208	| **| |	0.039
12	12	33.333	38.764	5.358	-5.431	22.287	-0.244	| | |	0.001
13	18	93.839	71.812	9.487	22.026	20.867	1.056	| |** |	0.038
14	6.5	25.000	21.821	9.231	3.179	20.981	0.152	| | |	0.001
15	-12	.	57.527	7.521	.	.	.		.
16	-15.5	100.000	80.553	11.894	19.447	19.595	0.992	| |* |	0.060
17	-100	77.738	93.010	14.995	-15.272	17.337	-0.881	| *| |	0.097
18	65	94.928	116.092	18.174	-21.164	13.969	-1.515	| ***| |	0.648
19	45	96.815	81.860	14.908	14.955	17.411	0.859	| |* |	0.090
20	-450	88.214	60.923	14.978	27.291	17.351	1.573	| |*** |	0.307
21	25	88.986	81.731	15.682	7.255	16.718	0.434	| | |	0.028

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

<table>
<tr><th>OBS</th><th>ID</th><th>ACTUAL</th><th>PREDICT VALUE</th><th>STD ERR PREDICT</th><th>RESIDUAL</th><th>STD ERR RESIDUAL</th><th>STUDENT RESIDUAL</th><th>-2-1-0 1 2</th><th>COOK'S D</th></tr>
<tr><td>22</td><td>-6.5</td><td>4.651</td><td>42.324</td><td>5.960</td><td>-37.673</td><td>22.133</td><td>-1.702</td><td>| ***| |</td><td>0.035</td></tr>
<tr><td>23</td><td>-115</td><td>0</td><td>.</td><td>.</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>24</td><td>-0.4</td><td>100.000</td><td>94.476</td><td>12.950</td><td>5.524</td><td>18.913</td><td>0.292</td><td>| | |</td><td>0.007</td></tr>
<tr><td>25</td><td>-1.5</td><td>.</td><td>19.881</td><td>11.611</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>26</td><td>1.5</td><td>2.410</td><td>26.376</td><td>8.498</td><td>-23.967</td><td>21.289</td><td>-1.126</td><td>| **| |</td><td>0.034</td></tr>
<tr><td>27</td><td>12</td><td>23.404</td><td>20.147</td><td>10.115</td><td>3.257</td><td>20.569</td><td>0.158</td><td>| | |</td><td>0.001</td></tr>
<tr><td>28</td><td>18</td><td>.</td><td>.</td><td>.</td><td>.</td><td>.</td><td>.</td><td></td><td>.</td></tr>
<tr><td>29</td><td>6.5</td><td>0.621118</td><td>21.414</td><td>11.351</td><td>-20.793</td><td>19.914</td><td>-1.044</td><td>| **| |</td><td>0.059</td></tr>
</table>

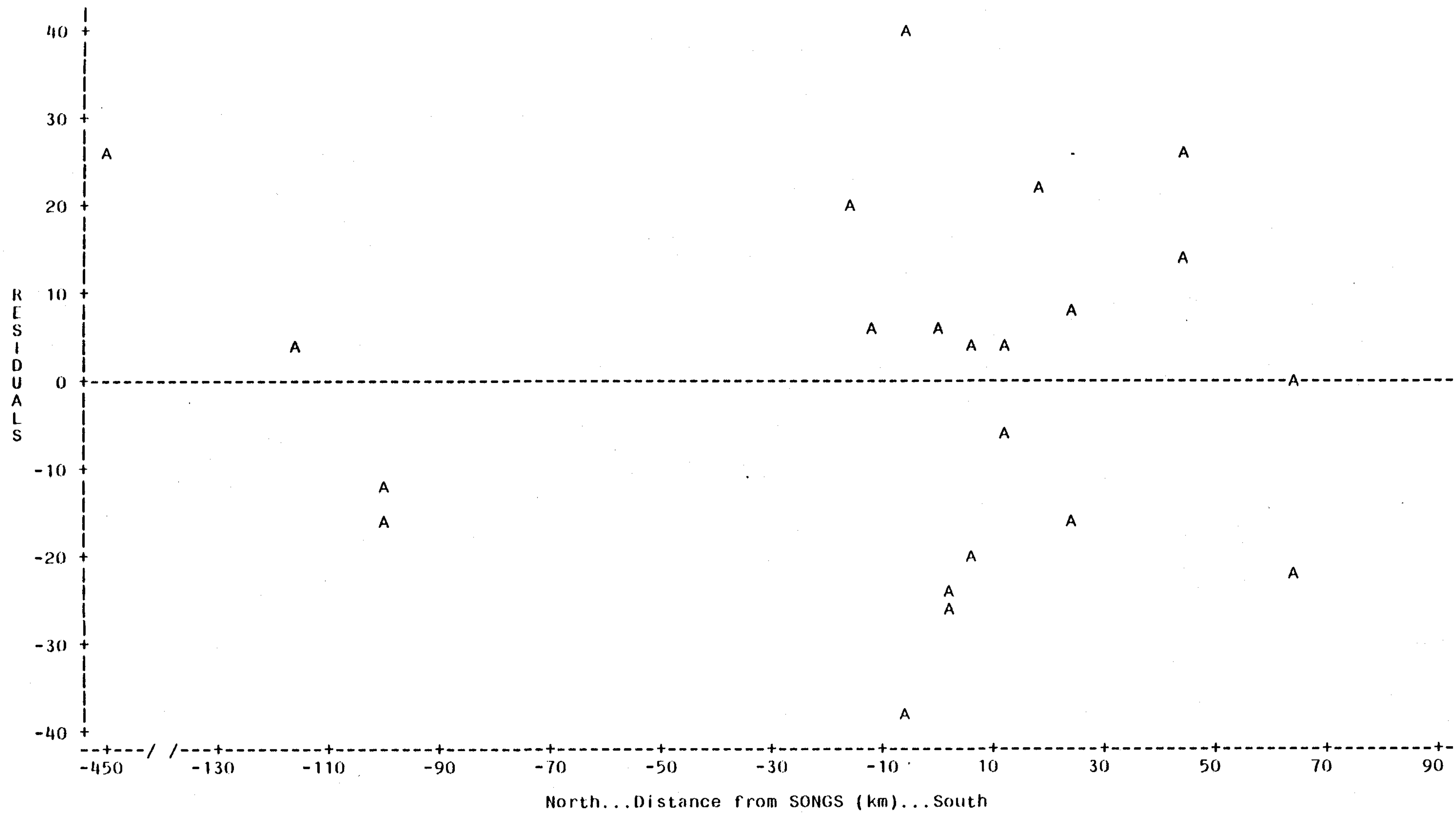
SUM OF RESIDUALS -7.96163E-12
SUM OF SQUARED RESIDUALS 8406.689

DURBIN-WATSON D 2.315
1ST ORDER AUTOCORRELATION -0.139

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR PERCENT OF FEMALES > 13MM WITH EGGS

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 7 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: PER1013 PERCENT OF FEMALES 10 TO 13MM WITH EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	19	23853.577	1255.451	2.510	0.1085
ERROR	7	3501.031	500.147		
C TOTAL	26	27354.608			

ROOT MSE	22.363974	R-SQUARE	0.8720
DEP MEAN	23.273953	ADJ R-SQ	0.5246
C.V.	96.09014		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-764.161	290.200	-2.633	0.0338	INTERCEPT
SESTON	1	-0.860330	0.773626	-1.112	0.3028	SESTON (MG/LITER)
SEDCHLOR	1	-12.128371	14.598619	-0.831	0.4335	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	67.649165	56.473034	1.198	0.2699	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-12.153618	6.242947	-1.947	0.0926	Water chlorophyll (microgram/liter)
WATPHAEO	1	-19.872002	16.216266	-1.225	0.2600	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	50.524431	51.111547	0.989	0.3558	Median grain size
GSDISP	1	-73.710580	110.401	-0.668	0.5257	Grain size dispersion
MOISTURE	1	-942.239	1118.875	-0.842	0.4275	
COBSAND	1	-1.218929	1.599458	-0.762	0.4709	PERCENT OF COBBLE IN SAND
COBWAT	1	0.526738	0.286082	1.841	0.1082	PERCENT OF COBBLE IN WATER
TEMP	1	41.815870	18.447641	2.267	0.0578	WATER TEMPERATURE
WTCOBBLE	1	0.838577	0.639399	1.312	0.2311	
WATCARB	1	2.311465	3.081937	0.750	0.4777	WATER CARBON (MG/LITER)
SEDCARB	1	456.338	1808.704	0.252	0.8081	Sediment carbon (mg/gram)
LT4PHI	1	58.257709	30.019957	1.941	0.0934	% silt/clay
GT1PHI	1	1.841575	1.926719	0.956	0.3710	% coarse sand
GSSKEW	1	-51.656839	53.605971	-0.964	0.3673	Grain size skewness
BSLOPE	1	4.661128	123.845	0.038	0.9710	BEACH SLOPE (DROP/HORDIST)
DISTANCE	1	-0.056442	0.093530	-0.603	0.5652	North...Distance from SONGS (km)...South

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	6.494	-2.306	20.164	8.799	9.673	0.910	| |* |	0.180
2	-15.5	0	16.913	16.328	-16.913	15.282	-1.107	| **| |	0.070
3	-100	0.639659	17.840	15.390	-17.200	16.226	-1.060	| **| |	0.051
4	65	16.667	15.166	22.246	1.501	2.294	0.654	| |* |	2.014
5	45	87.922	51.561	12.439	36.361	18.585	1.956	| |*** |	0.086
6	25	8.539	32.032	16.243	-23.493	15.373	-1.528	| ***| |	0.130
7	-6.5	0	2.588	18.652	-2.588	12.339	-0.210	| | |	0.005

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
8	-115	0	-.733522	15.978	0.733522	15.648	0.047	| | |	0.000
9	-0.4	4.444	13.539	19.196	-9.094	11.475	-0.793	| *| |	0.088
10	-1.5	13.333	3.285	21.411	10.049	6.459	1.556	| |*** |	1.330
11	1.5	0.396825	8.121	16.979	-7.724	14.556	-0.531	| *| |	0.019
12	12	27.273	27.666	20.792	-.393037	8.237	-0.048	| | |	0.001
13	18	24.834	12.831	19.553	12.003	10.855	1.106	| |** |	0.198
14	6.5	0	-1.296	17.462	1.296	13.973	0.093	| | |	0.001
15	-12	6.122	-.615010	19.759	6.737	10.475	0.643	| |* |	0.074
16	-15.5	78.571	68.202	20.804	10.369	8.207	1.263	| |** |	0.513
17	-100	48.780	46.691	21.539	2.090	6.018	0.347	| | |	0.077
18	65	86.463	90.305	22.153	-3.842	3.061	-1.255	| **| |	4.125
19	45	96.107	104.032	21.836	-7.926	4.829	-1.641	| ***| |	2.754
20	-450	0	-4.930	22.064	4.930	3.653	1.349	| |** |	3.321
21	25	79.283	75.178	21.601	4.105	5.793	0.709	| |* |	0.349
22	-6.5	0.186220	-3.890	16.648	4.076	14.933	0.273	| | |	0.005
23	-115	50.000	.	.	.	.	.		.
24	-0.4	21.365	30.772	21.537	-9.407	6.024	-1.562	| ***| |	1.559
25	-1.5	5.882	4.135	18.728	1.747	12.223	0.143	| | |	0.002
26	1.5	0.320513	13.056	14.989	-12.736	16.597	-0.767	| *| |	0.024
27	12	14.773	10.693	17.998	4.080	13.274	0.307	| | |	0.009
28	18	.	.	.	.	.	.		.
29	6.5	0	-2.439	22.204	2.439	2.668	0.914	| |* |	2.893

SUM OF RESIDUALS -2.84621E-11
SUM OF SQUARED RESIDUALS 3501.031

DURBIN-WATSON D 2.438
1ST ORDER AUTOCORRELATION -0.222

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: PER1013 PERCENT OF FEMALES 10 TO 13MM WITH EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	19555.444	3911.089	10.531	0.0001
ERROR	21	7799.164	371.389		
C TOTAL	26	27354.608			

ROOT MSE	19.271450	R-SQUARE	0.7149
DEP MEAN	23.273953	ADJ R-SQ	0.6470
C.V.	82.80265		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-267.293	96.999386	-2.756	0.0119	INTERCEPT
WATCHLOR	1	-8.529997	3.588605	-2.377	0.0270	Water chlorophyll (microgram/liter)
SEDCHLOR	1	-17.097476	9.613213	-1.779	0.0898	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	89.294925	33.609025	2.657	0.0148	Sediment phaeophytin (microgram/cm2)
L14PHI	1	24.011993	13.124256	1.830	0.0815	% silt/clay
TEMP	1	13.278380	5.083506	2.612	0.0163	WATER TEMPERATURE

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	6.494	13.847	5.502	-7.353	18.469	-0.398	|	0.002
2	-15.5	0	22.939	8.972	-22.939	17.056	-1.345	**|	0.083
3	-100	0.639659	15.023	7.023	-14.383	17.946	-0.801	*|	0.016
4	65	16.667	26.960	10.703	-10.293	16.026	-0.642	*|	0.031
5	45	87.922	45.607	5.520	42.316	18.464	2.292	|****	0.078
6	25	8.539	27.704	7.107	-19.165	17.913	-1.070	**|	0.030
7	-6.5	0	9.313	5.740	-9.313	18.397	-0.506	*|	0.004
8	-115	0	5.111	7.021	-5.111	17.947	-0.285	|	0.002
9	-0.4	4.444	0.192092	5.823	4.252	18.371	0.231	|	0.001
10	-1.5	13.333	-9.006	7.331	22.340	17.823	1.253	|**	0.044
11	1.5	0.396825	-4.160	6.524	4.557	18.133	0.251	|	0.001
12	12	27.273	21.602	4.440	5.671	18.753	0.302	|	0.001
13	18	24.834	8.356	9.159	16.478	16.956	0.972	|*	0.046
14	6.5	0	3.163	10.728	-3.163	16.010	-0.198	|	0.003
15	-12	6.122	21.415	6.200	-15.293	18.247	-0.838	*|	0.014
16	-15.5	78.571	31.198	7.857	47.374	17.597	2.692	|*****	0.241
17	-100	48.780	56.741	11.782	-7.961	15.250	-0.522	*|	0.027
18	65	86.463	82.587	17.867	3.875	7.222	0.537	|*	0.294
19	45	96.107	112.414	16.992	-16.307	9.091	-1.794	***|	1.874
20	-450	0	1.342	10.954	-1.342	15.856	-0.085	|	0.001
21	25	79.283	59.154	12.345	20.129	14.798	1.360	|**	0.215

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
22	-6.5	0.186220	19.799	5.581	-19.612	18.445	-1.063	| **| |	0.017
23	-115	50.000	.	.	.	.	.		.
24	-0.4	21.365	22.069	7.055	-.703915	17.934	-0.039	| | |	0.000
25	-1.5	5.882	1.512	7.150	4.370	17.896	0.244	| | |	0.002
26	1.5	0.320513	9.905	7.225	-9.584	17.866	-0.536	| *| |	0.008
27	12	14.773	16.099	8.757	-1.326	17.167	-0.077	| | |	0.000
28	18	.	.	.	.	.	.		.
29	6.5	0	7.513	7.827	-7.513	17.610	-0.427	| | |	0.006

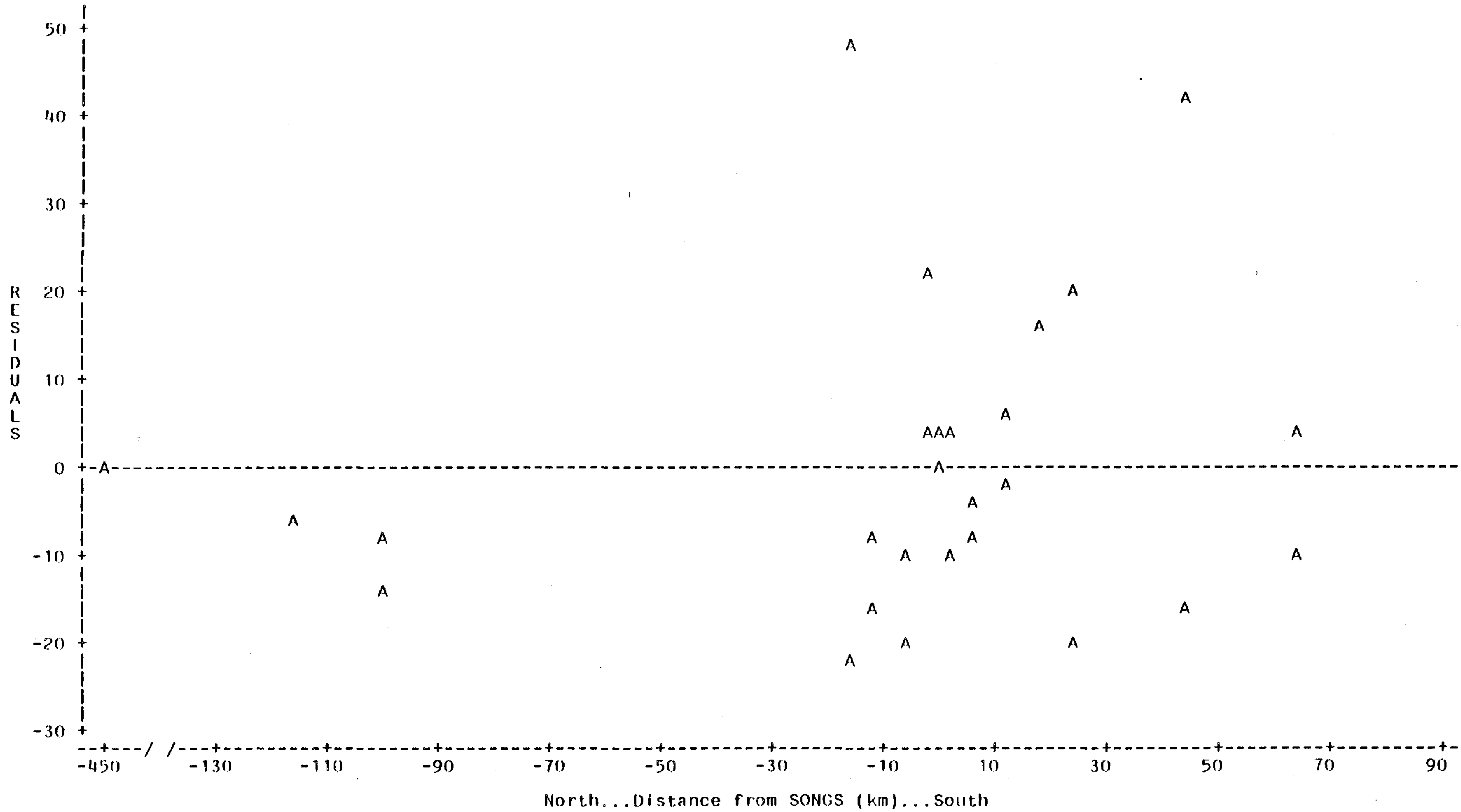
SUM OF RESIDUALS -8.42526E-12
SUM OF SQUARED RESIDUALS 7799.164

DURBIN-WATSON D 2.385
1ST ORDER AUTOCORRELATION -0.221

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR PERCENT OF FEMALES 10 TO 13MM WITH EGGS

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: PERSPT PERCENT OF ALL FEMALES WITH SPENT EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	9	2690.064	298.896	6.482	0.0438
ERROR	4	184.452	46.112970		
C TOTAL	13	2874.516			

ROOT MSE	6.790653	R-SQUARE	0.9358
DEP MEAN	18.232691	ADJ R-SQ	0.7915
C.V.	37.24438		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	110.347	35.382391	3.119	0.0356	INTERCEPT
SESTON	1	-0.214750	0.491225	-0.437	0.6846	SESTON (MG/LITER)
SEDPHAEO	1	-10.369827	9.971395	-1.040	0.3571	Sediment phaeophytin (microgram/cm2)
GSMEDIAN	1	-17.161171	10.069387	-1.704	0.1635	Median grain size
GSDISP	1	2.056299	43.490189	0.047	0.9646	Grain size dispersion
SEDCARB	1	-1898.030	727.454	-2.609	0.0595	Sediment carbon (mg/gram)
COBSAND	1	2.213859	0.773746	2.861	0.0459	PERCENT OF COBBLE IN SAND
WTCOBBLE	1	-0.679253	0.457532	-1.485	0.2118	
JWATCHL	1	-14.486813	3.924423	-3.691	0.0210	
JWATPHA	1	-26.221596	8.631657	-3.038	0.0385	

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	32.287	25.372	3.670	6.915	5.714	1.210	| |** |	0.060
2	-15.5	8.333	16.926	4.707	-8.593	4.895	-1.756	| ***| |	0.285
3	-100	17.140	14.359	3.191	2.781	5.994	0.464	| | |	0.006
4	65	2.814	2.958	6.781	-.143388	0.367447	-0.390	| | |	5.186
5	45	1.950	2.521	6.651	-.571422	1.369	-0.417	| | |	0.411
6	-450	1.496	-1.304	6.368	2.800	2.358	1.188	| |** |	1.029
7	25	6.910	9.808	5.999	-2.899	3.182	-0.911	| *| |	0.295
8	-6.5	26.203	28.767	4.940	-2.564	4.659	-0.550	| *| |	0.034
9	-115	25.000	.	.	.	.	.		.
10	-0.4	33.632	33.410	6.784	0.221872	0.297104	0.747	| |* |	29.078
11	-1.5	16.279	20.335	5.626	-4.056	3.803	-1.066	| **| |	0.249
12	1.5	42.509	40.199	4.820	2.309	4.783	0.483	| | |	0.024
13	12	35.393	34.342	6.588	1.051	1.647	0.638	| |* |	0.652
14	18	0	-2.984	5.815	2.984	3.507	0.851	| |* |	0.199
15	6.5	30.312	30.548	6.785	-.235079	0.276129	-0.851	| *| |	43.761

SUM OF RESIDUALS 1.10889E-12
SUM OF SQUARED RESIDUALS 184.4519

DURBIN-WATSON D 2.695
1ST ORDER AUTOCORRELATION -0.495

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: PERSPT PERCENT OF ALL FEMALES WITH SPENT EGGS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	2579.674	429.946	10.208	0.0036
ERROR	7	294.843	42.120370		
C TOTAL	13	2874.516			

ROOT MSE	6.490021	R-SQUARE	0.8974
DEP MEAN	18.232691	ADJ R-SQ	0.8095
C.V.	35.59552		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	103.680	13.863968	7.478	0.0001	INTERCEPT
SEDCARB	1	-2117.408	386.433	-5.479	0.0009	Sediment carbon (mg/gram)
JWATCHL	1	-10.808541	2.905889	-3.720	0.0075	
JWATPHA	1	-21.175680	5.819715	-3.639	0.0083	
GSMEDIAN	1	-22.678900	3.920034	-5.785	0.0007	Median grain size
COBSAND	1	2.177980	0.411513	5.293	0.0011	PERCENT OF COBBLE IN SAND
WICOBBLE	1	-0.627219	0.189267	-3.314	0.0129	

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	32.287	25.063	3.322	7.224	5.575	1.296	| |** |	0.085
2	-15.5	8.333	19.581	2.994	-11.248	5.758	-1.953	| ***| |	0.147
3	-100	17.140	12.766	2.109	4.374	6.138	0.713	| |* |	0.009
4	65	2.814	4.508	4.732	-1.694	4.441	-0.381	| | |	0.024
5	45	1.950	8.413	3.290	-6.463	5.594	-1.155	| **| |	0.066
6	-450	1.496	-1.962	6.008	3.459	2.454	1.409	| |** |	1.700
7	25	6.910	3.657	3.652	3.253	5.365	0.606	| |* |	0.024
8	-6.5	26.203	24.309	3.019	1.893	5.745	0.330	| | |	0.004
9	-115	25.000	.	.	.	.	.		.
10	-0.4	33.632	32.539	6.442	1.092	0.789359	1.384	| |** |	18.219
11	-1.5	16.279	20.926	2.845	-4.646	5.833	-0.797	| *| |	0.022
12	1.5	42.509	41.288	4.357	1.221	4.810	0.254	| | |	0.008
13	12	35.393	35.037	6.259	0.356299	1.718	0.207	| | |	0.082
14	18	0	-1.348	5.371	1.348	3.643	0.370	| | |	0.043
15	6.5	30.312	30.481	6.483	-.168547	0.306610	-0.550	| *| |	19.298

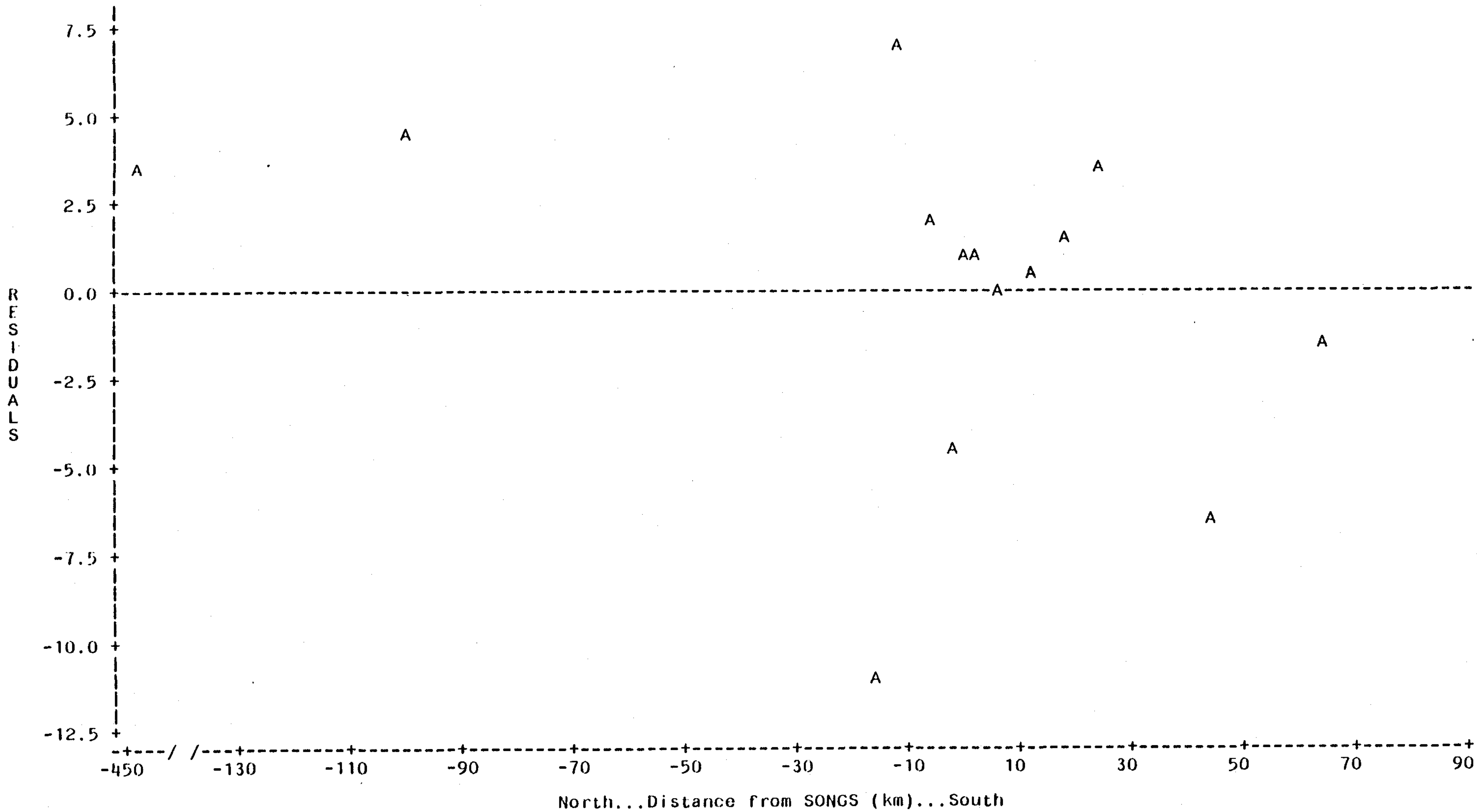
SUM OF RESIDUALS 7.39186E-13
SUM OF SQUARED RESIDUALS 294.8426

DURBIN-WATSON D 2.781
1ST ORDER AUTOCORRELATION -0.483

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR PERCENT OF ALL FEMALES WITH SPENT EGG CASES

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 1 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: SPTGE13 PERCENT OF FEMALES > 13MM WITH SPENT CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	6851.902	1141.984	6.551	0.1383
ERROR	2	348.654	174.327		
C TOTAL	8	7200.555			

ROOT MSE	13.203289	R-SQUARE	0.9516
DEP MEAN	30.438879	ADJ R-SQ	0.8063
C.V.	43.3764		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	233.315	47.568119	4.905	0.0391	INTERCEPT
SEDPHAEO	1	-67.342373	15.579599	-4.322	0.0496	Sediment phaeophytin (microgram/cm2)
SEDCARB	1	-1597.022	802.497	-1.990	0.1849	Sediment carbon (mg/gram)
COBSAND	1	4.834257	1.204764	4.013	0.0569	PERCENT OF COBBLE IN SAND
WTCOBBLE	1	-0.177159	2.188753	-0.081	0.9429	
JWATCHL	1	-61.559445	16.257248	-3.787	0.0632	
JWATPHA	1	-67.886047	18.234251	-3.723	0.0652	

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-100	17.738	13.067	7.859	4.671	10.610	0.440	| | |	0.015
2	65	2.174	1.408	13.119	0.765627	1.488	0.515	| |* |	2.940
3	45	1.592	1.685	13.202	-.092999	0.177951	-0.523	| *| |	214.752
4	-450	3.717	1.907	12.910	1.810	2.768	0.654	| |* |	1.328
5	25	4.517	13.940	10.095	-9.423	8.509	-1.107	| **| |	0.247
6	-6.5	59.302	68.319	11.171	-9.017	7.038	-1.281	| **| |	0.591
7	-115	33.333	.	.	.	.	.		.
8	1.5	71.687	59.382	8.504	12.305	10.100	1.218	| |** |	0.150
9	12	48.936	50.127	13.120	-1.191	1.477	-0.806	| *| |	7.332
10	6.5	64.286	64.115	13.202	0.170807	0.217151	0.787	| |* |	326.672

SUM OF RESIDUALS	7.75158E-13
SUM OF SQUARED RESIDUALS	348.6537
DURBIN-WATSON D	1.673
1ST ORDER AUTOCORRELATION	0.286

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION BEACHES, SELECTED VARIABLE REGRESSIONS

DEP VARIABLE: SPTGE13 PERCENT OF FEMALES > 13MM WITH SPENT CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	6850.760	1370.152	11.751	0.0348
ERROR	3	349.796	116.599		
C TOTAL	8	7200.555			

ROOT MSE	10.798082	R-SQUARE	0.9514
DEP MEAN	30.438879	ADJ R-SQ	0.8705
C.V.	35.47464		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	233.765	38.636182	6.050	0.0091	INTERCEPT
SEDPHAEO	1	-68.014437	10.781160	-6.309	0.0080	Sediment phaeophytin (microgram/cm2)
SEDCARB	1	-1582.678	640.105	-2.473	0.0899	Sediment carbon (mg/gram)
COBSAND	1	4.825063	0.980907	4.919	0.0161	PERCENT OF COBBLE IN SAND
JWATCHL	1	-61.723380	13.192125	-4.679	0.0184	
JWATPHA	1	-68.127346	14.711910	-4.631	0.0190	

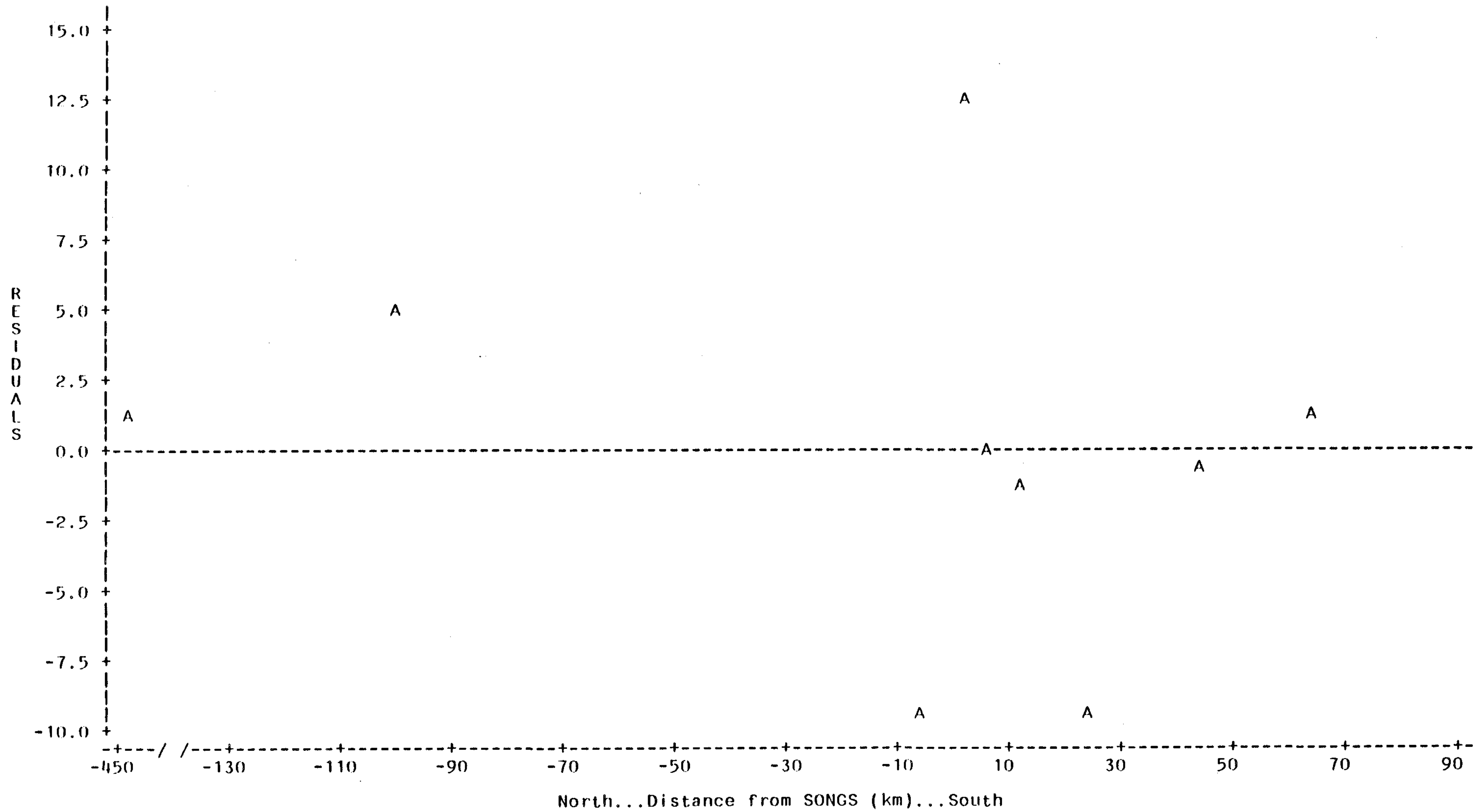
OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-100	17.738	12.911	6.232	4.827	8.818	0.547	| |* |	0.025
2	65	2.174	0.820192	8.934	1.354	6.066	0.223	| | |	0.018
3	45	1.592	2.505	6.933	-.912164	8.278	-0.110	| | |	0.001
4	-450	3.717	2.005	10.511	1.712	2.473	0.692	| |* |	1.443
5	25	4.517	13.772	8.079	-9.254	7.164	-1.292	| **| |	0.354
6	-6.5	59.302	68.480	8.990	-9.178	5.981	-1.534	| ***| |	0.887
7	-115	33.333	.	.	.	.	.		.
8	1.5	71.687	59.441	6.929	12.245	8.282	1.479	| |** |	0.255
9	12	48.936	49.951	10.582	-1.015	2.148	-0.472	| | |	0.902
10	6.5	64.286	64.064	10.785	0.221299	0.540204	0.410	| | |	11.148

SUM OF RESIDUALS	7.12763E-13
SUM OF SQUARED RESIDUALS	349.7957
DURBIN-WATSON D	1.610
1ST ORDER AUTOCORRELATION	0.301

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION BEACHES, SELECTED VARIABLE REGRESSIONS
RESIDUAL PLOT FOR PERCENT OF FEMALES > 13MM WITH SPENT CASES

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: SPT1013 PERCENT OF FEMALES 10 TO 13MM WITH SPENT CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	9	3385.113	376.124	1.771	0.3482
ERROR	3	637.275	212.425		
C TOTAL	12	4022.389			

ROOT MSE	14.574812	R-SQUARE	0.8416
DEP MEAN	21.364824	ADJ R-SQ	0.3663
C.V.	68.21873		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	137.313	83.254308	1.649	0.1976	INTERCEPT
SESTON	1	-0.629241	1.074769	-0.585	0.5994	SESTON (MG/LITER)
SEDPHAEO	1	-7.344888	23.196311	-0.317	0.7723	Sediment phaeophytin (microgram/cm2)
GSMEDIAN	1	-25.423134	21.614472	-1.176	0.3243	Median grain size
GSDISP	1	6.821925	94.234295	0.072	0.9468	Grain size dispersion
SEDCARB	1	-2547.103	1576.526	-1.616	0.2046	Sediment carbon (mg/gram)
COBSAND	1	2.489790	1.679456	1.482	0.2348	PERCENT OF COBBLE IN SAND
WTCOBBLE	1	-0.591288	0.984460	-0.601	0.5904	
JWATCHL	1	-16.626978	13.432571	-1.238	0.3038	
JWATPHA	1	-31.559665	19.989986	-1.579	0.2125	

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	45.918	26.580	7.886	19.338	12.257	1.578	| |*** |	0.103
2	-15.5	7.143	17.268	10.953	-10.126	9.615	-1.053	| **| |	0.144
3	-100	4.878	14.576	7.273	-9.697	12.630	-0.768	| *| |	0.020
4	65	3.057	3.762	14.563	-.704959	0.596008	-1.183	| **| |	83.521
5	45	1.226	-1.895	14.299	3.121	2.822	1.106	| |** |	3.139
6	-450	0	-.832107	13.747	0.832107	4.842	0.172	| | |	0.024
7	25	9.793	7.931	13.926	1.862	4.299	0.433	| | |	0.197
8	-6.5	27.933	31.171	12.756	-3.238	7.051	-0.459	| | |	0.069
9	-115	25.000	.	.	.	.	.		.
10	-0.4	48.368	48.871	14.565	-.502629	0.542636	-0.926	| *| |	61.811
11	-1.5	29.412	27.130	13.784	2.282	4.736	0.482	| | |	0.197
12	1.5	38.462	43.903	10.571	-5.442	10.034	-0.542	| *| |	0.033
13	12	43.182	40.596	14.177	2.586	3.383	0.764	| |* |	1.026
14	18	.	-3.925	24.170	.	.	.		.
15	6.5	18.372	18.683	14.565	-.310730	0.521273	-0.596	| *| |	27.743

SUM OF RESIDUALS 1.46283E-12
SUM OF SQUARED RESIDUALS 637.2754

DURBIN-WATSON D 1.771
1ST ORDER AUTOCORRELATION -0.192

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: SPT1013 PERCENT OF FEMALES 10 TO 13MM WITH SPENT CASES

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	3031.035	606.207	4.280	0.0420
ERROR	7	991.354	141.622		
C TOTAL	12	4022.389			

ROOT MSE	11.900504	R-SQUARE	0.7535
DEP MEAN	21.364824	ADJ R-SQ	0.5775
C.V.	55.70139		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	90.280252	26.387044	3.421	0.0111	INTERCEPT
JWATCHL	1	-5.422903	6.694958	-0.810	0.4446	
JWATPHA	1	-15.612833	11.917822	-1.310	0.2315	
SEDCARB	1	-2022.295	534.192	-3.786	0.0068	Sediment carbon (mg/gram)
GSMEDIAN	1	-23.434282	7.705016	-3.041	0.0188	Median grain size
COBSAND	1	1.383751	0.460769	3.003	0.0199	PERCENT OF COBBLE IN SAND

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	45.918	27.372	6.074	18.546	10.234	1.812	| |*** |	0.193
2	-15.5	7.143	24.327	5.574	-17.185	10.514	-1.634	| ***| |	0.125
3	-100	4.878	14.574	4.603	-9.696	10.974	-0.884	| *| |	0.023
4	65	3.057	-.567286	8.994	3.624	7.792	0.465	| | |	0.048
5	45	1.226	9.232	6.053	-8.007	10.246	-0.781	| *| |	0.036
6	-450	0	1.821	10.696	-1.821	5.216	-0.349	| | |	0.085
7	25	9.793	5.673	8.961	4.120	7.831	0.526	| |* |	0.060
8	-6.5	27.933	22.976	5.953	4.957	10.304	0.481	| | |	0.013
9	-115	25.000	.	.	.	.	.		.
10	-0.4	48.368	53.550	10.234	-5.182	6.074	-0.853	| *| |	0.344
11	-1.5	29.412	27.591	6.134	1.821	10.198	0.179	| | |	0.002
12	1.5	38.462	41.775	7.391	-3.314	9.327	-0.355	| | |	0.013
13	12	43.182	33.859	9.112	9.322	7.654	1.218	| |** |	0.350
14	18	.	8.820	15.065	.	.	.		.
15	6.5	18.372	15.559	11.527	2.813	2.957	0.951	| |* |	2.292

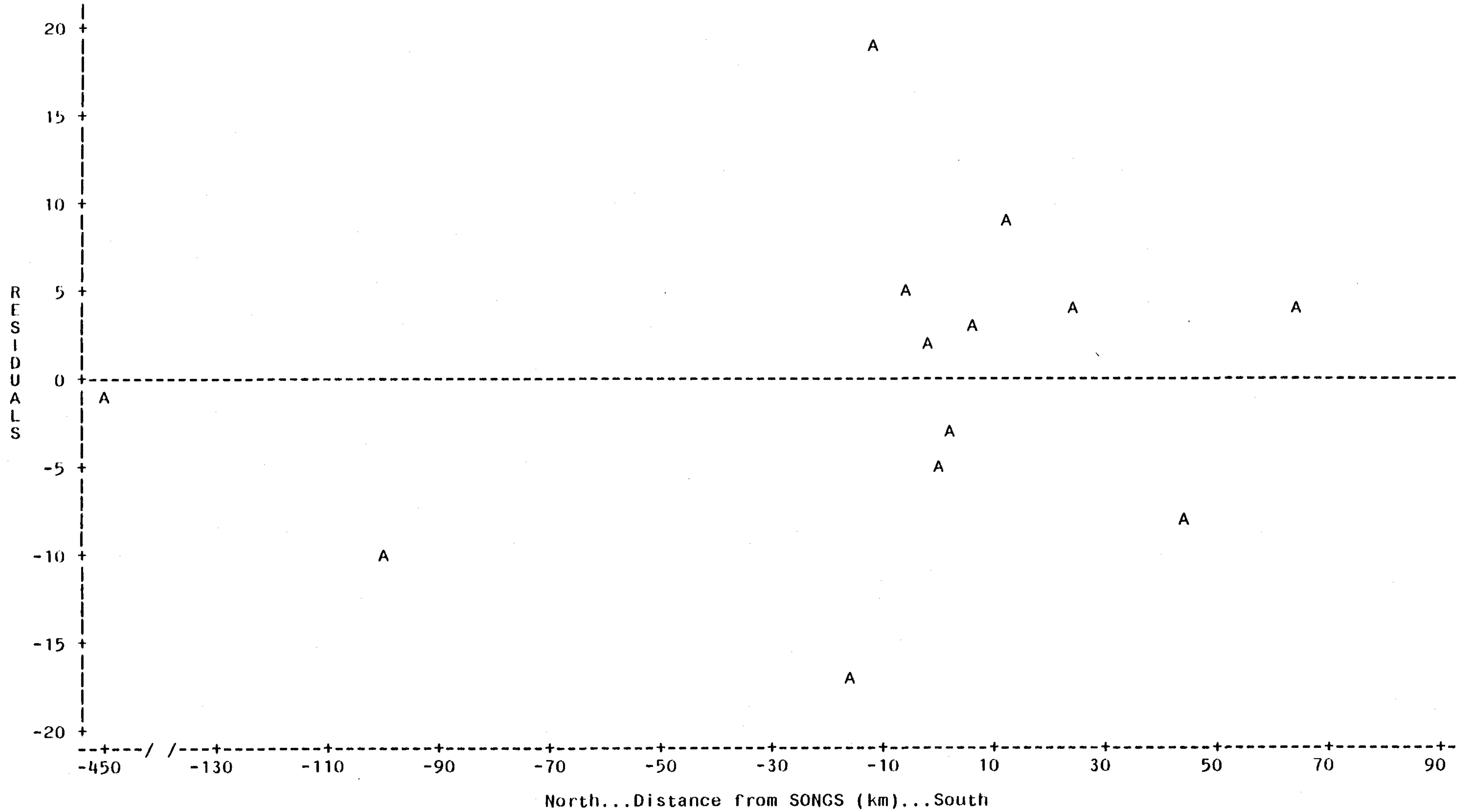
SUM OF RESIDUALS 6.94778E-13
SUM OF SQUARED RESIDUALS 991.3539

DURBIN-WATSON D 2.043
1ST ORDER AUTOCORRELATION -0.246

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR PERCENT OF FEMALES 10 TO 13MM WITH SPENT CASES

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: CLUTCH CLUTCH SIZE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	18	0.855686	0.047538	1.229	0.4671
ERROR	4	0.154712	0.038678		
C TOTAL	22	1.010398			

ROOT MSE	0.196667	R-SQUARE	0.8469
DEP MEAN	3.081565	ADJ R-SQ	0.1578
C.V.	6.382055		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	0.416856	4.280532	0.097	0.9271	INTERCEPT
SESTON	1	-0.00460216	0.016327	-0.282	0.7920	SESTON (MG/LITER)
SEDCHLOR	1	-0.016903	0.172153	-0.098	0.9265	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	0.163954	0.711598	0.230	0.8291	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-0.019164	0.091563	-0.209	0.8444	Water chlorophyll (microgram/liter)
WATPHAEO	1	-0.194253	0.258845	-0.750	0.4947	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	0.671520	1.141954	0.588	0.5881	Median grain size
GSDISP	1	-0.143574	2.079063	-0.069	0.9483	Grain size dispersion
MOISTURE	1	-20.852366	20.136820	-1.036	0.3589	
COBSAND	1	-0.011442	0.031215	-0.367	0.7325	PERCENT OF COBBLE IN SAND
COBWAT	1	0.004097488	0.004468381	0.917	0.4110	PERCENT OF COBBLE IN WATER
TEMP	1	0.249494	0.296428	0.842	0.4474	WATER TEMPERATURE
WTCOBBLE	1	0.002182837	0.007675966	0.284	0.7902	
WATCARB	1	-0.017959	0.066293	-0.271	0.7999	WATER CARBON (MG/LITER)
SEDCARB	1	6.555711	24.126695	0.272	0.7993	Sediment carbon (mg/gram)
LT4PHI	1	0.424898	0.363935	1.168	0.3079	% silt/clay
GT1PHI	1	0.009779143	0.033875	0.289	0.7872	% coarse sand
GSSKEW	1	-0.571019	1.216576	-0.469	0.6633	Grain size skewness
BSLOPE	1	-1.376271	1.495022	-0.921	0.4094	BEACH SLOPE (DROP/HORDIST)

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	3.219	3.100	0.182742	0.118946	0.072686	1.636	| |*** |	0.891
2	-15.5	.	3.040	0.349386	.	.	.		.
3	-100	2.912	2.969	0.111567	-.057103	0.161959	-0.353	| | |	0.003
4	65	3.159	3.174	0.195998	-.014977	0.016208	-0.924	| *| |	6.572
5	45	3.314	3.271	0.148119	0.042876	0.129378	0.331	| | |	0.008
6	25	3.296	3.285	0.167015	0.011134	0.103846	0.107	| | |	0.002
7	-6.5	3.235	3.149	0.172649	0.085940	0.094183	0.912	| |* |	0.147
8	-115	3.114	3.190	0.156808	-.076074	0.118698	-0.641	| *| |	0.038

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
9	-0.4	.	3.342	0.544042	.	.	.		.
10	-1.5	2.894	2.887	0.196001	0.007153	0.016168	0.442	| | |	1.514
11	1.5	.	3.201	0.315683	.	.	.		.
12	12	3.091	3.109	0.191795	-.017866	0.043505	-0.411	| | |	0.173
13	18	3.245	3.223	0.176639	0.021532	0.086468	0.249	| | |	0.014
14	6.5	2.991	3.071	0.186047	-.080159	0.063754	-1.257	| **| |	0.709
15	-12	2.912	2.890	0.183791	0.021586	0.069991	0.308	| | |	0.035
16	-15.5	.	3.091	0.680482	.	.	.		.
17	-100	3.074	3.040	0.193267	0.034295	0.036411	0.942	| |* |	1.316
18	65	3.355	3.358	0.195000	-.003319	0.025553	-0.130	| | |	0.052
19	45	3.273	3.288	0.196021	-.015013	0.015929	-0.942	| *| |	7.080
20	-450	3.397	3.379	0.187882	0.018116	0.058124	0.312	| | |	0.053
21	25	3.288	3.296	0.188390	-.007553	0.056455	-0.134	| | |	0.010
22	-6.5	2.858	3.001	0.172754	-.143174	0.093990	-1.523	| ***| |	0.413
23	-115	2.918	.	.	.	.	.		.
24	-0.4	3.016	3.026	0.195051	-.010077	0.025160	-0.401	| | |	0.507
25	-1.5	3.032	2.900	0.175178	0.131632	0.089390	1.473	| |** |	0.438
26	1.5	2.644	2.868	0.155772	-.223717	0.120054	-1.863	| ***| |	0.308
27	12	2.933	2.777	0.160780	0.156343	0.113259	1.380	| |** |	0.202
28	18	.	.	.	.	.	.		.
29	6.5	2.624	2.625	0.195744	-5.2E-04	0.019029	-0.027	| | |	0.004

SUM OF RESIDUALS -4.04121E-14
SUM OF SQUARED RESIDUALS 0.1547119

DURBIN-WATSON D 2.488
1ST ORDER AUTOCORRELATION -0.493

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: CLUTCH   CLUTCH SIZE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	0.762194	0.152439	10.441	0.0001
ERROR	17	0.248204	0.014600		
C TOTAL	22	1.010398			

ROOT MSE	0.120831	R-SQUARE	0.7544
DEP MEAN	3.081565	ADJ R-SQ	0.6821
C.V.	3.921107		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	3.994912	0.312668	12.777	0.0001	INTERCEPT
LT4PHI	1	0.219458	0.107363	2.044	0.0568	% silt/clay
GSMEDIAN	1	0.249431	0.080669	3.092	0.0066	Median grain size
MOISTURE	1	-7.490923	1.919896	-3.902	0.0011	
BSLOPE	1	-1.800973	0.635449	-2.834	0.0115	BEACH SLOPE (DROP/HORDIST)
COBSAND	1	-0.00854478	0.002427274	-3.520	0.0026	PERCENT OF COBBLE IN SAND

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	3.219	3.135	0.039193	0.083632	0.114298	0.732	| |* |	0.010
2	-15.5	.	3.070	0.070797	.	.	.		.
3	-100	2.912	2.993	0.049506	-.081263	0.110224	-0.737	| *| |	0.018
4	65	3.159	3.195	0.098985	-.036494	0.069298	-0.527	| *| |	0.094
5	45	3.314	3.147	0.039726	0.167323	0.114114	1.466	| |** |	0.043
6	25	3.296	3.196	0.037932	0.100369	0.114723	0.875	| |* |	0.014
7	-6.5	3.235	3.250	0.069468	-.014779	0.098866	-0.149	| | |	0.002
8	-115	3.114	3.097	0.064786	0.017026	0.101995	0.167	| | |	0.002
9	-0.4	.	3.075	0.054961	.	.	.		.
10	-1.5	2.894	2.856	0.059687	0.038090	0.105060	0.363	| | |	0.007
11	1.5	.	2.850	0.052413	.	.	.		.
12	12	3.091	3.122	0.051966	-.031311	0.109086	-0.287	| | |	0.003
13	18	3.245	3.211	0.062327	0.033665	0.103516	0.325	| | |	0.006
14	6.5	2.991	3.062	0.041785	-.070884	0.113377	-0.625	| *| |	0.009
15	-12	2.912	2.912	0.068086	3.1E-04	0.099822	0.003	| | |	0.000
16	-15.5	.	2.779	0.069333	.	.	.		.
17	-100	3.074	3.122	0.037596	-.047947	0.114834	-0.418	| | |	0.003
18	65	3.355	3.347	0.067864	0.008315	0.099974	0.083	| | |	0.001
19	45	3.273	3.217	0.045681	0.055680	0.111864	0.498	| | |	0.007
20	-450	3.397	3.297	0.093778	0.100361	0.076197	1.317	| |** |	0.438
21	25	3.288	3.376	0.073294	-.087971	0.096064	-0.916	| *| |	0.081

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
22	-6.5	2.858	3.145	0.049908	-.286790	0.110043	-2.606	| *****| |	0.233
23	-115	2.918	.	.	.	.	.		.
24	-0.4	3.016	3.007	0.072333	0.008865	0.096789	0.092	| | |	0.001
25	-1.5	3.032	2.895	0.042980	0.136652	0.112929	1.210	| |** |	0.035
26	1.5	2.644	2.854	0.050282	-.210192	0.109873	-1.913	| ***| |	0.128
27	12	2.933	2.801	0.055806	0.132020	0.107173	1.232	| |** |	0.069
28	18	.	3.096	0.041718	.	.	.		.
29	6.5	2.624	2.639	0.088104	-.014674	0.082692	-0.177	| | |	0.006

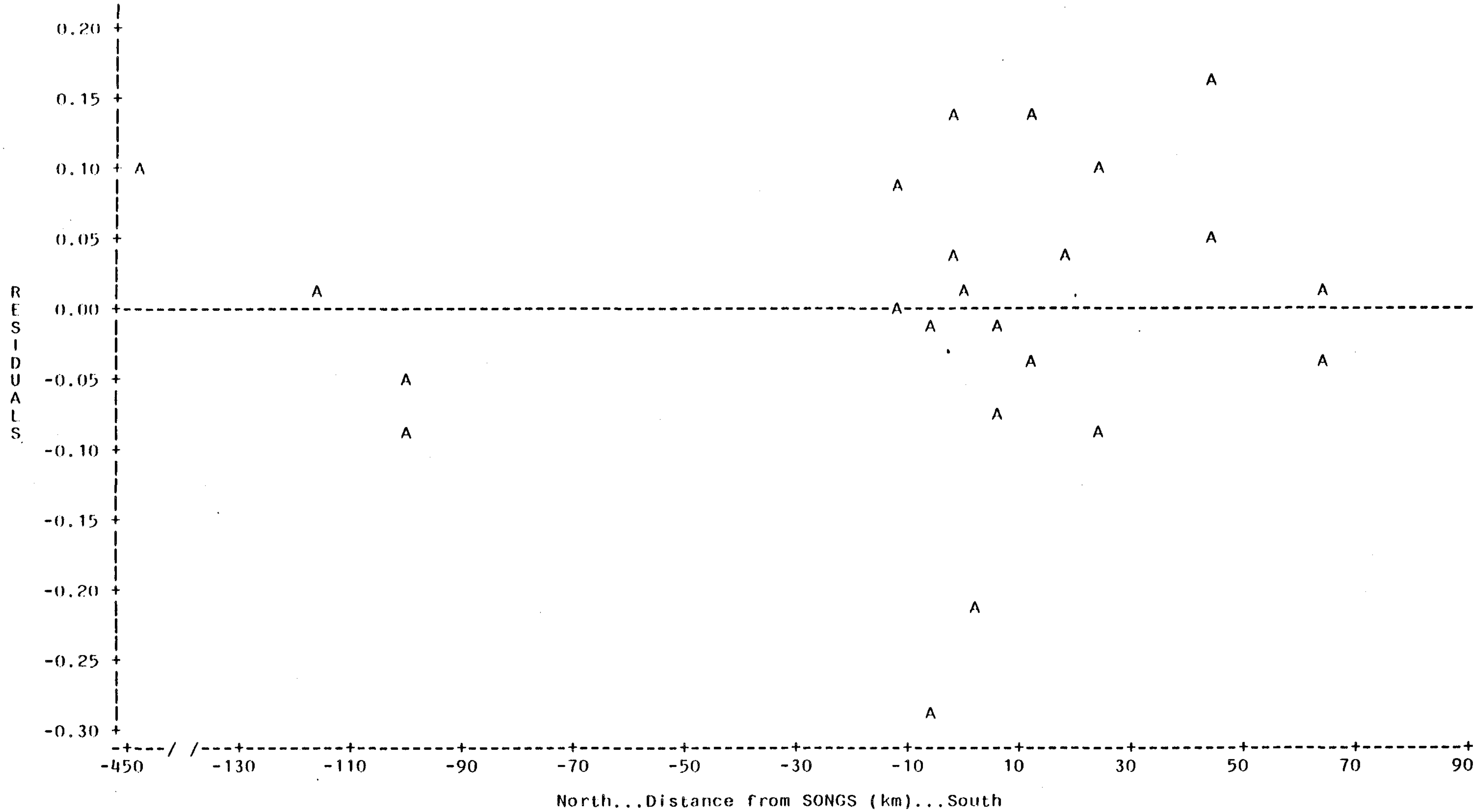
SUM OF RESIDUALS 7.14984E-14
SUM OF SQUARED RESIDUALS 0.2482041

DURBIN-WATSON D 1.770
1ST ORDER AUTOCORRELATION -0.105

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR CLUTCH SIZE

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 6 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION 100KM N EXCLUDED, STEP ZERO REGRESSIONS

DEP VARIABLE: PERCTNEW PERCENT OF SPENT FEMALES 8-13mm PRODUCING ANOTHER CLUTCH OF EGGS IN AUGUST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	8051.832	1341.972	9.126	0.2481
ERROR	1	147.043	147.043		
C TOTAL	7	8198.875			

ROOT MSE	12.126112	R-SQUARE	0.9821
DEP MEAN	35.125000	ADJ R-SQ	0.8745
C.V.	34.52274		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	-189.827	241.922	-0.785	0.5764	INTERCEPT
SESTON	1	0.580761	1.243366	0.467	0.7218	SESTON (MG/LITER)
SEDPHAEO	1	-15.731770	34.596164	-0.455	0.7283	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-44.845019	63.874465	-0.702	0.6103	Water chlorophyll (microgram/liter)
WATPHAEO	1	-64.032755	21.643581	-2.959	0.2075	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	22.030076	15.673378	1.406	0.3937	Median grain size
TEMP	1	13.180828	12.680673	1.039	0.4877	WATER TEMPERATURE

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	21.000	11.776	7.872	9.224	9.224	1.000	| |* |	0.104
2	-15.5	.	30.550	16.040	.	.	.		.
3	-100	.	-113.951	151.197	.	.	.		.
4	65	.	50.938	51.993	.	.	.		.
5	45	87.000	87.201	12.124	-.201326	0.201326	-1.000	| *| |	518.113
6	-450.	.	-102.154	80.230	.	.	.		.
7	25	80.000	79.634	12.121	0.366477	0.366477	1.000	| |* |	156.263
8	-6.5	25.000	23.463	12.028	1.537	1.537	1.000	| |* |	8.743
9	-115	.	.	.	.	.	.		.
10	-0.4	0	2.628	11.838	-2.628	2.628	-1.000	| *| |	2.898
11	-1.5	.	-25.803	28.197	.	.	.		.
12	1.5	0	6.933	9.949	-6.933	6.933	-1.000	| *| |	0.294
13	12	53.000	55.011	11.958	-2.011	2.011	-1.000	| *| |	5.052
14	18	.	.	.	.	.	.		.
15	6.5	15.000	14.354	12.109	0.645522	0.645522	1.000	| |* |	50.268

SUM OF RESIDUALS -1.45661E-12
SUM OF SQUARED RESIDUALS 147.0426

DURBIN-WATSON D 0.280
1ST ORDER AUTOCORRELATION 0.159

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION 100 KM N EXCLUDED, SELECTED VARIABLE REGRESSIONS

DEP VARIABLE: PERCINEW PERCENT OF SPENT FEMALES 8-13mm PRODUCING ANOTHER CLUTCH OF EGGS IN AUGUST

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	7826.798	3913.399	52.589	0.0004
ERROR	5	372.077	74.415391		
C TOTAL	7	8198.875			

ROOT MSE	8.626436	R-SQUARE	0.9546
DEP MEAN	35.125000	ADJ R-SQ	0.9365
C.V.	24.55925		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	46.459850	18.028231	2.577	0.0496	INTERCEPT
WATPHAEO	1	-63.221213	14.075760	-4.491	0.0064	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	27.339539	7.431647	3.679	0.0143	Median grain size

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	21.000	6.469	4.293	14.531	7.482	1.942	| |*** |	0.414
2	-15.5	.	17.192	5.025	.	.	.		.
3	-100	.	-39.797	20.420	.	.	.		.
4	65	.	82.828	6.447	.	.	.		.
5	45	87.000	82.128	5.671	4.872	6.501	0.749	| |* |	0.142
6	-450	.	-42.130	9.269	.	.	.		.
7	25	80.000	84.173	6.475	-4.173	5.700	-0.732	| *| |	0.231
8	-6.5	25.000	30.548	3.245	-5.548	7.993	-0.694	| *| |	0.026
9	-115	.	.	.	.	.	.		.
10	-0.4	0	2.699	5.452	-2.699	6.685	-0.404	| | |	0.036
11	-1.5	.	-7.816	5.951	.	.	.		.
12	1.5	0	4.274	4.572	-4.274	7.315	-0.584	| *| |	0.044
13	12	53.000	48.888	6.799	4.112	5.309	0.775	| |* |	0.328
14	18	.	69.121	4.509	.	.	.		.
15	6.5	15.000	21.821	4.832	-6.821	7.146	-0.955	| *| |	0.139

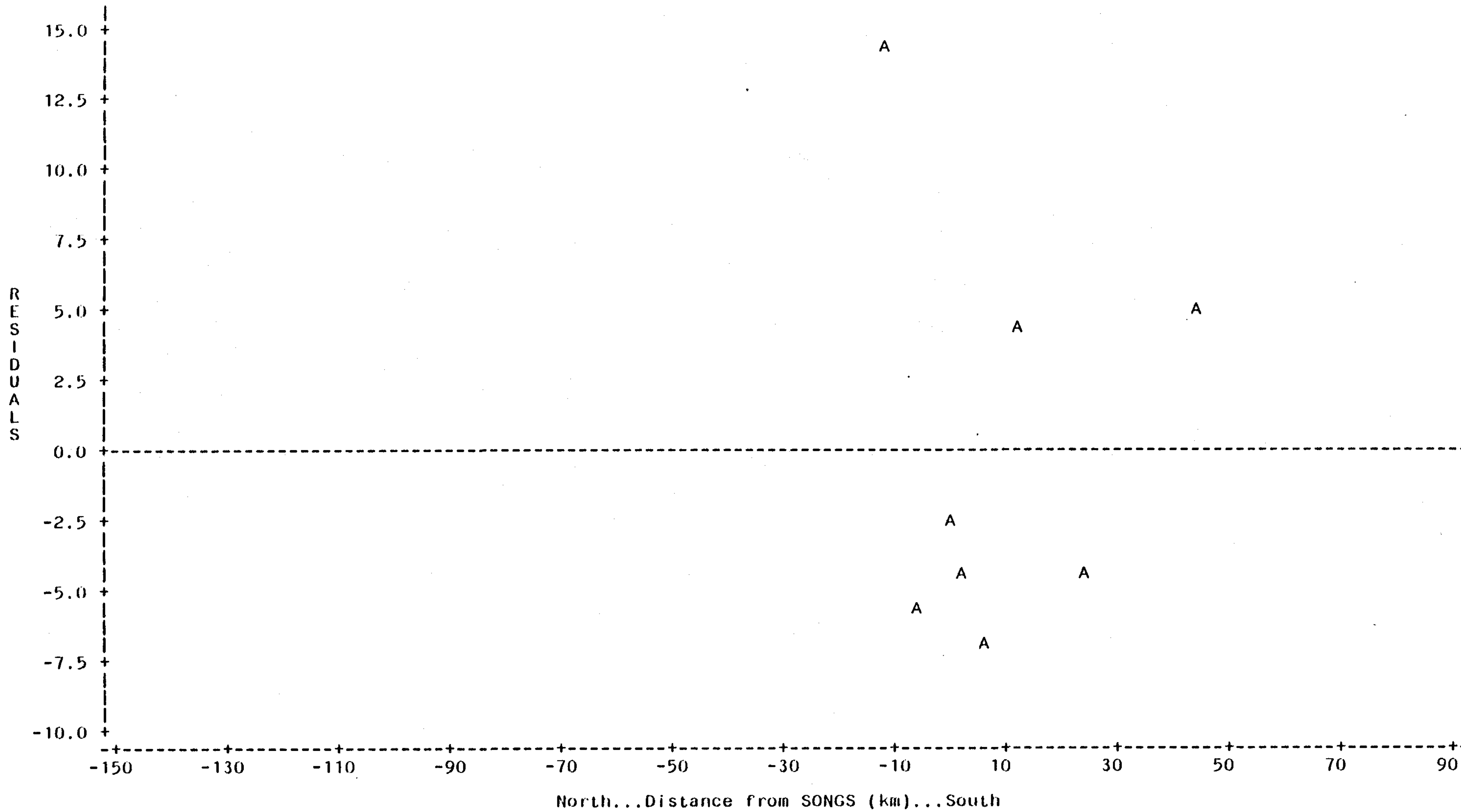
SUM OF RESIDUALS -7.46070E-14
SUM OF SQUARED RESIDUALS 372.077

DURBIN-WATSON D 0.279
1ST ORDER AUTOCORRELATION 0.022

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION 100 KM N EXCLUDED, SELECTED VARIABLE REGRESSIONS
RESIDUAL PLOT FOR PERCENT OF SPENT FEMALES 8-13MM PRODUCING ANOTHER CLUTCH OF EGGS IN AUGUST

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 7 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, STEP ZERO REGRESSIONS

DEP VARIABLE: PGM PHOSPHOGLUCOMUTASE ACTIVITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	7	6.570062	0.938580	4.594	0.0797
ERROR	4	0.817238	0.204309		
C TOTAL	11	7.387300			

ROOT MSE	0.452006	R-SQUARE	0.8894
DEP MEAN	1.605000	ADJ R-SQ	0.6958
C.V.	28.16237		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	4.170524	2.007087	2.078	0.1063	INTERCEPT
SESION	1	-0.024728	0.020112	-1.230	0.2863	SESTON (MG/LITER)
SEDCHLOR	1	-0.352817	0.278824	-1.265	0.2744	SEDIMENT CHLOROPHYLL (MICROGRAM/CM2)
SEDPHAEO	1	1.862643	1.049158	1.775	0.1505	Sediment phaeophytin (microgram/cm2)
WATCHLOR	1	-0.646235	0.804123	-0.804	0.4666	Water chlorophyll (microgram/liter)
WATPHAEO	1	1.847235	1.149847	1.607	0.1834	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSMEDIAN	1	-0.422635	0.523632	-0.807	0.4649	Median grain size
GSDISP	1	-4.243350	2.313666	-1.834	0.1406	Grain size dispersion

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	1.600	1.194	0.237544	0.405843	0.384555	1.055	| |** |	0.053
2	-15.5	0.400000	0.339844	0.436958	0.060156	0.115661	0.520	| |* |	0.483
3	-100	3.000	3.103	0.442142	-.103071	0.093916	-1.097	| **| |	3.337
4	65	2.500	2.461	0.450604	0.038996	0.035573	1.096	| |** |	24.101
5	45	2.300	2.392	0.447521	-.092455	0.063518	-1.456	| **| |	13.147
6	-450	2.300	2.049	0.404771	0.251377	0.201172	1.250	| |** |	0.790
7	25	2.000	1.722	0.403566	0.277767	0.203578	1.364	| |** |	0.914
8	-6.5	1.400	1.403	0.187114	-.003305	0.411458	-0.008	| | |	0.000
9	-115	.	.	.	.	.	.		.
10	-0.4	0.600000	0.956614	0.358484	-.356614	0.275316	-1.295	| **| |	0.356
11	-1.5	.	2.665	0.761702	.	.	.		.
12	1.5	0.860000	1.212	0.305628	-.352305	0.333018	-1.058	| **| |	0.118
13	12	1.000	1.401	0.353250	-.401265	0.282000	-1.423	| **| |	0.397
14	18	.	1.546	0.353136	.	.	.		.
15	6.5	1.300	1.025	0.282643	0.274877	0.352735	0.779	| |* |	0.049

SUM OF RESIDUALS 2.51882E-14
SUM OF SQUARED RESIDUALS 0.8172379

DURBIN-WATSON D 0.783
1ST ORDER AUTOCORRELATION 0.403

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES

DEP VARIABLE: PGM PHOSPHOGLUCOMUTASE ACTIVITY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	3	6.034112	2.011371	11.891	0.0026
ERROR	8	1.353188	0.169148		
C TOTAL	11	7.387300			

ROOT MSE	0.411277	R-SQUARE	0.8168
DEP MEAN	1.605000	ADJ R-SQ	0.7481
C.V.	25.62471		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|	VARIABLE LABEL
INTERCEP	1	2.453292	0.726792	3.376	0.0097	INTERCEPT
SEDPHAEO	1	0.578182	0.300820	1.922	0.0908	Sediment phaeophytin (microgram/cm2)
WATPHAEO	1	1.084100	0.265983	4.076	0.0036	WATER PHAEOPHYTIN (MICROGRAM/LITER)
GSDISP	1	-2.642239	0.863881	-3.059	0.0156	Grain size dispersion

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	-12	1.600	1.226	0.145525	0.373960	0.384670	0.972	| |* |	0.034
2	-15.5	0.400000	0.693493	0.212060	-.293493	0.352390	-0.833	| *| |	0.063
3	-100	3.000	3.255	0.382243	-.254876	0.151785	-1.679	| ***| |	4.471
4	65	2.500	2.642	0.325615	-.142084	0.251244	-0.566	| *| |	0.134
5	45	2.300	2.177	0.252793	0.122675	0.324413	0.378	| | |	0.022
6	-450	2.300	1.600	0.236835	0.700318	0.336241	2.083	| |**** |	0.538
7	25	2.000	1.631	0.250827	0.368863	0.325936	1.132	| |** |	0.190
8	-6.5	1.400	1.382	0.154363	0.018358	0.381209	0.048	| | |	0.000
9	-115	.	.	.	.	.	.		.
10	-0.4	0.600000	0.913643	0.234478	-.313643	0.337888	-0.928	| *| |	0.104
11	-1.5	.	1.905	0.196425	.	.	.		.
12	1.5	0.860000	1.364	0.139993	-.504275	0.386717	-1.304	| **| |	0.056
13	12	1.000	1.187	0.230370	-.187275	0.340702	-0.550	| *| |	0.035
14	18	.	1.481	0.216716	.	.	.		.
15	6.5	1.300	1.189	0.154680	0.111472	0.381081	0.293	| | |	0.004

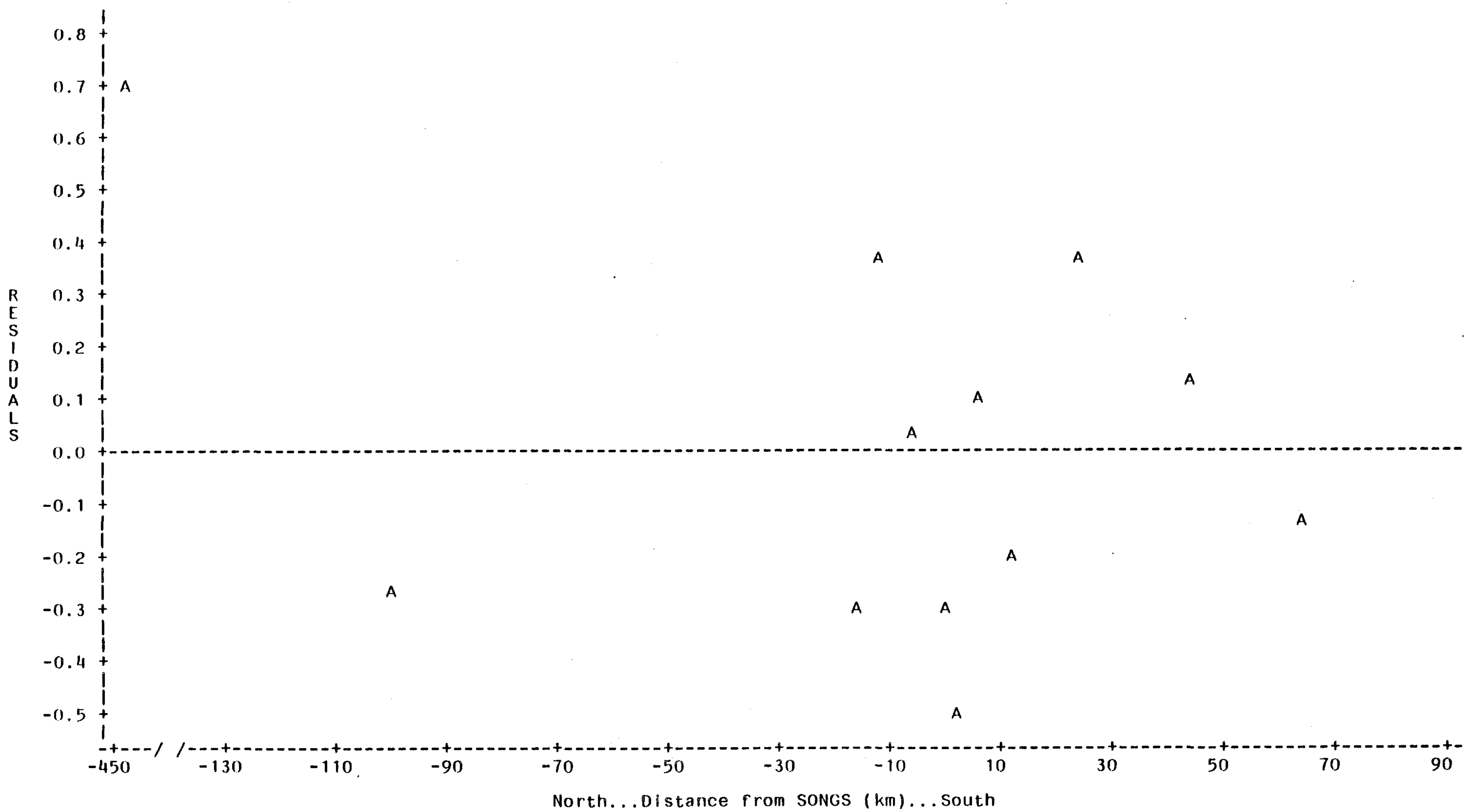
SUM OF RESIDUALS 1.54182E-14
SUM OF SQUARED RESIDUALS 1.353188

DURBIN-WATSON D 1.211
1ST ORDER AUTOCORRELATION 0.434

MARINE ECOLOGICAL CONSULTANTS
A STUDY OF SANDCRABS

MULTIPLE REGRESSION ALL BEACHES, SELECTED REGRESSION VARIABLES
RESIDUAL PLOT FOR PHOSPHOGLUCOMUTASE ACTIVITY

PLOT OF RESID*DISTANCE   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 3 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

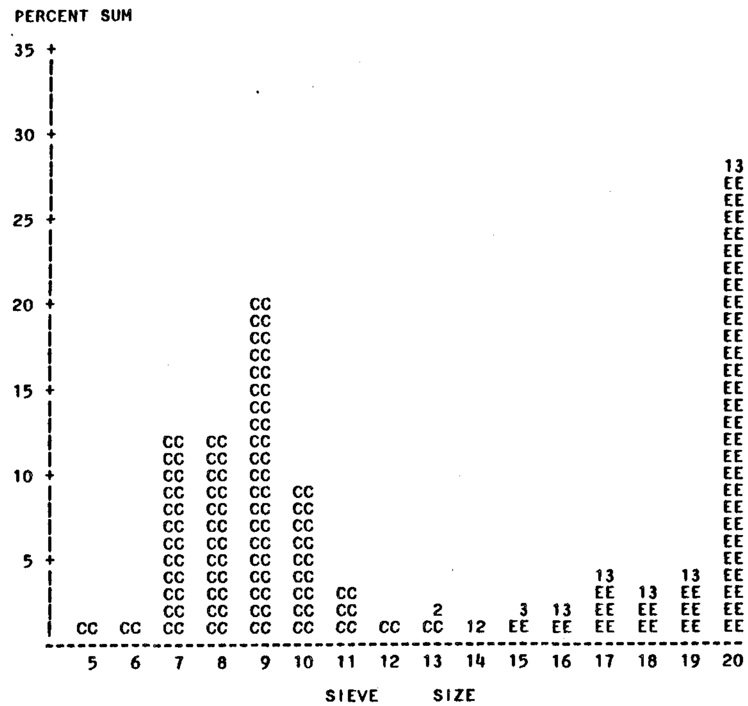
APPENDIX E

SIZE FREQUENCY HISTOGRAMS

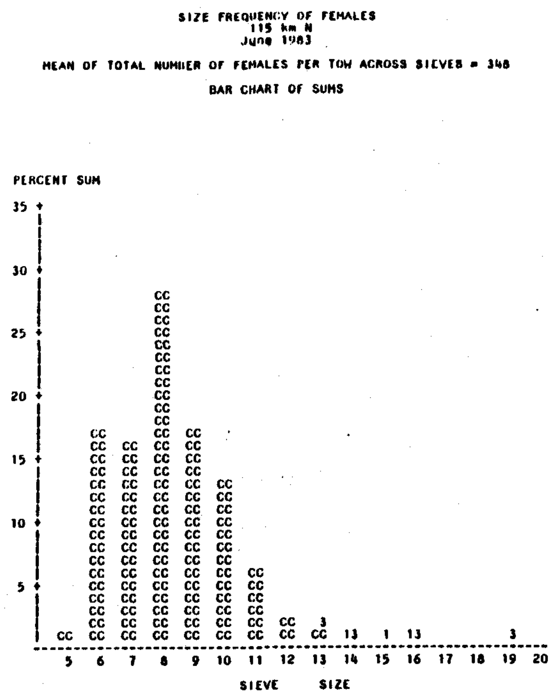
SIZE FREQUENCY OF FEMALES
450 km N
August 1983

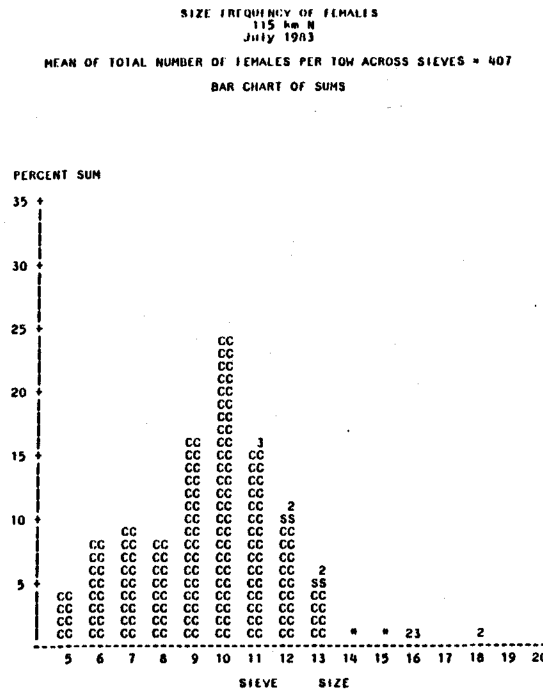
MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 446

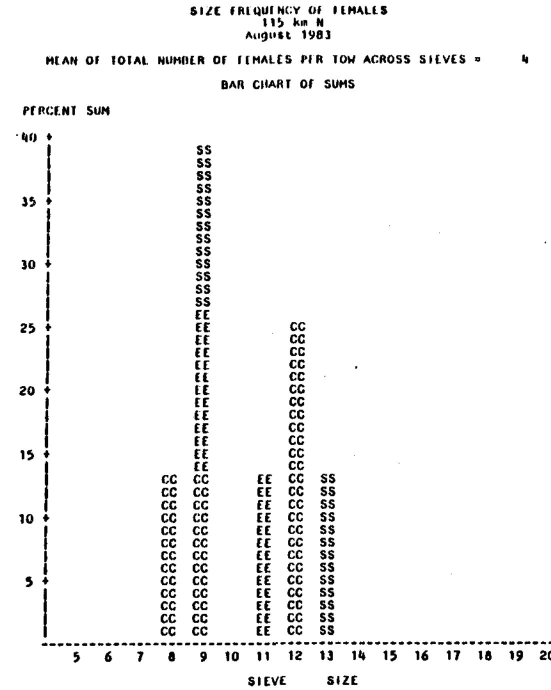
BAR CHART OF SUMS



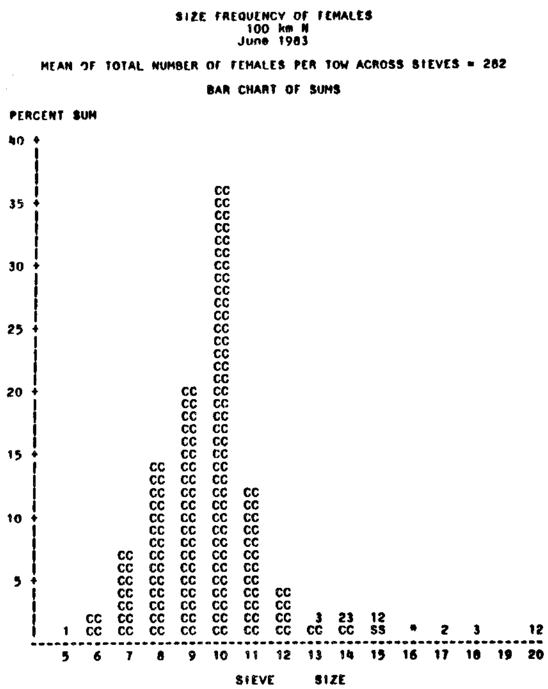
Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

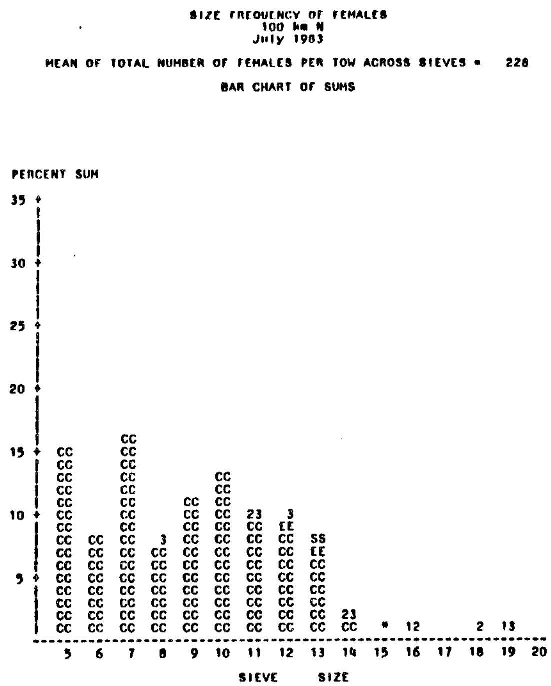


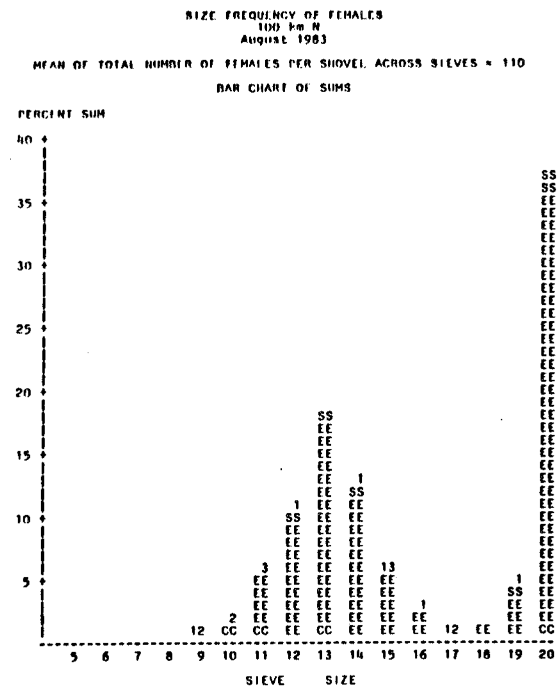




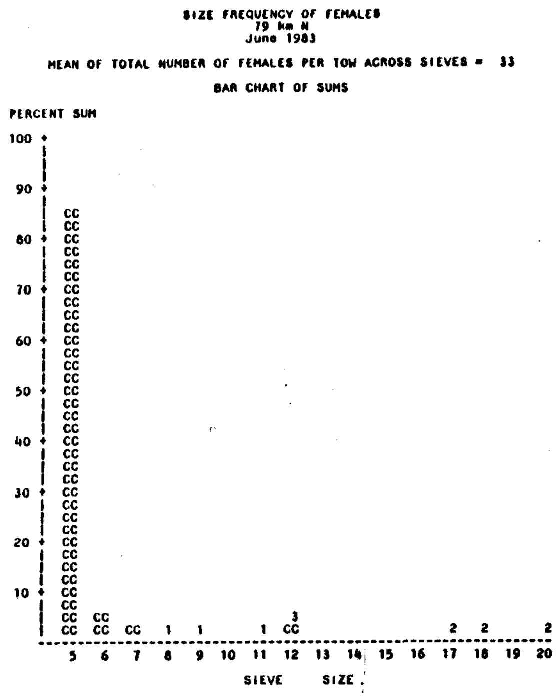
Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

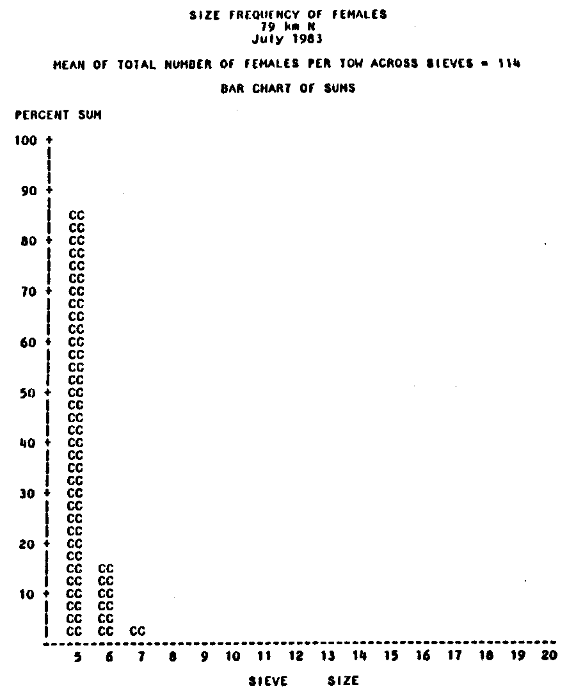


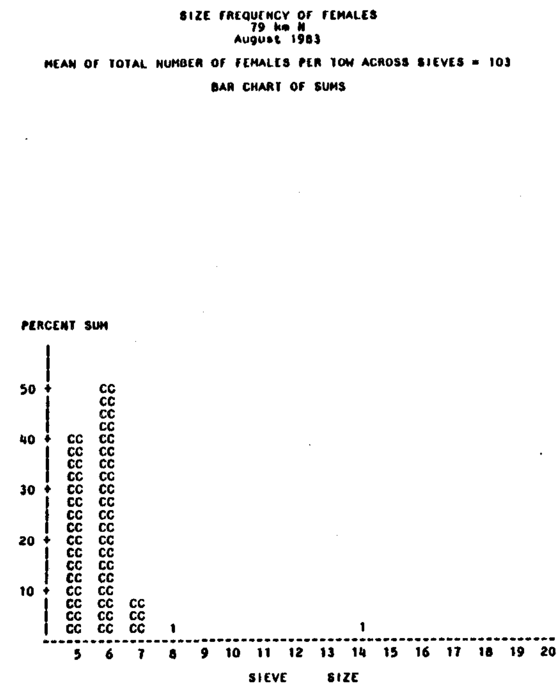




Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.





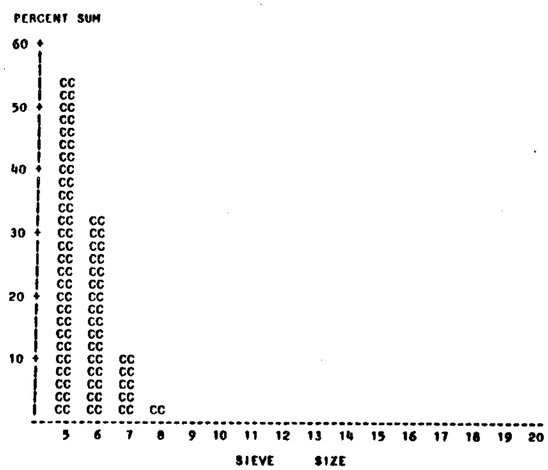


Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 2%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

SIZE FREQUENCY OF FEMALES
15.9 km N
June 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 8

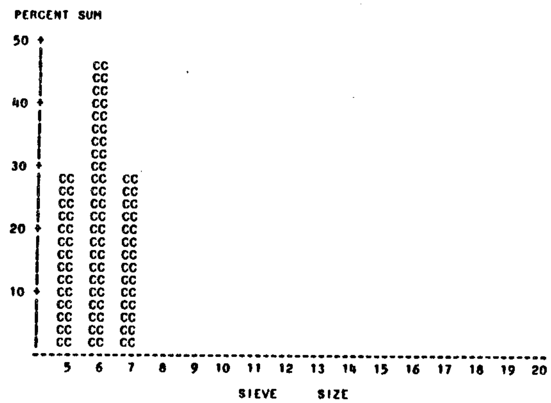
BAR CHART OF SUMS



SIZE FREQUENCY OF FEMALES
15.5 km N
July 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 2

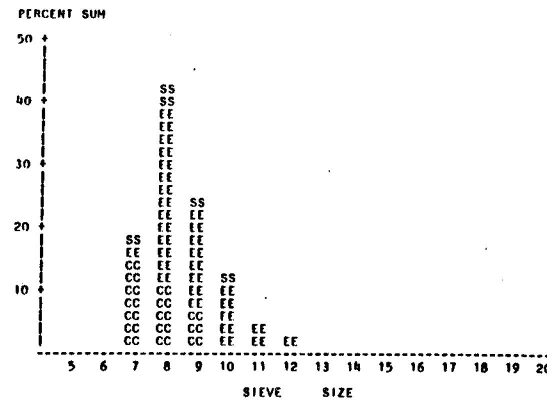
BAR CHART OF SUMS

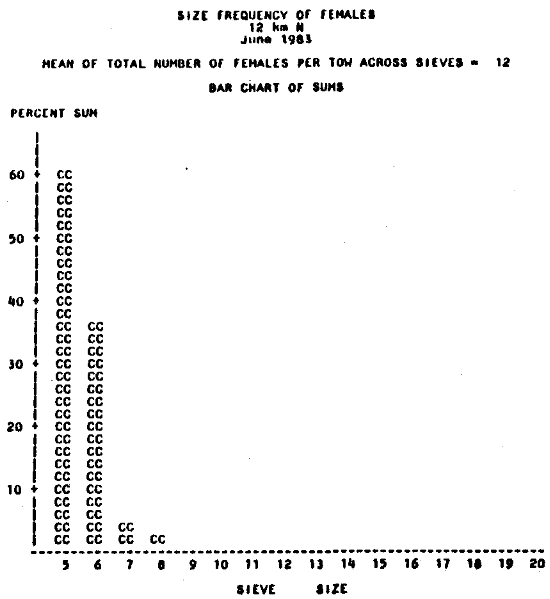


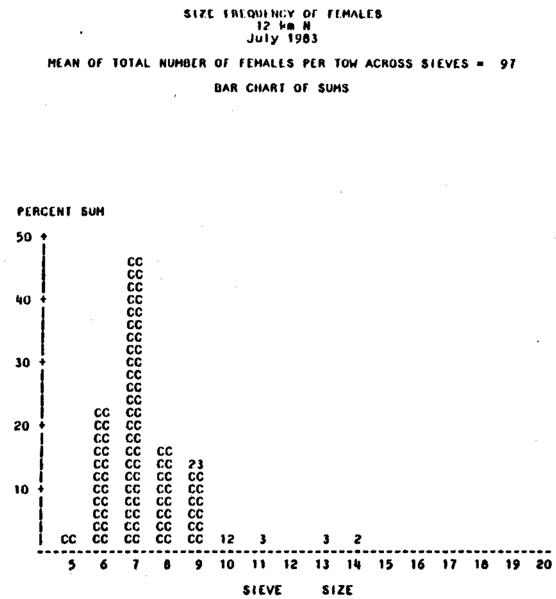
SIZE FREQUENCY OF FEMALES
15.5 km N
August 1983

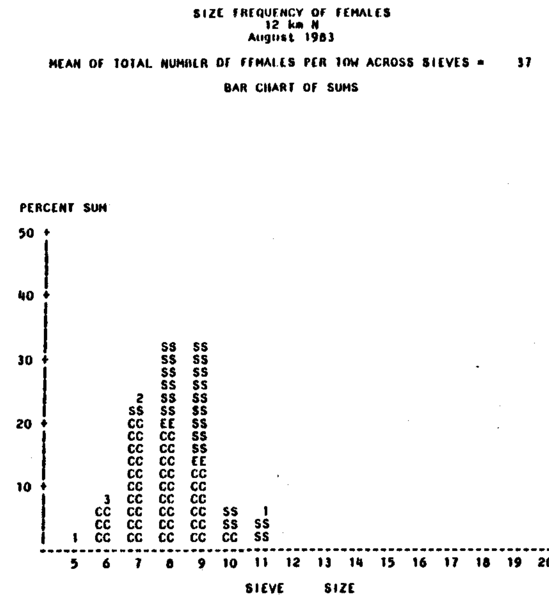
MEAN OF TOTAL NUMBER OF FEMALES PER SHOVEL ACROSS SIEVES = 12

BAR CHART OF SUMS

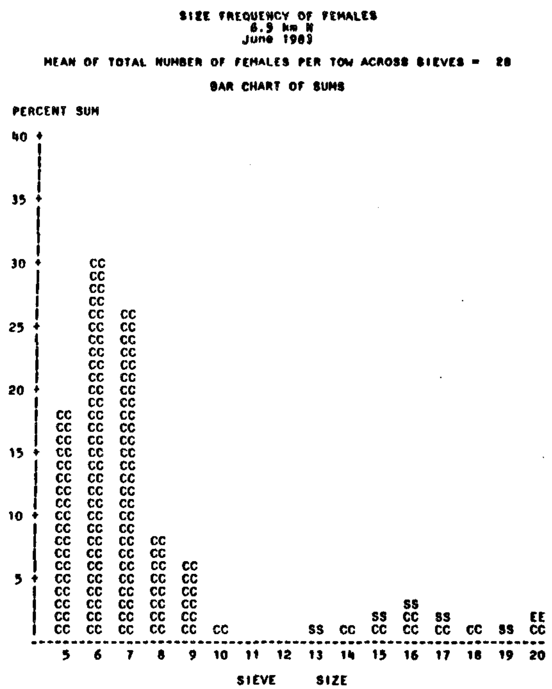


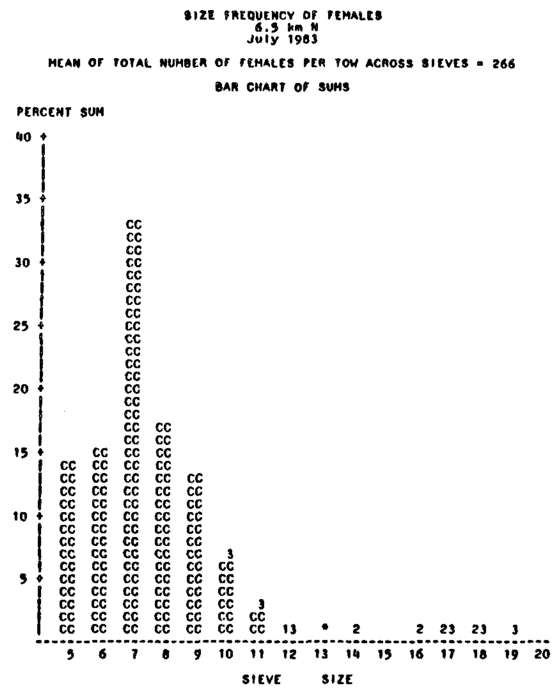


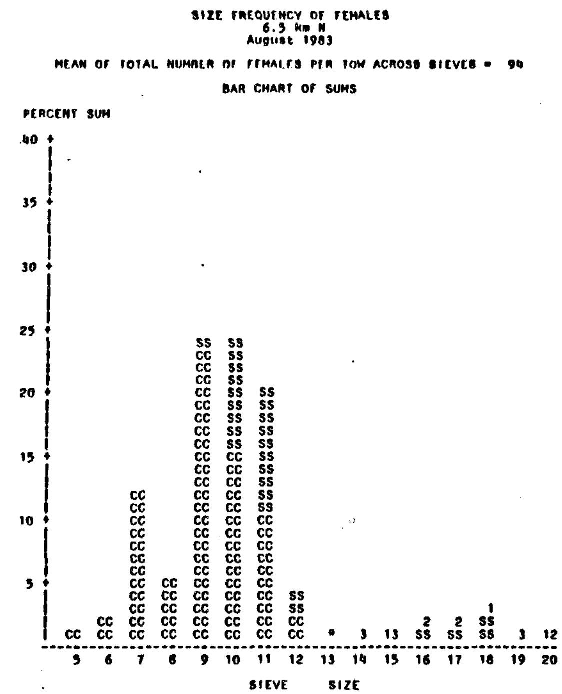




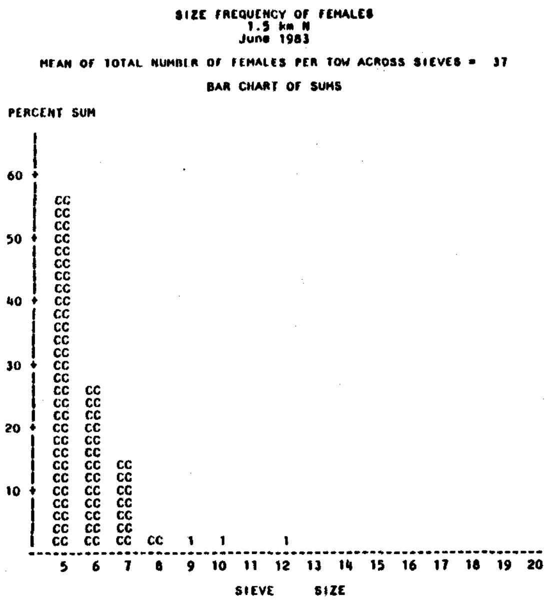
Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 2%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

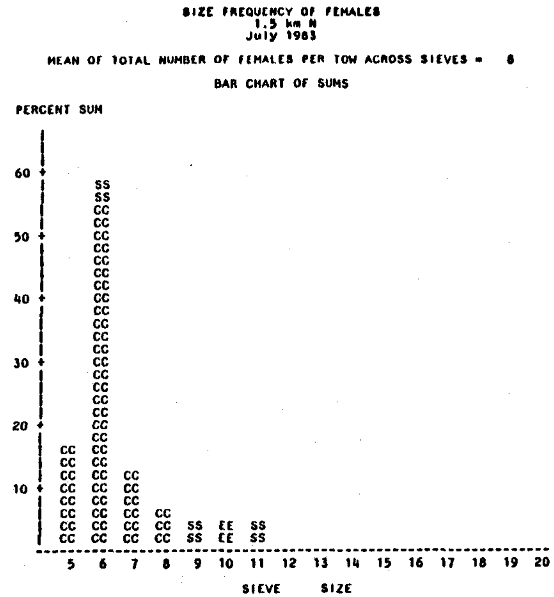


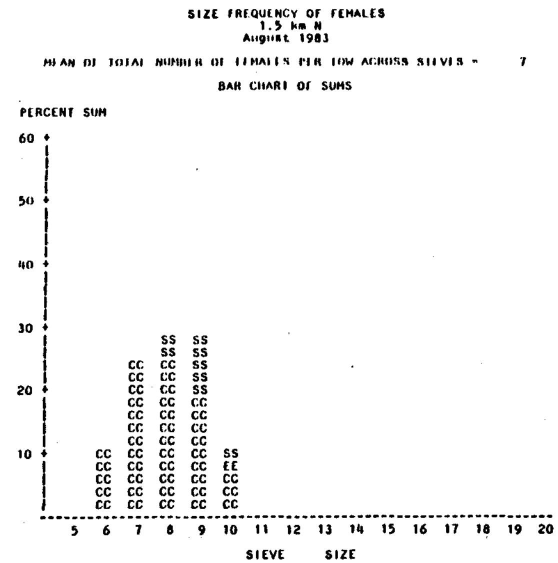




Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.





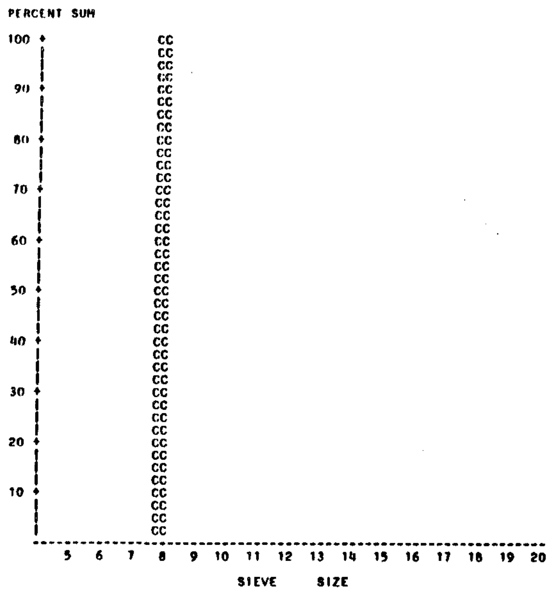


Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 2%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

SIZE FREQUENCY OF FEMALES
0.4 km N
June 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 0.17

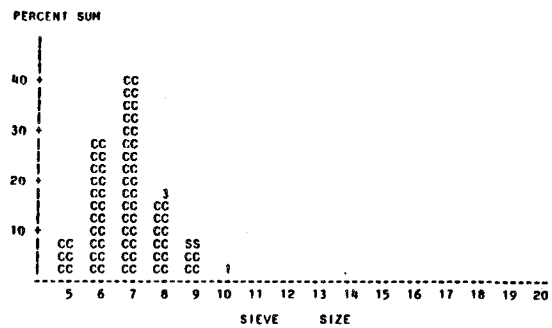
BAR CHART OF SUMS



SIZE FREQUENCY OF FEMALES
0.4 km N
July 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 51

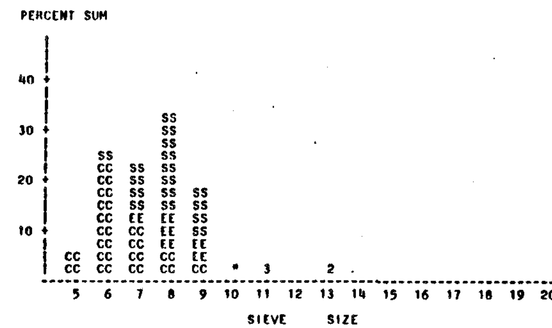
BAR CHART OF SUMS



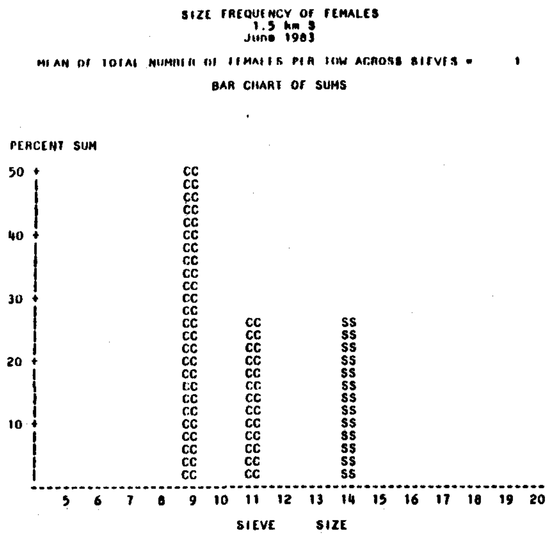
SIZE FREQUENCY OF FEMALES
0.4 km N
August 1983

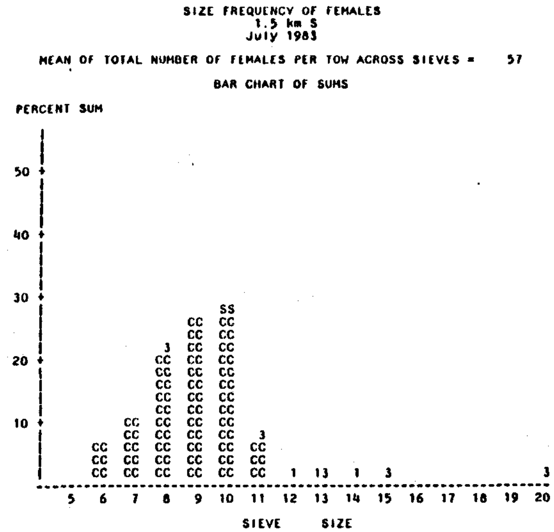
MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 237

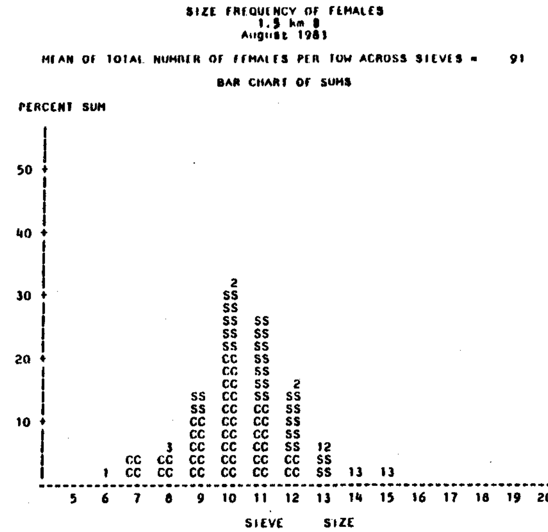
BAR CHART OF SUMS



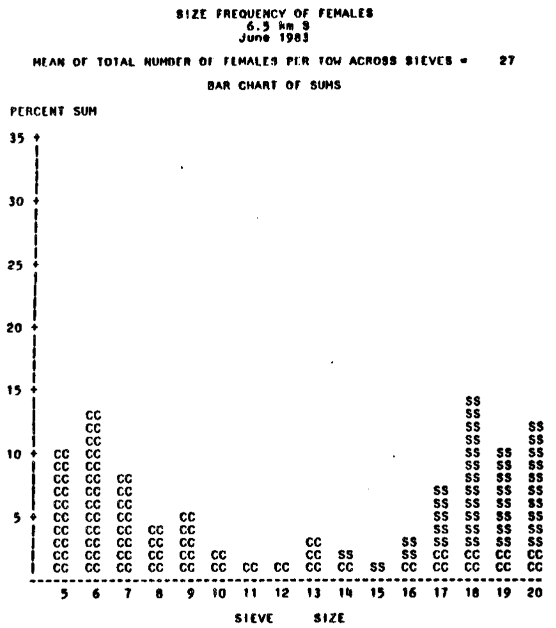
Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 2%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

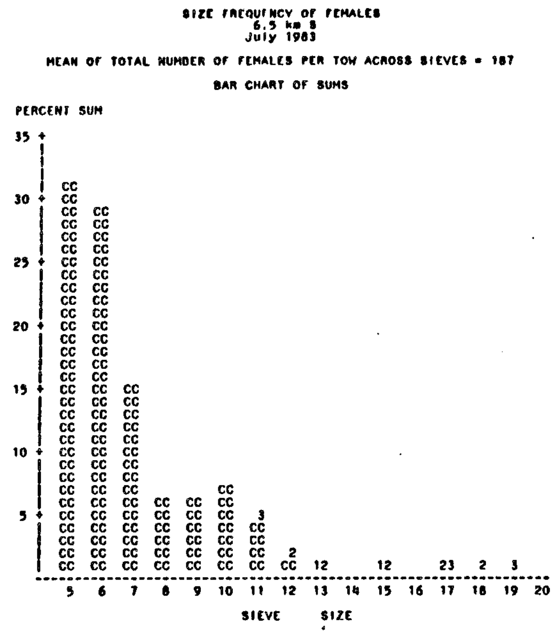


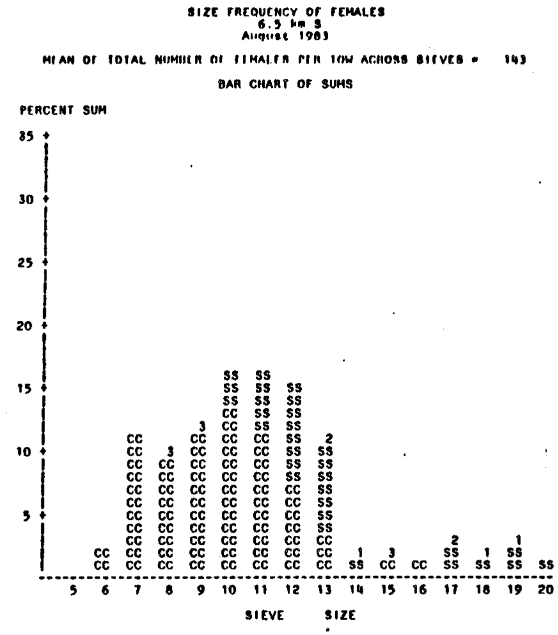




Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 2%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, # = females with eggs and females without eggs and females with spent egg cases.





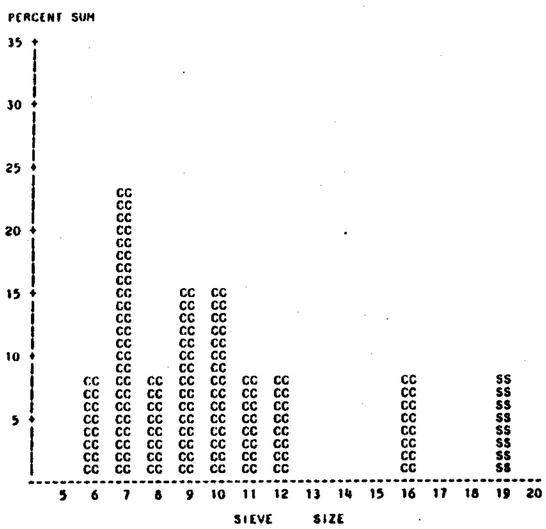


Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

SIZE FREQUENCY OF FEMALES
12 km S
June 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 2

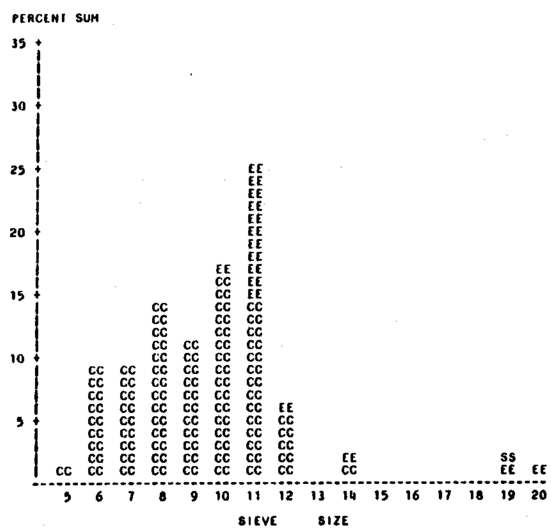
BAR CHART OF SUMS



SIZE FREQUENCY OF FEMALES
12 km S
July 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 19

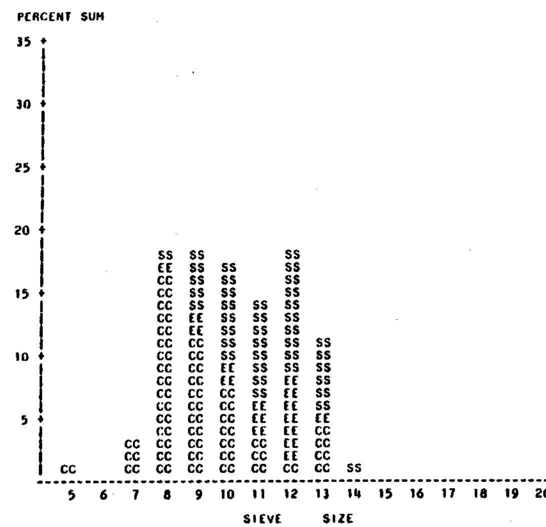
BAR CHART OF SUMS



SIZE FREQUENCY OF FEMALES
12 km S
August 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 20

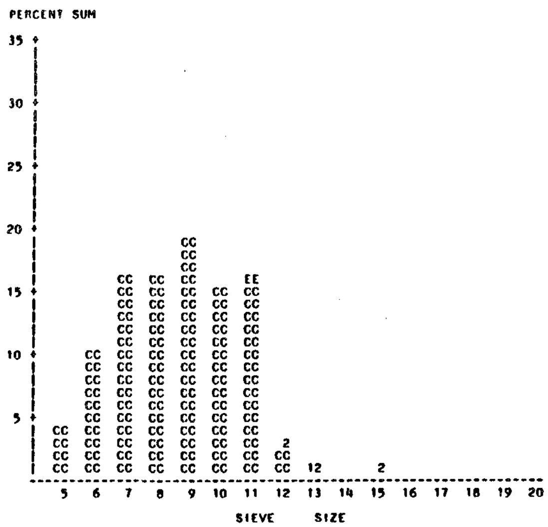
BAR CHART OF SUMS



SIZE FREQUENCY OF FEMALES
18 km S
June 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 346

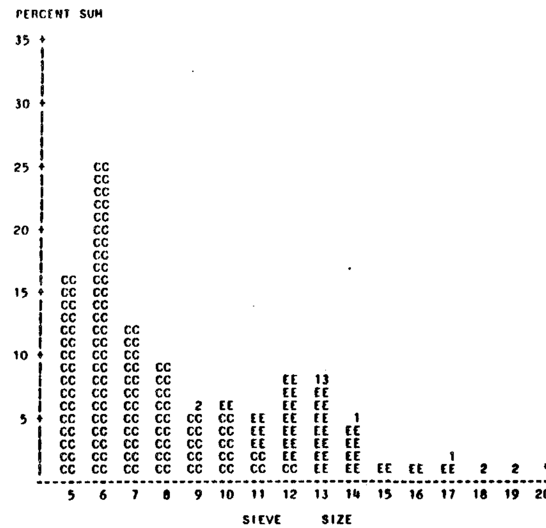
BAR CHART OF SUMS



SIZE FREQUENCY OF FEMALES
18 km S
July 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 476

BAR CHART OF SUMS

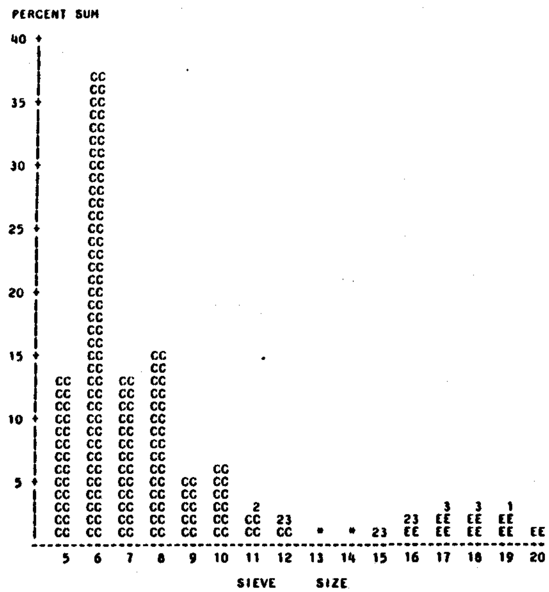


Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

SIZE FREQUENCY OF FEMALES
25 km S
June 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 564

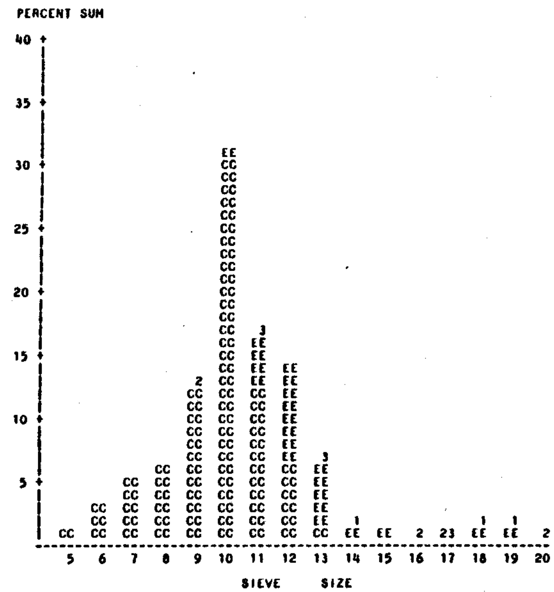
BAR CHART OF SUMS



SIZE FREQUENCY OF FEMALES
25 km S
July 1983

MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 271

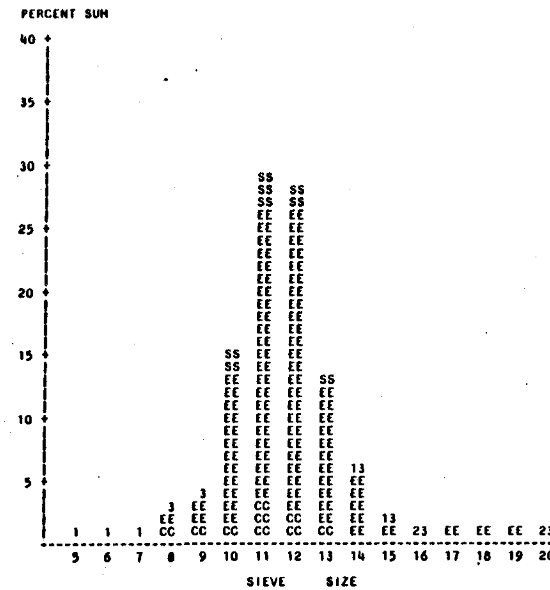
BAR CHART OF SUMS



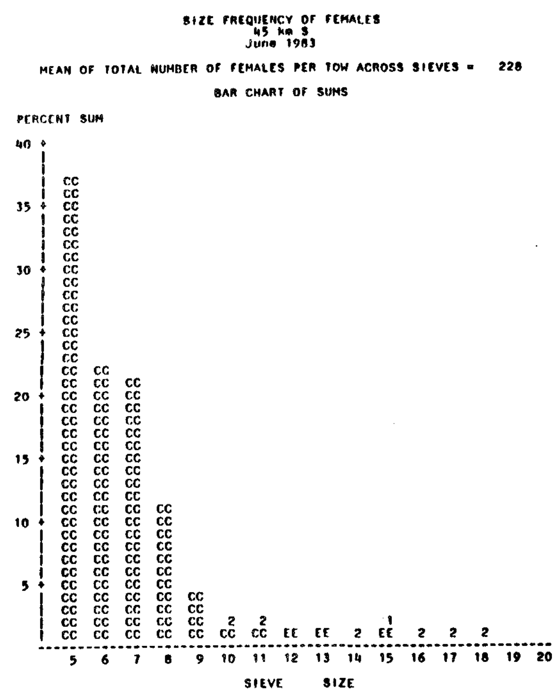
SIZE FREQUENCY OF FEMALES
25 km S
August 1983

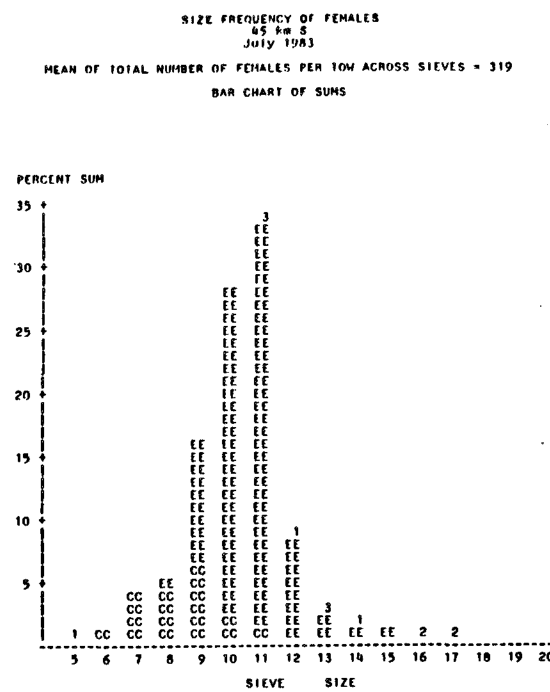
MEAN OF TOTAL NUMBER OF FEMALES PER TOW ACROSS SIEVES = 618

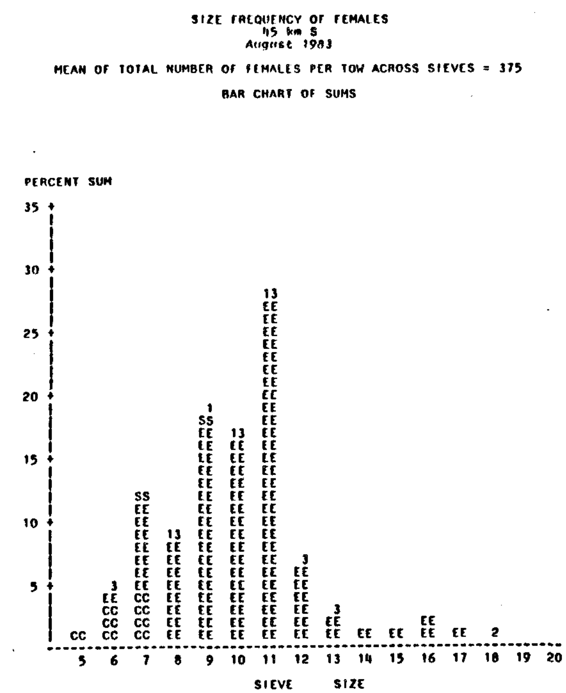
BAR CHART OF SUMS



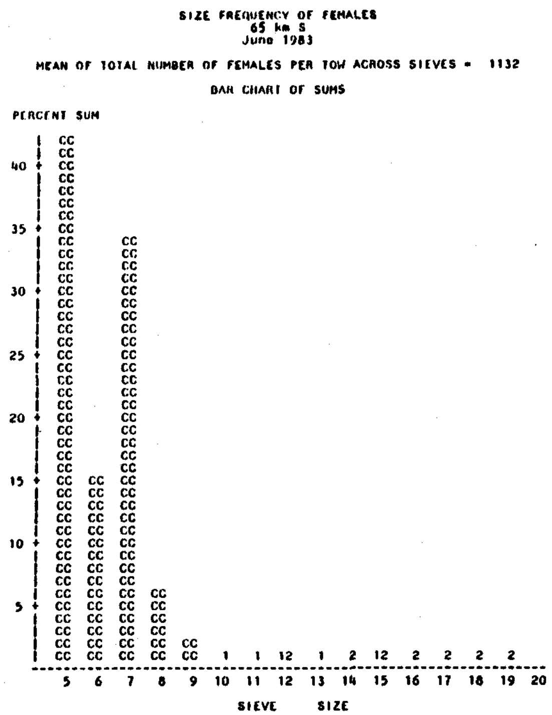
Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

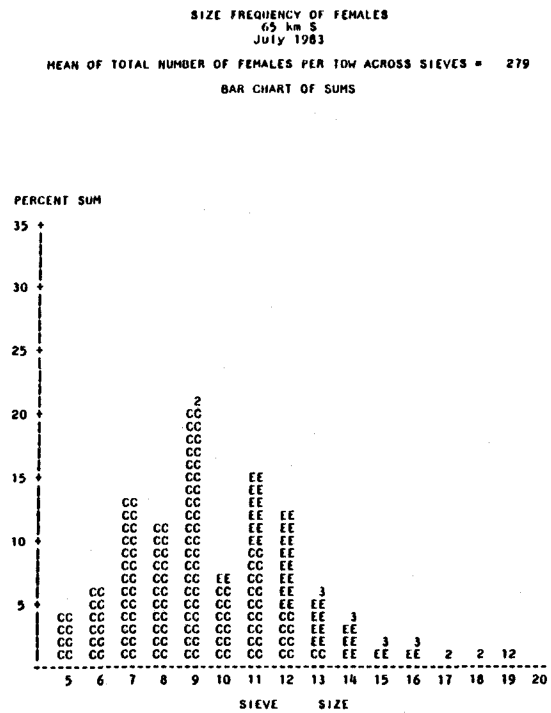


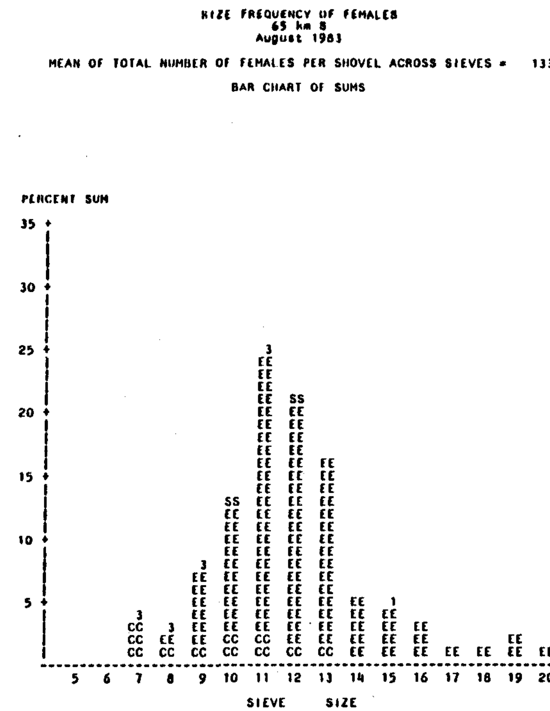




Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.







Note: number(s) above bar for each sieve size denotes the occurrence in tows of low percentages (less than 1%) of: 1 = females without eggs, 2 = females with eggs, 3 = females with spent egg cases, * = females with eggs and females without eggs and females with spent egg cases.

APPENDIX F

SUPPLEMENTAL TABLES AND FIGURES

Table F-1. The percentage of females between 10 mm and 13 mm in the reproductive population according to the developmental stage of their egg masses for June and July.

	June				July			
	Females > 10 mm to 13 mm				Females > 10 mm to 13 mm			
	Developmental Stage of Eggs				Developmental Stage of Eggs			
Beach site	Bright-Orange	Burnt-Orange	Gray	Spent	Bright-Orange	Burnt-Orange	Gray	Spent
450 km N	NS	NS	NS	NS	NS	NS	NS	NS
115 km N	-	-	-	-	0	0	0	100*
100 km N	-	-	-	-	60*	0	0	40*
79 km N	-	-	-	-	-	-	-	-
15.5 km N	-	-	-	-	-	-	-	-
12 km N	-	-	-	-	44*	11*	0	44*
6.5 km N	-	-	-	-	0	0	0	100*
1.5 km N	-	-	-	-	50*	0	0	50*
0.4 km N	-	-	-	-	67*	0	0	33*
1.5 km S	-	-	-	-	17*	0	0	83*
6.5 km S	-	-	-	-	0	0	0	100*
12 km S	-	-	-	-	100	0	0	0
18 km S	100*	0	0	0	100	0	0	0
25 km S	100*	0	0	0	97	0	0	3
45 km S	100*	0	0	0	94	5	<1	<1
65 km S	-	-	-	-	99	1	0	0

NS = not sampled

* = percentage based on less than 10 reproductive females

Note: females between 10 mm and 13 mm in June and July were not shown here b collected at all sites near and north of SONGS (see Appendix F, Table

NS = not sampled

* = percentage based on less than 10 reproductive females

Note: females between 10 mm and 13 mm in June and July were not shown here because fewer than 10 reproductive females were collected at all sites near and north of SONGS (see Appendix F, Table F-1).

Table F-2. Total number of females (interpatch replicates not included) within each reproductive category that are greater than 13 mm in carapace length.

JUNE

BEACH SITE	TOTAL FEMALES	FEMALES WITH BRIGHT ORANGE EGGS	FEMALES WITH BURNT-ORANGE EGGS	FEMALES WITH GRAY EGGS	FEMALES WITH SPENT EGG CASES	FEMALES WITH SPENT AND ORANGE EGGS
115 km N	35	0	0	0	3	0
100 km N	92	9	1	0	12	2
6.5 km N	15	1	0	0	7	0
6.5 km S	78	0	0	0	59	0
18 km S	28	8	0	0	0	0
25 km S	316	217	44	5	7	6
45 km S	27	20	3	2	0	0
65 km S	40	19	4	0	0	0

JULY

BEACH SITE	TOTAL FEMALES	FEMALES WITH BRIGHT ORANGE EGGS	FEMALES WITH BURNT-ORANGE EGGS	FEMALES WITH GRAY EGGS	FEMALES WITH SPENT EGG CASES	FEMALES WITH SPENT AND ORANGE EGGS
115 km N	380	11	0	8	38	6
100 km N	268	22	2	0	23	5
79 km N	15	3	6	3	0	0
18 km S	418	367	26	1	0	2
25 km S	402	248	11	7	3	0
45 km S	154	136	13	1	1	0
65 km S	249	163	31	0	4	0

AUGUST

BEACH SITE	TOTAL FEMALES	FEMALES WITH BRIGHT ORANGE EGGS	FEMALES WITH BURNT-ORANGE EGGS	FEMALES WITH GRAY EGGS	FEMALES WITH SPENT EGG CASES	FEMALES WITH SPENT AND ORANGE EGGS	FEMALES WITH VISIBLE INTERNAL EGGS
450 km N	1103	795	149	29	7	34	0
100 km N	840	417	136	100	135	14	11
6.5 km N	70	4	0	0	40	0	4
1.5 km S	155	4	0	0	104	1	8
6.5 km S	322	1	0	1	203	3	2
12 km S	36	8	0	1	14	1	2
25 km S	1786	1116	423	50	40	37	19
45 km S	312	231	58	13	3	2	2
65 km S	276	232	13	17	6	0	5

Table F-3. Total number of females (interpatch replicates not included) within each reproductive category that are greater than 10 mm and less than 13 mm in carapace length.

JUNE

BEACH SITE	TOTAL FEMALES	FEMALES WITH BRIGHT ORANGE EGGS	FEMALES WITH BURNT-ORANGE EGGS	FEMALES WITH GRAY EGGS	FEMALES WITH SPENT EGG CASES	FEMALES WITH SPENT AND ORANGE EGGS
115 km N	744	0	0	0	0	0
100 km N	761	0	0	0	0	0
6.5 km N	10	0	0	0	0	0
18 km S	537	6	0	0	0	0
25 km S	437	1	0	0	0	0
45 km S	35	1	0	0	0	0
65 km S	90	0	0	0	0	0

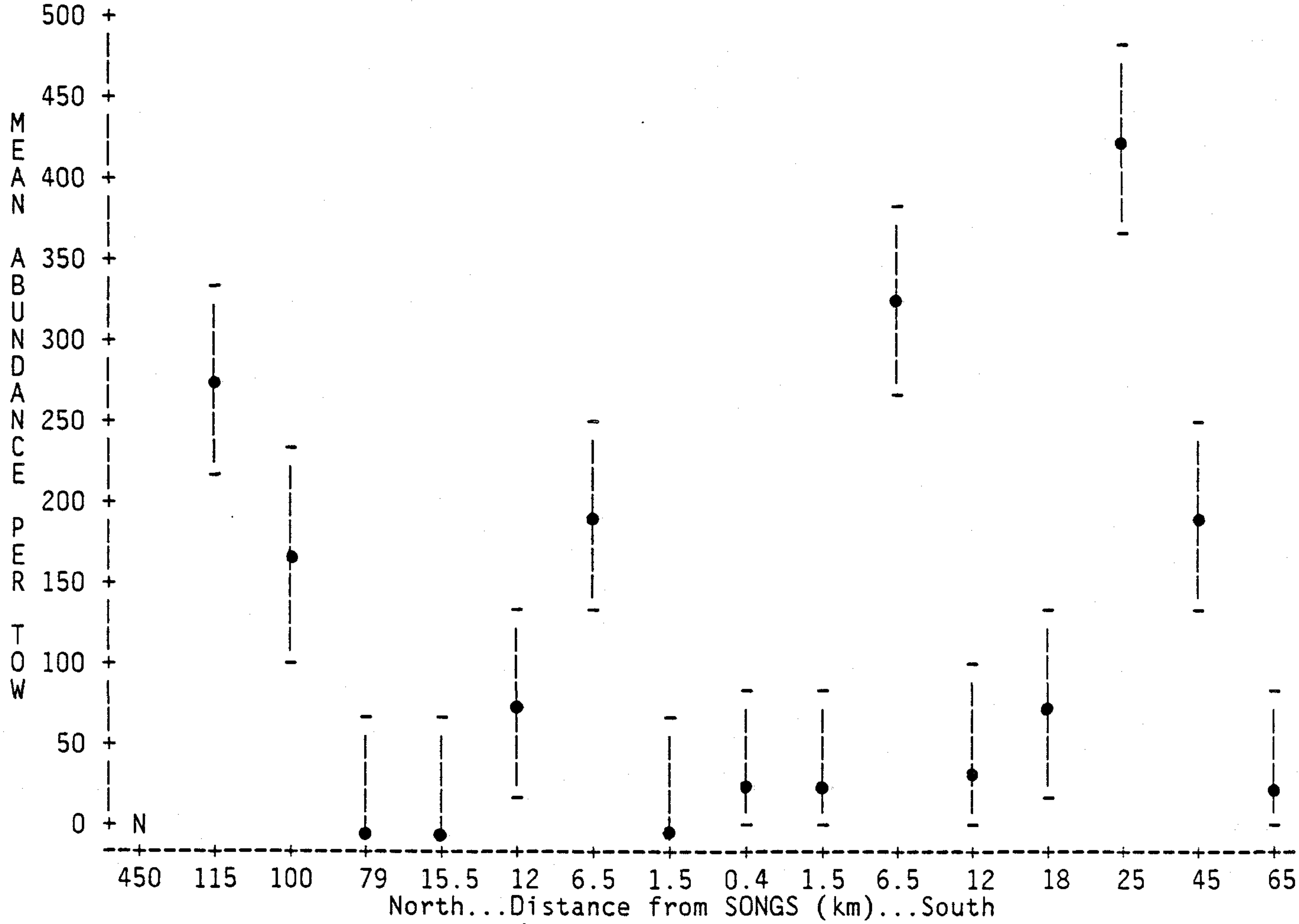
JULY

BEACH SITE	TOTAL FEMALES	FEMALES WITH BRIGHT ORANGE EGGS	FEMALES WITH BURNT-ORANGE EGGS	FEMALES WITH GRAY EGGS	FEMALES WITH SPENT EGG CASES	FEMALES WITH SPENT AND ORANGE EGGS
115 km N	1356	0	0	0	2	0
100 km N	469	3	0	0	0	2
12 km N	67	4	1	0	4	0
6.5 km N	308	0	0	0	1	0
1.5 km N	13	2	0	0	2	0
0.4 km N	30	2	0	0	1	0
1.5 km S	252	1	0	0	5	0
6.5 km S	179	0	0	0	1	0
12 km S	132	36	0	0	0	0
18 km S	296	69	4	0	0	0
25 km S	972	83	0	0	2	1
45 km S	977	812	46	1	0	1
65 km S	480	79	1	0	0	0

AUGUST

BEACH SITE	TOTAL FEMALES	FEMALES WITH BRIGHT ORANGE EGGS	FEMALES WITH BURNT-ORANGE EGGS	FEMALES WITH GRAY EGGS	FEMALES WITH SPENT EGG CASES	FEMALES WITH SPENT AND ORANGE EGGS	FEMALES WITH VISIBLE INTERNAL EGGS
450 km N	896	0	0	0	0	0	0
100 km N	26	10	0	4	2	0	0
15.5 km N	13	8	0	0	1	1	0
12 km N	98	3	3	0	39	6	0
6.5 km N	537	1	0	0	150	0	0
0.4 km N	337	65	7	0	135	28	0
1.5 km S	624	2	0	0	231	6	3
6.5 km S	430	0	0	0	77	2	0
12 km S	83	10	0	1	30	5	1
25 km S	1739	781	555	43	72	92	7
45 km S	1387	1118	180	35	14	3	0
65 km S	218	150	21	20	4	0	3

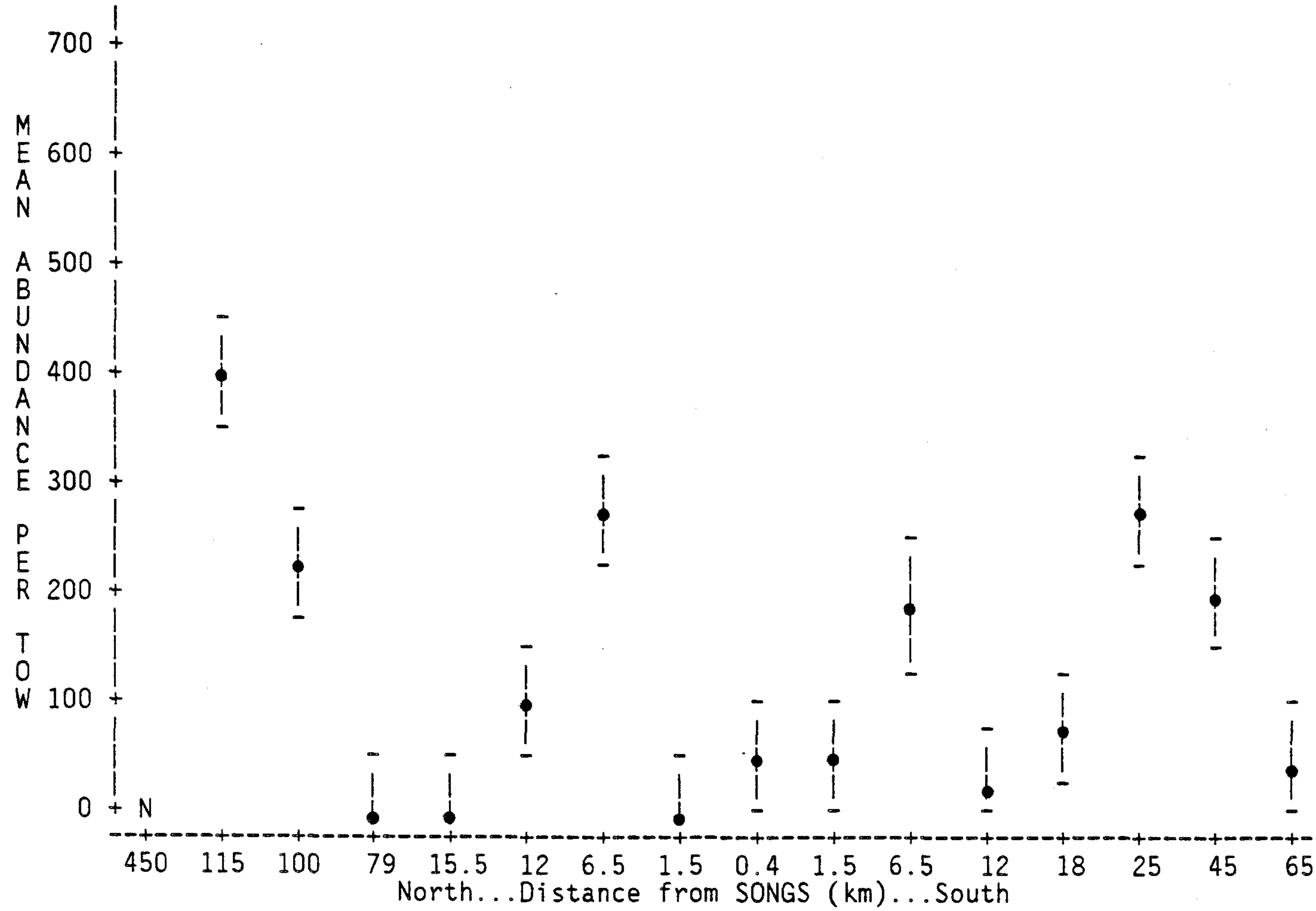
WEIGHTED MEAN ABUNDANCE PER TOW OF MALE SAND CRABS
JULY 1983



N = not sampled

Figure F-1a. Weighted mean abundance of male sand crabs in July 1983. Site means (dots) ± 2 S. E. are shown. Note that the "Distance" axis is not to scale.

WEIGHTED MEAN ABUNDANCE PER TOW OF FEMALE SAND CRABS
JULY 1983



N = not sampled

Figure F-1b. Weighted mean abundance of female sand crabs in July 1983. Site means (dots) ± 2 S. E. are shown. Note that the "Distance" axis is not to scale.

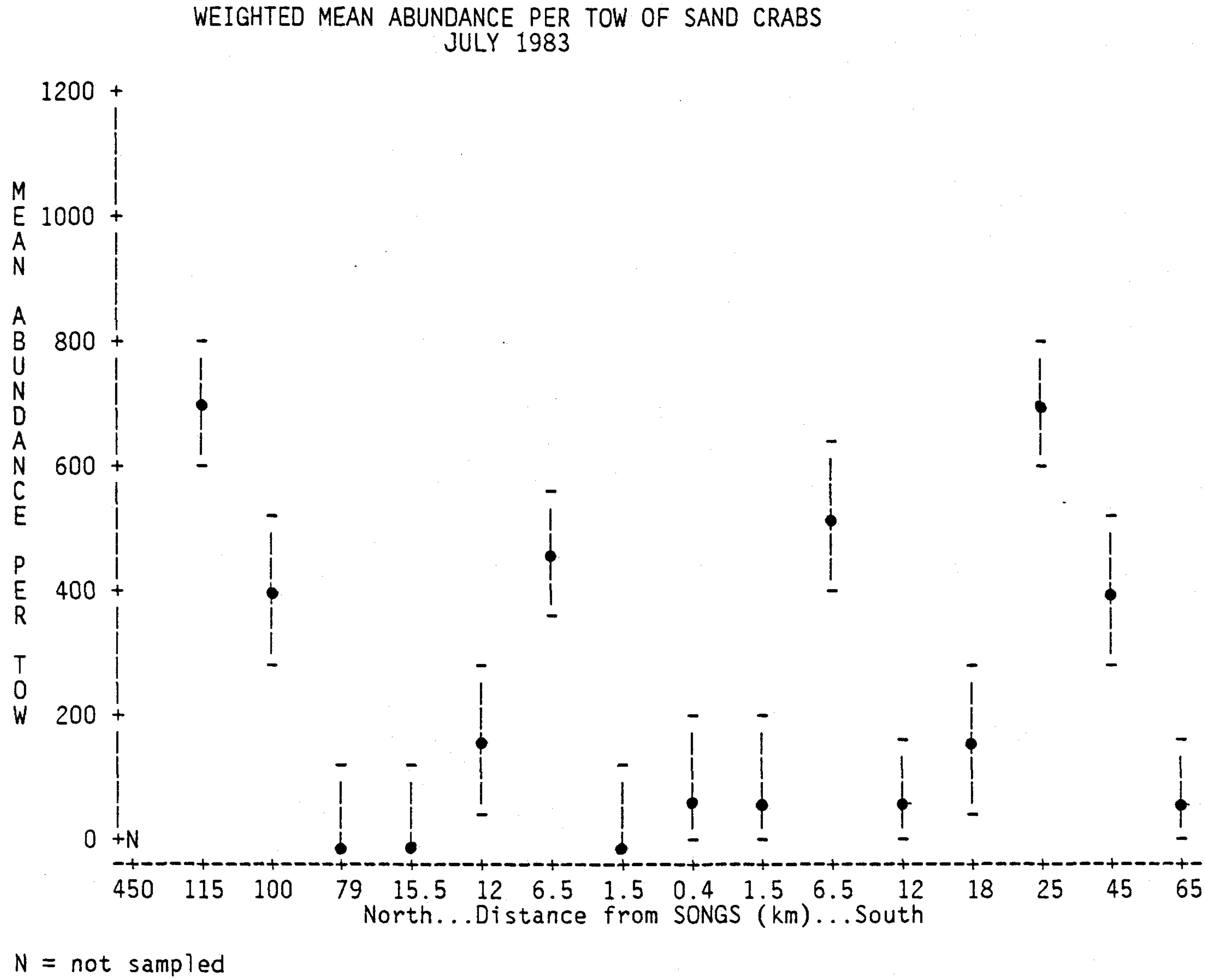
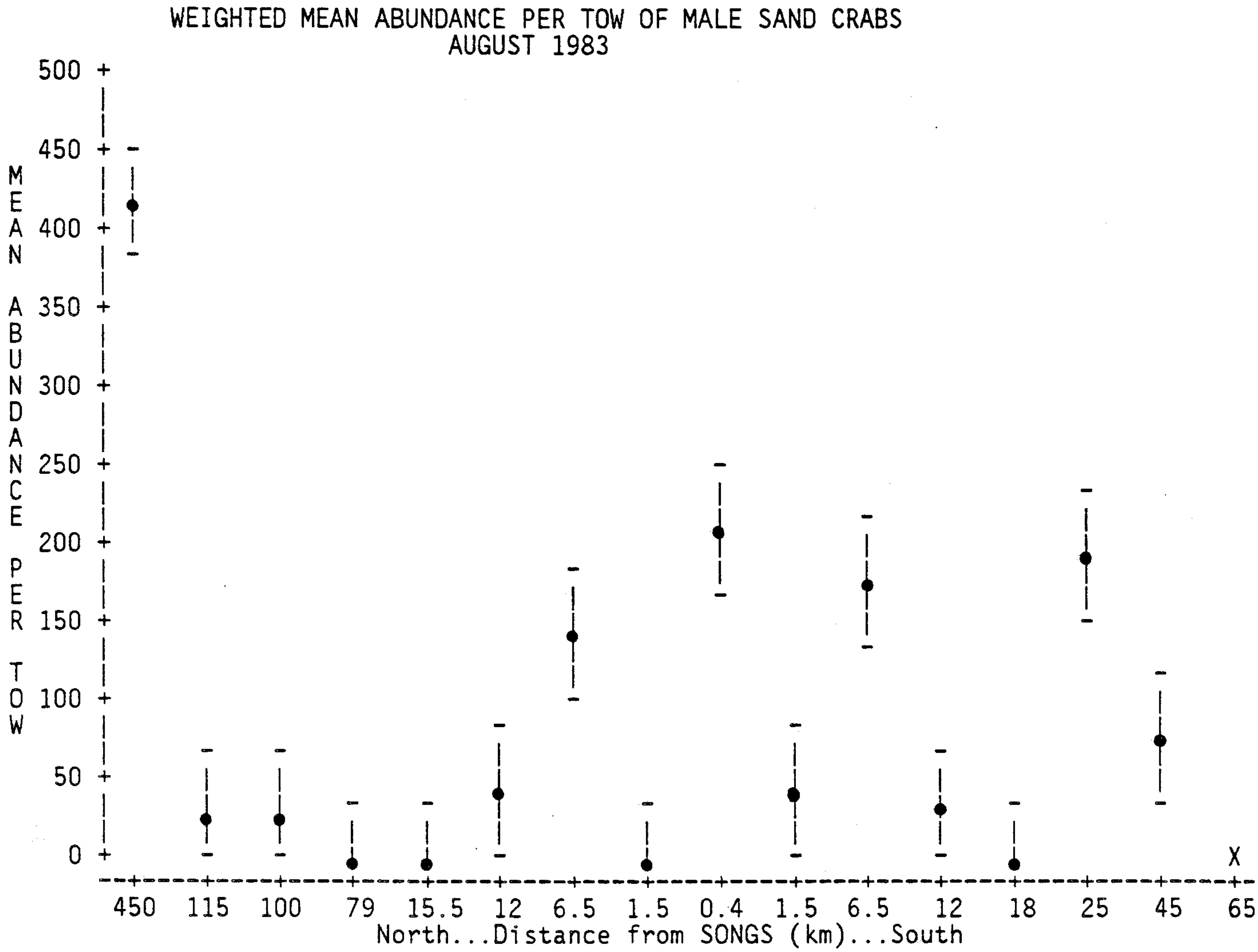


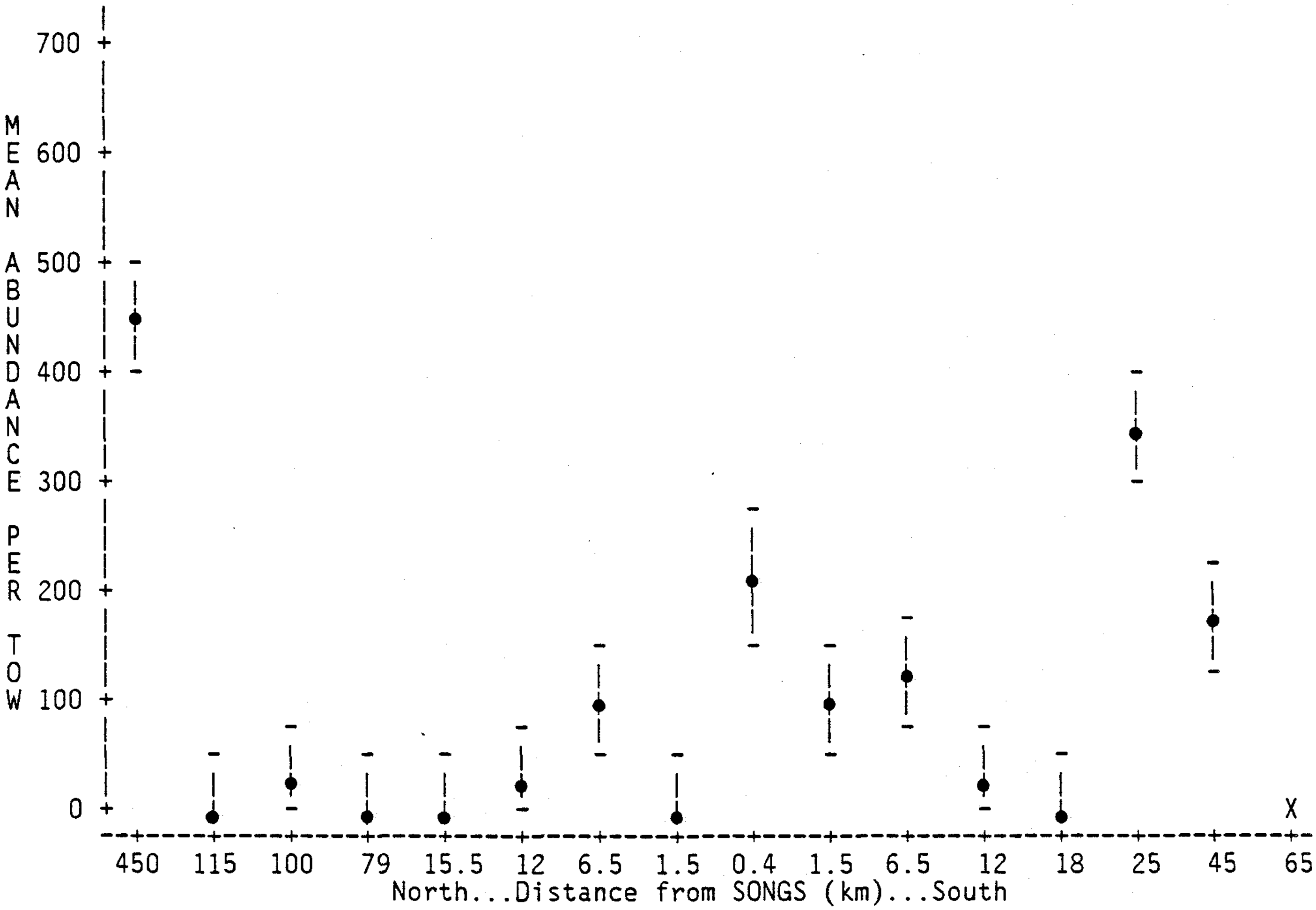
Figure F-1c. Weighted mean abundance of all sand crabs in July 1983. Site means (dots) ± 2 S. E. are shown. Note that the "Distance" axis is not to scale.



X = animals not sexed due to damage from lack of formalin

Figure F-2a. Weighted mean abundance of male sand crabs in August 1983. Site means (dots) ± 2 S. E. are shown. Note that the "Distance" axis is not to scale.

WEIGHTED MEAN ABUNDANCE PER TOW OF FEMALE SAND CRABS
AUGUST 1983



X = animals not sexed due to damage from lack of formalin

Figure F-2b. Weighted mean abundance of female sand crabs in August 1983. Site means (dots) ± 2 S. E. are shown. Note that the "Distance" axis is not to scale.

WEIGHTED MEAN ABUNDANCE PER TOW OF SAND CRABS
AUGUST 1983

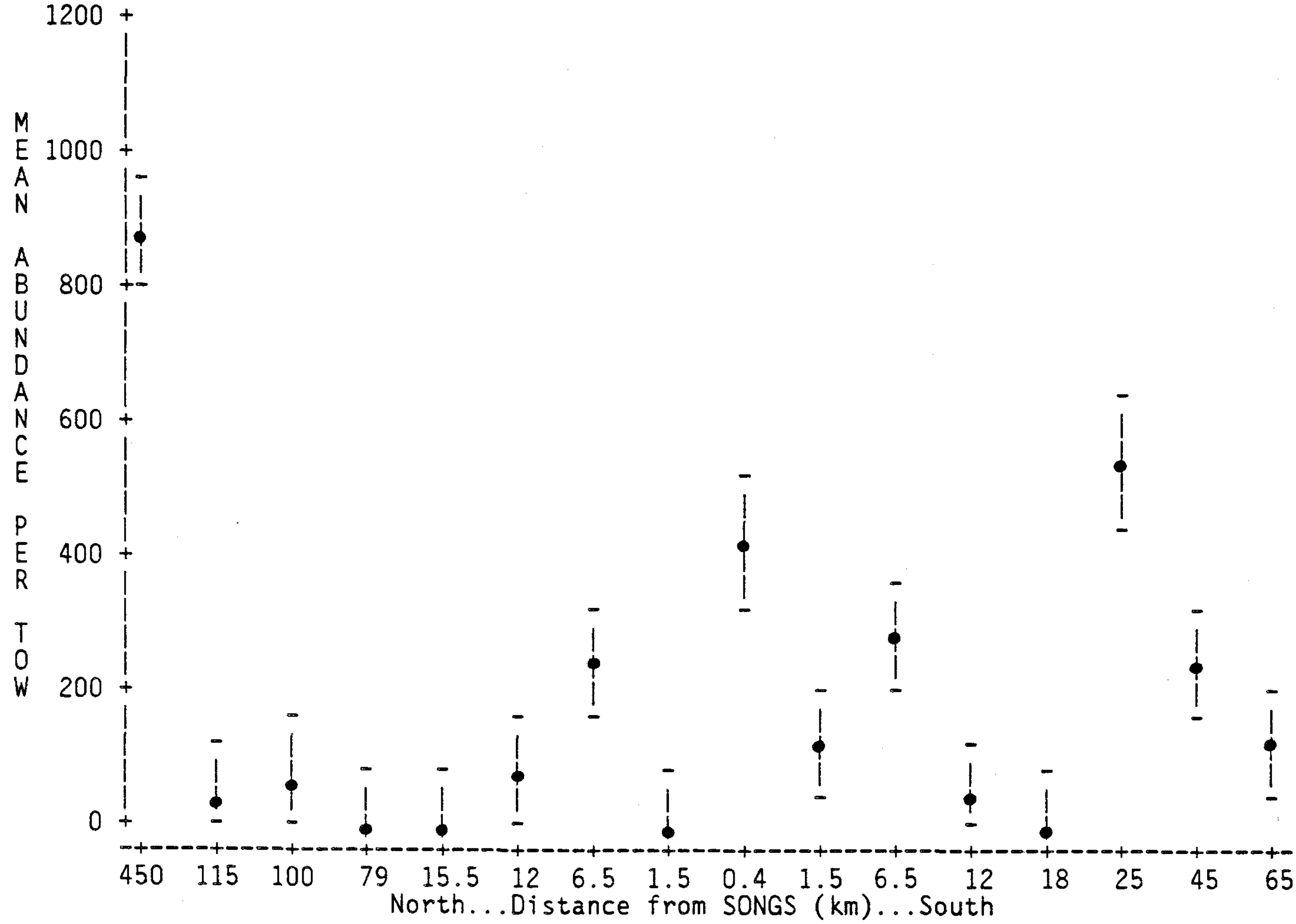


Figure F-2c. Weighted mean abundance of all sand crabs in August 1983. Site means (dots) ± 2 S. E. are shown. Note that the "Distance" axis is not to scale.

APPENDIX G

POPULATION GENETICS OF SAND CRABS

RESEARCH AND DEVELOPMENT SERIES __-RD-_

POPULATION GENETICS OF MARINE ORGANISMS

I. POPULATION GENETICS OF THE SAND CRAB, EMERITA ANALOGA

by

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SUMMARY

Genetic variation at 25 enzymatic loci was studied by means of starch and acrylamide gel electrophoresis in populations of the sand crab *Emerita analoga*. Average heterozygosity was 0.07 (± 0.03) and five loci were polymorphic. Chi-square contingency analysis indicated only a slight heterogeneity at one locus (malate dehydrogenase). Genotypic ratios at an esterase locus showed a significant heterozygote deficit in some samples but a non-significant excess in others. Activities of a phosphoglucomatase and a glucosephosphate isomerase locus were markedly reduced in some samples, notably those from the vicinity of San Onofre Nuclear Generating Station (SONGS) and from Cabrillo Beach. It has not yet been determined whether this is due to a decrease in the amount of the enzymes present or an inhibition of their activity. Animals from these localities have been shown to have reduced reproductive success.

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INTRODUCTION

This study reports on the population genetics of the sand crab, *Emerita analoga* in southern California. Wenner (1982) presented evidence that sand crab populations in the vicinity of the San Onofre Nuclear Generating Station (SONGS) were under some type of biological stress. This study examined genetic evidence for population differentiation and was part of a larger study of sand crab biology and sand crab interactions with SONGS.

The sand crab is one of the most abundant members of the intertidal sandy beach fauna of California. Adult sand crabs are ubiquitous, but patchily distributed (Efford 1965). Larvae spend up to four months in the plankton before settling in the Winter and Spring (Barnes and Wenner 1968, Efford 1970). Since the animals have such a good potential for dispersal, one might expect to find little evidence for population differentiation. However, commercial sand crab fishermen claim to be able to determine the source of a given individual from its appearance (K. Herbinson, pers. comm.) which suggests either phenotypic response to a particular location, or perhaps post-settlement selection and differentiation. The latter effect has been documented in several intertidal organisms (Koehn et al. 1973, Koehn et al. 1976). The presumed "stress" on the populations in the vicinity of SONGS might then be detected as an alteration of typical allele or genotype frequencies at one or more enzymatic loci.

MATERIALS AND METHODS

Sand crabs were collected from several localities in California by personnel of Marine Ecological Consultants (MEC), Solana Beach, California. All animals were collected between 2 and 6 August 1983. Animals were washed free of sand and sorted by size while still alive, then individuals to be used for electrophoresis were frozen on dry ice. Samples were kept at -20°C until used.

Procedures for starch gel electrophoresis followed Nelson and Hedgecock (1980) with some exceptions. Several enzymes as well as general proteins were more easily resolved after electrophoresis on 6% (w/v) polyacrylamide gels. Starch gels were 10% (w/v) Sigma starch (Lot #23F-0712). Esterase was assayed using the eserine method of Selander et al. (1971) with α-napthylbutyrate and β-napthylacetate as substrates. Malate dehydrogenase, mannosephosphate isomerase and phosphoglucomutase were also assayed after Selander et al. (1971). Glucosephosphate isomerase was assayed by the method of Corbin (1977). All stains that used glucose-6-phosphate dehydrogenase were modified according to Buth and Murphy (1980). Table 1 gives stain and buffer combinations as well as the number of loci resolved with each enzyme stain. Multiple loci are named in order of increasing anodal mobility.

Not all individuals were analyzed for variation at all loci. An initial survey determined that five loci were sufficiently polymorphic to be informative in an analysis of population differences (PGM-2, MDH-2, MPI, GPI and EST-3). Those loci were analyzed in all individuals from six samples: Morro Bay, Hermosa Beach, SONGS 0.4 km N, SONGS 1.5 km S, Horno Canyon, and

Table 1. Stain and buffer combinations for electrophoresis. Buffer systems: POUL = discontinuous Borate-Tris-citrate, "Poulik" (Selander et al. 1971); TC7 = Tris-citrate-EDTA, pH 7.0 (Ayala et al. 1973); TBE 9.2 = Tris-borate-EDTA, pH 9.2 (Ayala et al. 1973); TBE 8.2 = Tris-borate-EDTA, pH 8.2 (Maniatis et al. 1982). Enzymes marked with a "*" were run on polyacrylamide gels.

Enzyme	Abbreviation	E.C. #	Buffer	# of Loci
Acid phosphatase	ACP	3.1.3.2	TC7	2
Esterase	EST*	-	TBE 8.2	3
General Proteins	GP*	-	TBE 8.2	6
Glucosephosphate isomerase	GPI	5.3.1.9	POUL	1
Glucose-6-phosphate dehydrogenase	G-6-PDH*	1.1.1.49	TBE 8.2	1
Glutamate dehydrogenase	GDH	1.4.1.2	TBE 9.2	1
Glyceraldehydephosphate dehydrogenase	GAPDH*	1.2.1.12	TBE 8.2	1
Lactate dehydrogenase	LDH	1.1.1.27	POUL	1
Leucine aminopeptidase	LAP	3.4.1.1	POUL	1
Malate dehydrogenase	MDH	1.1.1.37	TC7	2
Mannosephosphate isomerase	MPI	5.3.1.8	TBE 9.2	1
Phosphoglucomutase	PGM	2.7.5.1	POUL	2
Superoxide dismutase	SOD	1.15.1.1	TBE 9.2	2
Tetrazolium reductase	TR	-	TBE 9.2	2

La Jolla (Fig. 1). A small number of indivudals from seven other samples were studied only for levels of activity of PGM and GPI. Most of the data analysis was performed using the BIOSYS-1 package of computer programs (Swofford and Selander 1981).

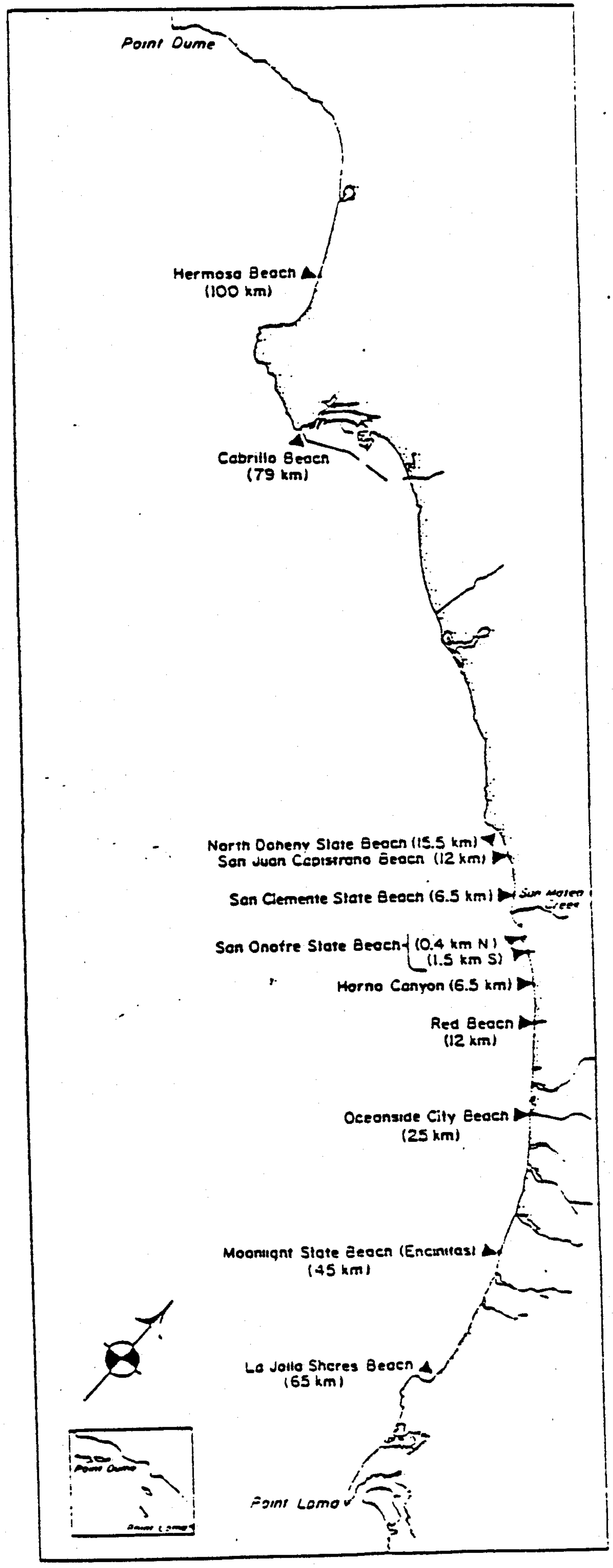

Figure 1. Locations of samples of Emerita analoga. Distances given are north or south of SONGS. A sample was also taken from the Morro Bay Sand Spit (450 km N).

RESULTS

Genetic variation was measured at 25 presumed genetic loci. Although initially I tried to duplicate the electrophoretic procedures of Nelson and Hedgecock (1980) exactly, I was not able to successfully resolve several enzymes using their methods. I was able to increase the number of loci, in a few cases, by changing to different electrophoresis or stain buffers, but for some loci I could not discover the proper set of conditions. This might be due to differences between lots of starch or other unknown factors (Shaw and Prasad 1970).

The average heterozygosity at all loci was 0.07 (± 0.03) and five loci were polymorphic (frequency of the most common allele less than 0.95). Allele frequencies at the polymorphic loci for six populations are in Table 2.

There was only a slight indication of genetic differentiation among the six samples. Chi-square contingency analysis of all loci combined indicated no significant heterogeneity. However, there was significant differentiation at the MDH-2 locus when measured alone (Table 3). One can also investigate population differences in more detail by calculating genetic distances, and associated Chi-squares, for all pairs of populations (Nei and Roychoudhury 1974). When data from all loci were used (Table 4) none of the pairs of populations was different. Although the comparison between Morro Bay and Horno Canyon was suspicious ($p < .05$), because it was one of 15 comparisons based on the same data the level of divergence was not sufficient to be significant. When only data from single loci were used, two comparisons based on the MDH-2 locus were significant, while one based on the EST-3 locus

Table 2. Allele frequencies for *Emerita analoga*. Population code: 1 = Morro Bay, 2 = Hermosa Beach, 3 = SONGS 0.4 km N, 4 = SONGS 1.5 km S, 5 = Horno Canyon, 6 = La Jolla.

	Population					
Locus	1	2	3	4	5	6
PGM						
(N)	39	39	8	15	29	37
A	0.000	0.000	0.000	0.000	0.052	0.041
B	0.333	0.397	0.438	0.433	0.414	0.338
C	0.628	0.590	0.563	0.567	0.534	0.622
D	0.038	0.013	0.000	0.000	0.000	0.000
MDH						
(N)	37	37	34	23	33	37
A	0.257	0.392	0.191	0.283	0.424	0.297
B	0.743	0.608	0.809	0.717	0.576	0.703
MPI						
(N)	50	40	24	25	36	39
A	0.020	0.025	0.000	0.000	0.028	0.013
B	0.950	0.925	0.938	0.980	0.931	0.987
C	0.030	0.050	0.063	0.020	0.042	0.000
GPI						
(N)	19	28	1	4	28	33
A	0.816	0.857	1.000	1.000	0.893	0.909
B	0.158	0.143	0.000	0.000	0.107	0.091
C	0.026	0.000	0.000	0.000	0.000	0.000
EST						
(N)	43	37	59	16	35	39
A	0.035	0.095	0.034	0.031	0.029	0.051
B	0.721	0.595	0.627	0.719	0.529	0.590
C	0.221	0.311	0.339	0.250	0.429	0.346
D	0.023	0.000	0.000	0.000	0.014	0.013

Table 3. Chi-square contingency analysis of allele frequencies among samples of *Emerita analoga*.

Locus	No. of Alleles	Chi-square	D.F.	P
PGM-2	4	18.173	15	0.25370
MDH-2	2	12.062	5	0.03394*
MPI	3	7.964	10	0.63237
GPI	3	7.894	10	0.63918
EST-3	4	18.544	15	0.23516
Totals		64.637	55	0.17546

Table 4. Matrix of genetic distance (below diagonal) and Chi-square (above diagonal) based on all loci. Chi-square with 5 degrees of freedom. (* $p < .05$)

Population		1	2	3	4	5	6
1	Morro Bay	--	7.186	4.021	3.556	14.407*	7.549
2	Hermosa Beach	0.002	--	7.598	6.409	2.129	6.503
3.	SONGS 0.4 km N	0.002	0.003	--	3.359	10.633	5.204
4.	SONGS 1.5 km S	0.002	0.002	0.001	--	8.194	2.808
5.	Horno Canyon	0.004	0.001	0.003	0.003	--	7.241
6.	La Jolla	0.001	0.001	0.001	0.001	0.001	--

was borderline (Table 5). In each case, the comparison between Morro Bay and Horno Canyon was significant or nearly so.

Deviations of genotypic ratios from Hardy-Weinberg equilibrium were tested in two ways. Table 6 gives the results of a Chi-square analysis in which expected frequencies are corrected for small sample sizes and continuity (Levine 1949). There are significant deviations in the EST-3 locus of Hermosa Beach and La Jolla. An alternate analysis, using an exact probability test, resulted in four instances of significant deviations: EST-3 in Hermosa Beach, Horno Canyon and La Jolla, and PGM-2 in Horno Canyon (Table 7). The exact probability test required pooling rare alleles into one synthetic allele. The test thus loses some information about rare alleles but is more powerful. Also, the Chi-square test is suspect when the expected frequencies of some classes are low.

All of the significant deviations at the EST-3 locus were due to a scarcity of heterozygotes between the common allele and other alleles. However, other samples showed a slight (non-significant) surplus of EST-3 heterozygotes. The only significant deviation at the PGM-2 locus was due to a surplus of heterozygotes, but again, some other samples showed a non-significant heterozygote deficit.

Analysis of PGM-2 and GPI variability in some samples was complicated by an unexpected difficulty. In some samples, PGM-2 or GPI genotypes could not be resolved in most individuals. Numerous experiments, running and re-running individuals of several samples on the same gels, gave repeatable results. As far as could be determined, the PGM-2 or GPI alleles (when they could be seen) were identical in electrophoretic mobility to those of other samples. It was either the amount of the enzyme or its activity that was altered. Modifying the conditions of homogenization and extraction,

Table 5. Matrices of genetic distance and Chi-square based on MDH-2 and EST loci. Chi-square for each one degree of freedom (* p <.05; **p <.01)

Population	1	2	3	4	5	6
LOCUS: MDH-2						
1. Morro Bay	---	3.083	0.873	0.091	4.388*	0.304
2. Hermosa Beach	0.029	---	6.854**	1.439	0.151	1.466
3. SONGS 0.4 km N	0.005	0.059	---	1.303	8.567**	2.149
4. SONGS 1.5 km S	0.001	0.020	0.010	---	2.343	0.030
5. Horno Canyon	0.046	0.002	0.083	0.034	---	2.449
6. La Jolla	0.002	0.015	0.014	0.000	0.028	---

Population	1	2	3	4	5	6
LOCUS: EST						
1. Morro Bay	---	2.839	1.970	0.001	6.158*	3.130
2. Hermosa Beach	0.022	---	0.203	1.481	0.637	0.004
3. SONGS 0.4 km N	0.020	0.004	---	0.925	1.765	0.276
4. SONGS 1.5 km S	0.001	0.016	0.013	---	3.279	1.615
5. Horno Canyon	0.075	0.025	0.018	0.061	---	0.560
6. La Jolla	0.028	0.003	0.001	0.020	0.012	---

Table 6. Deviations from Hardy-Weinberg equilibrium. Levene's (1949) correction for small samples sizes and Yates' correction for continuity used in calaculation of Chi-square.

Locus	Class	Observed frequency	Expected frequency	Chi-square	DF	P
POPULATION: MORRO BAY						
PGM-2						
	B-B	6	4.221			
	B-C	13	16.545			
	B-D	1	1.013			
	C-C	17	15.273			
	C-D	2	1.909			
	D-D	0	0.039			
				1.047	3	0.790
MDH-2						
	A-A	2	2.342			
	A-B	15	14.315			
	B-B	20	20.342			
				0.002	1	0.961
MPI						
	A-A	0	0.010			
	A-B	1	1.919			
	A-C	1	0.061			
	B-B	46	45.101			
	B-C	2	2.879			
	C-C	0	0.030			
				3.331	3	0.343
GPI						
	A-A	13	12.568			
	A-B	4	5.027			
	A-C	1	0.838			
	B-B	1	0.405			
	B-C	0	0.162			
	C-C	0	0.000			
				0.077	3	0.994
EST-3						
	A-A	0	0.035			
	A-B	3	2.188			
	A-C	0	0.671			
	A-D	0	0.071			
	B-B	23	22.247			
	B-C	11	13.859			
	B-D	2	1.459			
	C-C	4	2.012			
	C-D	0	0.447			
	D-D	0	0.012			

Table 6. Cont'd.

Locus	Class	Observed frequency	Expected frequency	Chi-square	DF	P
POPULATION: HERMOSA BEACH						
PGM-2						
	B-B	7	6.039			
	B-C	17	18.519			
	B-D	0	0.403			
	C-C	14	13.442			
	C-D	1	0.597			
	D-D	0	0.000			
				0.092	3	0.993
MDH-2	A-A	4	5.562			
	A-B	21	17.877			
	B-B	12	13.562			
				0.671	1	0.413
MPI						
	A-A	0	0.013			
	A-B	2	1.873			
	A-C	0	0.101			
	B-B	34	34.190			
	B-C	4	3.747			
	C-C	0	0.076			
				0.000	3	1.000
GPI						
	A-A	20	20.509			
	A-B	8	6.982			
	B-B	0	0.509			
				0.039	1	0.844
EST-3						
	A-A	0	0.288			
	A-B	3	4.219			
	A-C	4	2.205			
	B-B	18	12.959			
	B-C	5	13.863			
	C-C	7	3.466			
				10.175	3	0.017*

Table 6. cont'd.

Locus	Class	Observed frequency	Expected frequency	Chi-square	DF	P
POPULATION: SONGS 0.4 km N						
PGM-2						
	B-B	0	1.400			
	B-C	7	4.200			
	C-C	1	2.400			
				2.176	1	0.140
MDH-2						
	A-A	1	1.164			
	A-B	11	10.672			
	B-B	22	22.164			
				0.000	1	1.000
MPI						
	B-B	22	21.064			
	B-C	1	2.872			
	C-C	1	0.064			
				3.645	1	0.056
EST-3						
	A-A	0	0.051			
	A-B	3	2.530			
	A-C	1	1.368			
	B-B	26	23.085			
	B-C	19	25.299			
	C-C	10	6.667			
				2.786	3	0.426
POPULATION: SONGS 1.5 km S						
PGM-2						
	B-B	3	2.690			
	B-C	7	7.621			
	C-C	5	4.690			
				0.002	1	0.965
MDH-2						
	A-A	3	1.733			
	A-B	7	9.533			
	B-B	13	11.733			
				0.823	1	0.364
MPI						
	B-B	24	24.000			
	B-C	1	1.000			
	C-C	0	0.000			
				0.000	3	1.000

Table 6. cont'd.

Locus	Class	Observed frequency	Expected frequency	Chi-square	DF	P
EST-3						
	A-A	0	0.000			
	A-B	1	0.742			
	A-C	0	0.258			
	B-B	7	8.161			
	B-C	8	5.935			
	C-C	0	0.903			
				0.646	3	0.886
POPULATION: HORNO CANYON						
PGM-2						
	A-A	0	0.053			
	A-B	1	1.263			
	A-C	2	1.632			
	B-B	2	4.842			
	B-C	19	13.053			
	C-C	5	8.158			
				4.272	3	0.234
MDH-2						
	A-A	5	5.815			
	A-B	18	16.369			
	B-B	10	10.815			
				0.104	1	0.747
MPI						
	A-A	0	0.014			
	A-B	2	1.887			
	A-C	0	0.085			
	B-B	31	31.141			
	B-C	3	2.831			
	C-C	0	0.042			
				0.000	3	1.000
GPI						
	A-A	23	22.273			
	A-B	4	5.455			
	B-B	1	0.273			
				0.359	1	0.549
EST-3						
	A-A	0	0.014			
	A-B	0	1.072			
	A-C	2	0.870			
	A-D	0	0.029			
	B-B	13	9.652			
	B-C	10	16.087			
	B-D	1	0.536			
	C-C	9	6.304			
	C-D	0	0.435			
	D-D	0	0.000			
				4.308	6	0.635

Table 6. cont'd.

Locus	Class	Observed frequency	Expected frequency	Chi-square	DF	P
POPULATION: LA JOLLA						
PGM-2						
	A-A	0	0.041			
	A-B	1	1.027			
	A-C	2	1.890			
	B-B	3	4.110			
	B-C	18	15.753			
	C-C	13	14.178			
				0.316	3	0.957
MDH-2						
	A-A	4	3.164			
	A-B	14	15.671			
	B-B	19	18.164			
				0.129	1	0.719
MPI						
	A-A	0	0.000			
	A-B	1	1.000			
	B-B	38	38.000			
				0.000	1	1.000
GPI						
	A-A	27	27.231			
	A-B	6	5.538			
	B-B	0	0.231			
				0.000	1	1.000
EST-3						
	A-A	1	0.078			
	A-B	0	2.390			
	A-C	2	1.403			
	A-D	0	0.052			
	B-B	19	13.442			
	B-C	7	16.130			
	B-D	1	0.597			
	C-C	9	4.558			
	C-D	0	0.351			
	D-D	0	0.000			
				13.716	6	0.033*

Table 7. Significance test, using exact probabilities, for deviations from Hardy-Weinberg genotype ratios. R1 = Homozygotes for most common allele. R2 = Common/Rare Heterozygotes. R3 = Other genotype classes.

Locus	R1	R2	R3	P
POPULATION: MORRO BAY				
PGM-2	17	15	7	0.307
MDH-2	20	15	2	1.000
MPI	46	3	1	0.098
GPI	13	5	1	0.489
EST-3	23	16	4	0.704
POPULATION: HERMOSA BEACH				
PGM-2	14	18	7	0.749
MDH-2	12	21	4	0.320
MPI	34	6	0	1.000
GPI	20	8	0	1.000
EST-3	18	8	11	0.001**
POPULATION: SONGS 0.4 km N				
PGM-2	1	7	0	0.138
MDH-2	22	11	1	1.000
MPI	22	1	1	0.064
EST-3	26	22	11	0.161
POPULATION: SONGS 1.5 km S				
PGM-2	5	7	3	1.000
MDH-2	13	7	3	0.299
MPI	24	1	0	1.000
EST-3	7	9	0	0.256
POPULATION: HORNO CANYON				
PGM-2	5	21	3	0.027*
MDH-2	10	18	5	0.723
MPI	31	5	0	1.000
GPI	23	4	1	0.257
EST-3	13	11	11	0.040*

Table 7. cont'd.

Locus	R1	R2	R3	P
POPULATION: LA JOLLA				
PGM-2	13	20	4	0.495
MDH-2	19	14	4	0.692
MPI	38	1	0	1.000
GPI	27	6	0	1.000
EST-3	19	8	12	0.001**

electrophoresis or enzyme staining did not markedly alter the results. Each individual was scored with an index of enzyme activity: 0 = no visible stain, 1 = barely visible, 2 = clear, 3 = dark. An average index was calculated for each sample and the results presented in Table 8. In addition to the six samples that had been completely analyzed for all enzymes, 8 to 17 individuals of seven other samples were analyzed for PGM and GPI activity. Most of the samples with low PGM activity (less than 1.0) were within 15 km of SONGS. The only exception was the sample from Cabrillo Beach. Data for the GPI locus were similar. However, results for the GPI locus were confounded by a second factor: GPI activity declined in all samples after prolonged storage of whole animals at -20°C. PGM activity seemed to be much less labile under the same storage conditions. The GPI activity index was inversely correlated with storage time (Spearman's rank correlation $r_s = .489$, $P < .05$, one-tailed test). The PGM activity index was not significantly correlated with storage time ($r_s = .085$).

To examine this effect in more detail, new samples of _E. analoga_ were collected. Spectrophotometric assays of PGM and GPI activity (Bergmeyer, 1974) were used to measure weight specific enzyme activity in newly collected and stored specimens. After 28 days of storage at -20°C, GPI declined an average of 98% (from 18 units/g wet weight to 0.38 units/g wet weight), while PGM activity declined 68% (from 9.5 units/g wet weight to 3 units/g wet weight). Note that although weight-specific enzyme activity did decline in PGM, the residual activity was still sufficient for clear staining on a gel, and therefore would not have been noticed in the crude index of activity used earlier.

Table 8. Ezyme activity indices for GPI and PGM in samples of *Emerita analoga*.

Sample	GPI Activity		PGM Activity			Date
	$\bar{X}$	s	$\bar{X}$	s	N	assayed
Morro Bay	1.28	1.02	2.30	0.48	40	29 Nov 83
Hermosa	2.08	1.38	3.00	0	39	28 Oct 83
Cabrillo	0	0	0.43	0.79	8	21 Nov 83
N. Doheny	0	0	0.41	0.51	17	21 Nov 83
Capistrano	0	0	1.58	1.17	12	21 Nov 83
Clemente	0	0	1.42	0.79	12	18 Nov 83
SONGS						
0.4 km N	0.09	0.30	0.57	0.79	35	2 Nov 83
1.5 km S	0.38	0.52	0.86	0.69	35	11 Nov 83
Horno Canyon	0.94	0.93	1.30	0.98	36	18 Oct 83
Red Beach	0.71	1.25	1.00	0.85	12	18 Nov 83
Oceanside	0	0	2.00	1.00	8	21 Nov 83
Moonlight	0.43	0.79	2.29	0.76	8	21 Nov 83
La Jolla	2.04	1.35	2.50	0.51	40	20 Oct 83

DISCUSSION

Nelson and Hedgecock (1980) surveyed electrophoretic variability in a large number of decapod crustaceans, including *Emerita analoga*. They measured variation at 20 enzymatic loci and found the average heterozygosity to be 0.114. This was not significantly different from the present estimate of 0.07 (based on 25 loci). Heterozygosities for individual loci in common between the two studies were also similar.

It is difficult to explain the lack of success in this study when staining for some of the enzymes used by Nelson and Hedgecock and using their methods. However, I was also able to add several loci, including LAP, an enzyme that Nelson and Hedgecock were not able to resolve.

It seems that the EST-3 locus scored in this study was different from either of the two loci scored by Nelson and Hedgecock (D. Hedgecock, pers. comm.). They found two slowly migrating loci (on starch gels), whereas I scored a single fast migrating polymorphic locus (on polyacrylamide). I was unable to resolve either of the two loci referred to by Nelson and Hedgecock using their methods. Nelson and Hedgecock also scored two polymorphic loci with PGM activity with overlapping alleles. The PGM locus used here corresponds to their PGM-2. Activity at the locus corresponding to their PGM-1 was always low and was usually too poor to be scored unambiguously. Corbin (1977) studied GPI variation in the related East Coast species *Emerita talpoida*. The two species appear to have no alleles in common at this locus.

There were no obvious patterns of geographic differentiation among samples of *Emerita analoga*. This is perhaps to be expected among local populations of a widely dispersing species. There was no evidence of regular or clinal variation at any locus. The few instances of significant differences between pairs of samples appeared to be random. Even the sample from Morro Bay, taken hundreds of kilometers to the north of the rest of the samples, did not appear uniquely different from the range of samples found in southern California. This was true even for the MDH-2 locus, which had the greatest amount of differentiation among samples. Reduced migration rates do not seem to be an important factor in determining the genetic structure of *E. analoga* populations.

Corbin (1977) demonstrated clinal variation with latitude for two GPI alleles in *E. talpoida*. He related this to variation in temperature and salinity and argued that each genotype responded differently to variation in each variable. He also showed that characteristic genotypic ratios did not vary after metamorphosis from the megalops stage. If one ignores the GPI data from the two samples, SONGS 0.4 km N and SONGS 1.5 km S (where sample sizes are very small), the rest of the GPI data presented here might also be seen as a cline. However, since the ends of the "cline" were not significantly different from each other, one should not conclude that a similar causal situation exists. Note, also, that E. analoga and E. talpoida share no GPI alleles.

Allele frequencies at the MDH-2 locus were heterogeneous, but they did not seem to vary in a regular or predictable fashion. If the differences had some biological basis due to natural selection, the populations must have been responding to something in the environment with reticulate variation. Given that the greatest divergence was between the samples from Horno Canyon and SONGS 0.4 km N, separated by less than 7 km, the differences were more likely due to post-settlement alterations of genotypic ratios. Since neither sample was far from Hardy-Weinberg equilibrium, selection can not have been acting simply at one genotype. Another alternative is that although larvae were widely dispersed, they were not well mixed, so that the larvae that settle to make up a single population were not a random sample of the entire larval pool. The two alternatives might be distinguished by sampling the same locations over several years to see if allele frequencies remain characteristic of a given location.

The observed deviations from expected Hardy-Weinberg genotypic ratios also could have been due to differential survival of genotypes. The number of instances of significant deviation was small, but the Chi-square test is not a very powerful one. Since there were no obvious trends toward heterozygote deficit or excess for any locus, the causes are likely to be complex. It is interesting that the two samples from the vicinity of SONGS showed no evidence of altered genotypic ratios.

Samples from the vicinity of SONGS did differ from the other samples in one unexpected way. Many individuals from the SONGS 0.4 km N and SONGS 1.5 km S samples gave very poor results when stained for PGM or GPI activity. Activity of other enzymes appeared normal. Although a few individuals stained normally, many individuals gave no detectable result. Other samples in the vicinity of SONGS (15 km N or S) also had reduced activities as well as a sample from Cabrillo Beach. There are a number of alternative explanations. The simplest is that these samples were badly handled in some way, e.g. allowed to thaw before analyzed. There is no evidence that this is the case (L. Gleye, MEC, pers. comm.). Other possibilities include a reduced amount of these enzymes present or inactivation of the enzymes in some way. The first alternative might be a result of an alteration in the genetic control of enzyme production due to an unknown environmental or genetic factor. The second alternative could be due to an environmental pollutant forming an inactive complex with the enzyme (heavy metals are one possibility). Nevo et al. (1983) have reviewed the effects of marine pollution on allozyme polymorphisms. They have shown selection for different PGM or GPI alleles of marine crustaceans and snails after heavy metal pollution. Pontecorvo et al. (1983) showed that heavy metal concentration influenced the activity of some PGM allozymes in the shrimp Palaemon elegans. Nevo et al. (1978) presented evidence for selection acting on allozymes after petrochemical pollution. One can not yet differentiate among alternatives, but further work should certainly be done. The first step should be to repeat the observations on a new set of samples, then one could purify the enzymes and make antibodies to them. One could then assay enzyme activity and amount independently and ultimately look for causal factors. Although it is little more than empty speculation at this point, it is interesting that the only sample to show the effect strongly, away from the vicinity of SONGS, came from an area of heavy industrial impact. Pollution, in some form, is clearly one suspicious environmental factor.

Preliminary results from the ongoing study of sand crab biology conducted by MEC (Barnett 1983) indicated that there was considerable variation in several biological parameters among beaches in southern California. Using multivariate techniques, they were able to account for 56% of the variance in sand crab density and 70% to 90% of the variance in reproductive parameters by differences in environmental factors (notably sediment type and food availability) among sites (K. Green, pers. comm.). Interestingly, although sites near SONGS were not significantly different from other beaches in July, those same sites formed a unique group in August (when the samples discussed here were taken). In addition, samples from

Cabrillo were often most like those from SONGS, with similar reductions in percentages of females with eggs and other reproductive parameters. Unfortunately, no animals were taken from Venice Beach in August; this site has been suggested by Wenner (cited in Barnett 1983) to also show signs of reproductive stress. Although both tissue and sediment samples have been collected to be analyzed for potential pollutants, these analyses have not yet been completed so possible causal factors remain obscure.

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APPENDIX H

OVARIAN HISTOLOGY OF SAND CRABS

Ovarian Histology of the Sand Crab, *Emerita analoga* from San Onofre Nuclear Generating Station, California and Adjacent Beaches

Stephen R. Goldberg

Abstract: I investigated the ovarian histology of 366 sand crabs to assess possible reproductive abnormalities from contamination associated with the San Onofre Nuclear Generating Station (SONGS). It was found that examining ovaries of females carrying eggs in advanced states of development or spent egg cases gives information as to whether another egg mass will be formed. Reproductive differences were noted between the examined populations. Moon and Ocea contained the highest percentages of reproductively active females that would have produced an additional egg mass and 0.4 N and 1.5 S showed the lowest. Atretic oocytes were identified and described. Low incidences of these structures were commonly observed. It was found that most examined crabs had been feeding and digesting their food and all were apparently healthy. On the basis of their healthy condition and low frequency of atresia, it was concluded that termination of reproduction was likely due to natural factors operating at the close of the reproductive season.

Introduction

The use of invertebrates as indicators of environmental pollution is a relatively new concept. The sand crab, *Emertia analoga* seems ideally suited for this work as it is small, readily available and occurs in urban beaches. The purpose of my investigation was to examine ovaries of sand crabs from SONGS and adjacent areas and report on the status of their reproductive condition.

Methods

Sand crabs were placed in 10% formalin on capture. Collections were made during August 1983 from San Onofre Nuclear Generating Station (SONGS), San Diego County, California and other beaches. By design, I was not told which samples were from SONGS so as not to bias my interpretations. In addition, I examined ovaries of 11 sand crabs that were collected July 1983. Sand crabs were dissected under a dissecting microscope. Ovaries were removed with jewelers forceps and were embedded in Paraplast. Histological sections were cut at 8 μm. Slides were stained with Harris' hematoxylin followed by eosin counterstain.

Results and Discussion

In examining the sand crabs, difficulties were encountered due to small sizes of specimens and insufficient fixation. The small size of many of the samples made locating the ovaries very difficult. I recommend that whenever possible, large sand crabs be selected for histological studies. Fixation was poor in several samples. This might be remedied by injecting fixative into the body cavity with a syringe, thereby insuring rapid penetration. Mature, yolk-filled ovaries were extremely brittle which made for difficult sectioning. I suggest using a different fixative such as Davidson's fixative (Humason, 1979) as an alternative to 10% formalin. This fixative has been used in other crustacean ovarian studies (Haefner, 1977; Wenner, 1979). Also, a small pipette would be helpful in transferring the ovaries as the fragile stroma supporting them frequently broke resulting in the loss of some of the mature oocytes.

The ovaries of the sand crab are located underneath the intestine. During times of inactivity or after an egg mass has recently been extruded, they are transparent and contain immature oocytes (Fig. 1A) embedded in a fibrous connective tissue stroma. In this state they are similar to those seen in deep sea lobsters (Wenner, 1979), deep sea red crabs, Geryon quinquedans (Haefner, 1977) and the blue crab Callinectes sapidus (Johnson, 1980). As vitellogenesis progresses for the next egg mass, the ovaries enlarge and spread anteriorly, ventral to the intestine. They start to turn yellow and one can begin to distinguish individual oocytes under a dissecting microscope. The ripe, mature ovary commonly proliferates laterally into the anterior corners of the body cavity.

From examining a series of practice animals with a gradual development of extruded eggs (Table 1), I noted a progressive sequence in develooment of the ovary during the reproductive cycle. This might be taken as a normal model for the ovarian cycle that would occur during periods of peak reproductive activity. In females that have bright, recently extruded immature eggs, the ovary is in an undeveloped condition. It consists primarily of resting oocytes (Fig. 1A) which approximate 30 μm (diameter). In some cases the same ovary may contain early (55 μm) diameter vitellogenic oocytes (yolk deposition in progress) (Fig. 1B). These early vitellogenic oocytes are not yellow to the naked eye. Thus, without histology, one could not distinguish an early vitellogenic ovary from one containin only primary oocytes. I noted that in females with more highly develope extruded eggs, ovaries contained enlarging vitellogenic oocytes. In the spent condition in which crabs had been released from the underside of the sand crab, the ovaries contained yolk-filled mature oocytes (Fig. 2A) which approximated 260 μm (mean diameter). Mature yolk-filled oocytes are surrounded by a thin chorionic membrane. This membrane may be derrived from the accessory cells (Ryan, 1967).

Accessory cells and developing oocytes are the two types of cells present within the ovarian lobes of the blue crab (Johnson, 1980). Ovarian development is synchronous in the sand crab as only one group of oocytes undergoes vitellogenesis at a given time.

I often encountered animals (Table 2) which did not correspond to the sequence outlined in Table 1. These animals, in the burnt, greyish-burnt, grey and spent condition contained inactive ovaries comparable to the bright condition. This discrepancy could be due either to the normal conclusion of the reproductive cycle or to some environmental trauma that reminated reproduction. If the cycle were abruptly terminated, we would expect to see an unusually large frequency of atretic oocytes. The atretic process has adaptive value because should environmental conditions change from less than optimum, the animal is allowed to channel energy (invested in yolk) away from a reproductive effort that probably would have been abortive and use it on another body function.

In atresia, there is a spontaneous breakdown of the oocyte. This may occur at any stage of development and may thus be seen in the smallest oocyte to the mature, yolk-filled oocyte. As expected, in the sand crab, atresia was noted in oocytes of all sizes. It can best be characterized as a disruption (Fig. 2B) of the ooplasm. In late atresia (Fig. 3A), the interior of the oocyte is filled by a mass of connective tissue. The mechanics of this process are not clear, but it is conceivable that it may in part be due to an invasion of ovarian accessory cells (follicle cells) that penetrate into the ooplasm. This is suggested by the frequent occurrences of what looks to be accessory cells (Fig. 3B) in the ooplasm of atretic oocytes.

While several atretic oocytes were commonly seen in different sand crabs, I only noted a single ovary (Ocea spent) in which the majority of oocytes were undergoing atresia. Thus, one would not have expected that the populations under examination, (on the basis of histological criteria) had been recently exposed to any environmental trauma. This seems likely as on dissection, all animals appeared to be healthy. Most of their stomachs contained food and there was a fecal mass in the intestine.

The use of atresia as an indicator of environmental stress has been described in the northern anchovy, Engraulis mordax by Hunter and Macewicz (1985). By starving fish in the laboratory, they timed the atretic degeneration of oocytes. Also, at the close of a reproductive season, many of the oocytes that initiated, but failed to complete yolk deposition, undergo atrseia (Goldberg, 1981). These structures disappear within several weeks. The identification of these structures in the sand crab will be useful in subsequent investigations as an indicator of environmental stress on reproduction.

It was previously reported (Cox and Dudley, 1968) that sand crabs may breed repeatedly during a reproductive season. The developing of yolk-filled eggs within females containing extruded egg masses bears this out. Thus, we can make comparisons among the different samples so as to determine percentages of females that would have produced an additional egg mass during summer 1983.

In order to interpret these results, one must consider other factors: (1) sizes of females are important as larger females typically begin reproduction earlier and terminate it later than do smaller females. Hence, to avoid size class biases, samples should include the different size classes present at a beach; (2) During 1983 an "El niño" condition existed during which time water temperatures were higher than normal. It is conceivable this may have effected the duration of the sand crab reproductive cycle; (3) In selecting samples, they should be taken from the peak period of reproduction. If, for example, they were taken when females were producing their final egg masses of the year, what would be a normal termination of reproduction might be misinterpreted as being due to some environmental pollutant. If they were collected before the population started to reproduce, one would erroneously describe the population as being nonreproductive.

The question as to how long it takes for a female to deposit sufficient yolk to form a clutch of eggs is difficult to answer. Ideally, this information could be best gathered by performing experiments in the laboratory. A number of factors will influence this problem. Female size will partly effect the rate of yolk deposition as vitellogenesis would be expected to occur faster in larger females than in smaller females. Also, time of the reproductive season should be considered. Yolk deposition proceeds faster early to middle of the season than late in the season. One might get an approximation of time required by collecting females at weekly intervals early in the reproductive season before the first egg clutch is formed. However, as previously mentioned, the rate would be different later in the season than it would be early in the season.

In analyzing the categories (Table 2), I have not included the bright category. This is because it is difficult to find ovaries in this stage as they have recently extruded egg masses and are at their smallest sizes. More importantly, it is very difficult to know if females in this condition will reproduce again during the current reproductive season. Even in those cases of bright females with yolk deposition in progress, it would be hard to conclusively state that another egg mass would be produced that season. Hence, females with more advanced external egg masses (burnt, grey and most definitely, spent) will give the best information as to what percentage of a population will continue reproductive activity in a given year.

In my report of those females that will produce another egg mass (Table 2), I have based my observations on macroscopic as well as histological observations. In looking at Table 2, differences were noted between the various populations. The moon population had the highest degree of reproductive activity and would clearly have produced another egg mass. Ocea also would have produced another egg mass. 0.4 N would not have. This is evident as none of the 15 females with spent eggs showed ovarian reproductive activity. The Herm population was probably in the process of producing the last egg mass. This is likely as none of the spent females had ovarian activity; whereas the other classes did.

In the KS population, it appears about half of the population will produce another egg mass. In the 6.5 S population, only 15% will reproduce again and reproduction was over in 1.5 S. About one-fourth of Sanc and one-fifth of Capi would have produced another egg mass.

A total of 11 crabs from July 1983 were analyzed to see if reproduction was different one month earlier (other samples were from August). None of the 1.55 E sample was reproductively active (Table 2). The sample 1.5 N would have produced another egg mass. Only 13% of the 0.4 N spent group would have reproduced again in comparison to none of the August group. Thus, this population had a low rate of ovarian activity in July when we would have expected a higher rate of reproduction (Cox and Dudley, 1968).

The question as to what was responsible for the high percentages of crabs with advanced external eggs that would not have produced another egg mass in the 0.4 N, 6.5 S, 1.5 S, Sanc and Capi groups is complicated. One might suspect it was due to exposure to environmental pollutants. I doubt this. On the basis of my histological examination, there was nothing observed to indicate an abrupt, abnormal termination of the reproductive cycle which would have been evidenced in a high incidence of oocyte atresia. Nor, for that matter, were any ovarian structures observed that could have been interpreted as being pathological. The above information coupled with observations that the crabs had been feeding and digesting food lead me to conclude that the populations examined were healthy. I thus feel that the low frequency of certain populations producing an additional egg mass is likely due to a normal termination of the breeding cycle.

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Table 1. External egg condition and corresponding internal histological ovarian condition in the sand crab, *Emerita analoga*

External Egg Condition	Histological Condition
1) Bright, newly extruded immature egg	Ovaries contain primary oocytes, yolk deposition may be in progress
2) Burnt, more developed, eyespots becoming visible	Developing vitellogenic oocytes
3) Greyish-burnt, between burnt and grey	" " " "
4) Grey (or brown) more developed than burnt, eyespots very apparent	" " " "
5) Spent, eggs released from sand crab	Yolk-filled mature oocytes, may be ready to be released

Table 2. Percentages of sand crab, Emerita analoga from July and August 1983 that would have produced an additional egg mass.

Date	Locality	Category	N	% Females to Form Another Egg Mass
August	Moon	burnt, 7-11	10	90
August	Moon	grey, 7-11	5	100
August	Moon	greyish-burnt, 7-11	5	100
August	Moon	spent, 7-11	15	87
August	Moon	spent w grey, 7-11	2	100
August	Ocea	burnt, 7-11	10	60
August	Ocea	greyish-burnt, 7-11	5	80
August	Ocea	grey, 7-11	5	100
August	Ocea	spent w bright, 7-11	2	50
August	Ocea	spent w grey, 7-11	3	100
August	Ocea	spent, 7-11	15	80
August	0.4 N	burnt, 7-11	13	8
August	0.4 N	greyish-burnt, 7-11	1	0
August	0.4 N	spent w bright, 7-11	5	0
August	0.4 N	spent w burnt, 7-11	6	0
August	0.4 N	spent, 7-11	15	0
August	Herm	burnt, 7-11	2	50
August	Herm	burnt, 12-20	6	83
August	Herm	grey, 7-11	1	100
August	Herm	grey, 12-20	4	100
August	Herm	greyish-burnt, 12-20	2	100
August	Herm	spent w burnt, 7-11	1	100

Table 2 (Continued)

Date	Locality	Category	N	% Females to Form Another Egg Mass
August	Herm	spent w grey, 7-11	2	100
August	Herm	8304, spent, 7-11	4	0
August	Herm	8304, spent, 12-20	13	0
August	Herm	8304, slightly spent 12-20	3	0
August	12 KS	spent w grey, 7-11	1	100
August	12 KS	spent, 7-11	19	53
August	6.5 S	spent, 7-11	20	15
August	1.5 S	spent, 7-11	20	0
August	Sanc	spent, 7-11	20	25
August	Capi	spent, 7-11	19	21
August	Capi	spent, 12-20	1	100
July	1.55 E	spent	2	0
July	1.5 N	spent	1	100
July	0.4 N	spent	8	13

APPENDIX I

ANNOTATED HISTORY OF SAND CRAB STUDIES THAT WERE RELATED TO SONGS

I.1 HISTORICAL BACKGROUND

I.1.1 1976-1977 Auyong Study

Janice S.H. Auyong, a student of Dr. Adrian M. Wenner of the University of Santa Barbara (UCSB), conducted a study of sand crabs living at increasing distances from SONGS. The study resulted in a thesis for a Master of Arts degree from UCSB. The results, in part, are presented in MRC Document 77-09 No. 2 (Annual Report to the California Coastal Commission August, 1976 - August, 1977, Appendix 1. Estimated effects of SONGS Unit 1 on Marine Organisms: Technical Analysis and Results).

The stated objective of the study was "to determine if differences among populations of E. analoga {size and reproduction} were correlated with distance from SONGS." Environmental features, including temperature and organic solids in the surf zone were monitored during the study.

Five beach sites at increasing distance from SONGS (i.e., 0.4 km N, 1.5 km N, 1.5 km S, 6.5 km N, and 6.5 km S) were sampled for sand crabs every two weeks during four consecutive periods from mid-August 1976 through mid-August 1977. Sand crabs were also collected at two sites, 16 km S and 64 km S of SONGS, during the spring and summer of 1977.

Auyong (1981) reported an inverse correlation between proximity to the plant and several variables related to the size of male and female sand crabs. No correlation was found for the proportion of ovigerous females, the single reproductive variable considered. No correlations between temperature or organic solids in the wash zone and variations in sand crab size were reported.

I.1.2 1980 Wenner Study

Dr. Adrian M. Wenner of UCSB conducted a study of sand crabs from April to November 1980. A preliminary report was submitted to the MRC 25 November 1980; final results of the 1980 study were submitted 1 July 1982 as part of a report (Wenner, 1982) covering sampling periods from 1 April 1980 to 1 April 1982.

The stated objectives of the 1980 study were twofold: "1) to gather comparative data on population structure from Goleta, San Onofre, and La Jolla beaches within one growing and reproductive season, and 2) to provide a comprehensive description (qualitative and quantitative) of sand crab distribution in the beach habitat."

Three beach sites (Goleta, 0.4 km N of SONGS, and La Jolla) were sampled at intervals spanning a month or less. Other sites away from SONGS (Capistrano, 6.5 km N, 6.5 km S, Oceanside, and Solana Beach) were sampled once in July 1980.

Wenner (1982) reported that the sand crab data (size and reproductive) gathered near SONGS did not differ markedly from data gathered at Goleta and at La Jolla in 1980.

I.1.3 1981 Wenner Study

Dr. Wenner conducted a six-month study of sand crabs from April to October 1981. A final report of the results from the 1981 study was submitted to the MRC 1 July 1982 as part of a report (Wenner, 1982) covering the period 1 April 1980 to 1 April 1982.

The specific objectives of the 1981 study were: "(1) to determine the effect of different tidal heights on sampling results, (2) to provide additional data concerning variation in sample results due to longshore variability, and (3) to gather comparative data at each of the

5 study sites at SONGS every 6 weeks during the 1981 reproductive season, before Units 2 and 3 began operating."

The same 5 beach sites sampled by Auyong in 1977 (i.e., 6.5 km N, 6.5 km S, 1.5 km N, 1.5 km S, and 0.4 km N) were sampled in 1981. A beach in La Jolla and two beaches in Goleta were also sampled. Beach sites near SONGS were sampled every 4-6 weeks from April to October 1981, La Jolla was sampled at 4-8 week intervals from May to September, the Goleta site near UCSB was sampled once in May and then at two week intervals from August to September, and the other Goleta site was sampled in June, August and September.

Wenner (1982) reported that in 1981 males were smaller, on the average, at the 1.5 km N and 0.4 km N sites when compared to the size of males at 1.5 km S and more distant sites within 6.5 km of SONGS and at La Jolla. Differences in the size of females were less clear. Females, on the average, were smaller at the 1.5 km N and 0.4 km N sites but females at 1.5 km S, 6.5 km N, and 6.5 km S were of similar size or larger than at La Jolla. He also reported that lower percentages of the females were carrying eggs at the 5 sites within 6.5 km of SONGS than at La Jolla. No comparisons were made with sand crabs from Goleta.

I.1.4 1982 Wenner Study

Dr. Wenner conducted a study from June to July 1982 without funds from the MRC. Results of this study were submitted with the report of the 1980-1981 results (submitted to the MRC 1 July 1982 in the report covering the period 1 April 1980 to 1 April 1982). Recently, the results were published in the journal Marine Biology (1984, 80: 341-345).

The purpose of the study was to examine the reproductive condition of female sand crabs at beach sites in the vicinity of SONGS and farther away. Four sites were sampled in June (i.e., Goleta, 6.5 km N, 1.5 km N, and La Jolla). Eleven sites were sampled in July (i.e., Salt Creek, Doheny Beach north, Doheny Beach south, 6.5 km N, 1.0 km N, 1.5 km S, 6.5 km S, Camp Pendleton Red Beach, Del Mar Recreational Beach, Oceanside, and La Jolla).

Wenner (1982) reported that the percentages of females with eggs were lower for a stretch of beach nearly 40 km long, centered on SONGS. Wenner contended that the lower percentages of females with eggs in the vicinity of SONGS were the result of "egg rupturing". This interpretation was based, in part, on the observation that most females in the vicinity of SONGS carried masses of "ruptured egg shells" rather than eggs. It was also based on a laboratory experiment that showed that females (including females with "ruptured egg cases") collected from 6.5 km N produced more masses of orange eggs after 2-3 weeks when held in flow-through seawater tanks at UCSB than did the field population.

In his recent paper, Wenner (1984) stated that the "abnormal reproduction" of sand crabs was most likely caused by: (1) runoff of agricultural pesticides from a creek 3 km north of the nuclear generating plant, (2) release of metals from corroding cooling pipes, and/or (3) increased turbidity of the nearshore waters.

I.2 1983 MRC REVIEW OF EARLIER WORK

The MRC (memo from W. Murdoch 14 January 1983, memo from J. Connell and J. Palmer 30 March 1983) reviewed the above-mentioned studies and concluded that information was insufficient to evaluate whether beach populations of sand crabs were affected by the operation of SONGS. This is so because the findings of Wenner and others for 1982 and before did not clearly establish that SONGS interfered significantly with sand crabs. Not only did differences occur between sites, without regard to distance from SONGS, but between seasons and years at the same site. There were few occasions of concurrent data from the same season, in a given year, from San Onofre and other beaches, which limited evaluation of among-beach comparisons. Finally, insufficient information was collected regarding the beach habitats themselves. Thus, it was not possible to evaluate whether differences in sand crab populations were related to the habitats of the beach sites or to SONGS effects.

I.3 1983 WORK ESTABLISHED BY MRC

Although inconclusive, the findings were considered to be of sufficient importance to warrant more study. Three major questions were of interest to the MRC: (1) What is the nature of the biological phenomena? (2) Is there a SONGS locality effect? (3) How does this effect, if it exists, relate to the construction or operation of SONGS?

Through a series of MRC memoranda concerning recommended approaches and design, a proposal of study by MEC, meetings, and telephone conferences, these questions were redefined for the 1983 study as:

(1) are sand crab attributes at beach sites near SONGS within the variation observed at other beaches in 1983?

(2) do sand crab attributes exhibit a distinct trend with distance from SONGS; in particular do the attributes previously reported to vary within 6.5 km of SONGS vary thus in 1983, and is there a locality effect when distances farther than 6.5 km from SONGS are considered?

(3) to what extent are selected attributes correlated with the physical-chemical environment.

Specifically excluded from the 1983 work was the direct establishment of causal mechanisms between SONGS and sand crab attributes, which would have entailed both laboratory and field experiments. This exclusion was adopted by the MRC to avoid expensive experimental work before its need was fully demonstrated.

I.4 1983 MEC STUDY

The final work statement contracted to MEC by the MRC required a survey each in June, July, and August 1983, with nine beach sites sampled within 18 km of SONGS, three sites further south and three sites further north. Most of the sites previously sampled by Auyong and Wenner were included. Sampling gear and methodology was to be designed so that sand crab abundance[1] could be estimated as well as size and reproductive attributes.

The biological parameters studied included, but were not limited to, the ones studied by Wenner. These are listed in Table 1. The environmental variables are shown in Table 2. Sampling was to take place at night when crabs were likely to be more uniformly distributed both on the beach slope and longshore. Patches were to be sampled quantitatively with a sled. Shovel samples were to be taken to supplement analyses.

As a potential cost saving measure, the following proposed analyses became optional to the MRC, pending the results of the rest of the study: (1) histology; (2) metals in tissue, water, and sediment; and (3) organic pollutants in tissue, water, and sediment.

I.5 AMENDMENTS TO THE 1983 STUDY

I.5.1 Addition of Morro Bay

Morro Bay sand spit (north of Point Conception) was to be included in the array of beaches sampled during August (memo from H. Kaspar 20 July 1983). The inclusion of Morro Bay sand spit was based on the observation by A. Wenner that this beach had coarse sand and gravel, which one might suspect could be factors detrimental to sand crab habitation, yet the beach supported great numbers of *Emerita*.

I.5.2 Additional 1983 Surveys (End of Season)

Because of reported high percentages of spent females at sites in late August, two simplified sampling surveys were authorized (memo from H. Kaspar 29 September 1983) at six study sites (115 km N, 100 km N, 65 km S, 45 km S, and two between 6.5 km S and 6.5 km N of SONGS) to monitor the fecundity of females found at those beaches and document the end of the reproductive season. The physical environment was to be ignored in these abbreviated surveys. MEC sent personnel to all six sites for the two authorized surveys and to 65 km S once and 45 km S twice more in order to fully document the end of the sand crab reproductive season.

I.5.3 Histology of ovaries of female sand crabs

MEC submitted a proposal to the MRC 24 February 1984 recommending the analyses of histological samples and metal and organic pollutant samples. The histological analysis of ovaries was funded May 1984 and included in the report of the 1983 study. The analyses of metals and organic pollutant samples are pending.

I.5.4 Storage and Curation

The MRC also authorized: (1) preliminary treatment (extraction) of fresh water samples for non-metallic pollutants in order to bring them to a state suitable for long-term storage, and (2) non-curation or minimal curation (i.e., animals sorted by sieve size were combined into one sample for each sled tow sample prior to storage) of the sand crab samples.

I.6 RESULTS OF THE 1983 MEC SAND CRAB STUDY

The 1983 MEC sand crab study answered the three questions in the statement of work regarding magnitudes of sand crab attributes relative to variability among beaches, gradients in the magnitude of attributes with distance from SONGS, and correlations between sand crab attributes and environmental variables.

Abundances at beach sites near SONGS were lower than abundances at other beach sites in June but not in July or August. The June difference appeared to be the result of a delay in recruitment and colonization.

Measurements of the sizes[2] of sand crabs at beach sites near SONGS were within the variation of these measurements at other beach sites. Factors such as the presence of overwintered individuals at a site, differences in recruitment, and in the case of females, initiation of reproduction appeared to account for most of the differences observed in size.

The reproductive output of sand crabs at beach sites within 12 km of SONGS was generally lower than at other beach sites. This was indicated by the lower overall percentage of females that carried clutches of eggs or spent egg cases during the peak reproductive period (August) and by the apparently fewer clutches that were produced by each female during the reproductive season.

Female populations within 12 km of SONGS futher differed from those at most other sites in the condition of their clutches. Females within 12 km of SONGS predominantly carried clutches composed of spent egg cases rather than developing eggs. Late in the reproductive season (September), large percentages of females at the Los Angeles beach sites (115 km N and 100 km N) also carried clutches of spent egg cases. Although supportive evidence was obtained for each alternative, insufficient information was gathered to determine whether these clutches of spent egg cases resulted from abortion, normal hatching (synchrony or a longer than usual retention of the egg cases by females at the end of the reproductive season), or some combination of both.

With one exception, there were no gradients with distance from SONGS in any measurement of sand crab populations. Results indicated a decrease with proximity to SONGS in the percentage of females (8-13 mm) with spent egg cases that were producing another clutch of eggs in August. Some of the trends within 6.5 km of SONGS noted in earlier studies were also found in 1983; however, these trends did not persist over the larger sampling scale of 1983. The sand crab measurements that did vary relative to San Onofre displayed generally "lower" values within 12-15.5 km of SONGS relative to sites further away, rather than gradients.

Environmental variables could account for much ($R^2 = .69-.96$, $p < .05$) of the variability among beach sites in the reproductive attributes of female sand crabs. In general, lesser reproductive potential appeared to be accounted for by factors such as less food, more seston, cooler temperatures, and coarse, unstable beach substrate. However, it must be emphasized that correlation does not demonstrate causal relationship and additional work will have to be done before such relationships between environmental variables and sand crabs can be established.

The 1983 study was not designed to directly address potential impacts from SONGS on sand crabs. However, the relative timing between the pumping operations and the "effects" seen in various years was considered. There was not a clear relationship between the results of the 1976-1983 studies and the actual volumes of water circulated through the Plant.

It was not possible to evaluate whether factors such as metallic or organic pollution could account for the differences observed in sand crab populations in the San Onofre area. Although appropriate samples were collected, their analyses have not yet been funded by the MRC.

I.7 PROPOSED STUDIES PENDING MRC AUTHORIZATION

I.7.1 Status of Metal and Organic Pollutant Samples

Samples of sediment, water, and sand crab tissue were collected as part of the 1983 study for the potential analyses of metallic and organic pollutants (Tables 3 and 4). MEC submitted a proposal to the MRC 24 February 1984 recommending these analyses.

To date samples have been stored appropriately to maintain their integrity for all options of quanitative analyses. Aquatic Terrestrial Research Corporation (ATR), as subcontractor to MEC, was in charge of storage until 30 September 1984. (On 24 September 1984 the samples were tranferred to Aquatic Research Corporation (ARC) for temporary storage.)

As part of their subcontract, ATR was to provide information on potential analytical techniques. They did this in two interim reports, copies of which were delivered to the MRC. ATR was also to prepare sand crab tissue, then run a toxification/detoxification analysis on one subsample immediately after collection and on another subsample after one month of frozen storage to demonstrate that the results were stable. A third subsample has been retained to determine whether or not results are stable if and when similar analyses are done on MRC samples.

The Technical Review Committee of the MRC is presently determining the type of analyses to be done on the samples. Alternatives are bulk analysis and/or toxification/detoxification of metals (e.g., Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn), parent organic compounds (e.g., PCBs, DDTs, Napthene), and organic metabolites (e.g., PCBols, DDTols, Napthols)

I.7.2 1984 Sand Crab Study

A critical question remaining after the 1983 study is whether or not the high percentages of females with spent egg cases in the San Onofre area, observed in past studies and in 1983, resulted from abnormal or normal reproduction. MEC submitted a proposal to the MRC 9 July 1984 to specifically address this question. Weekly sampling during the summer reproductive season was proposed to monitor the onset of reproduction for first-year females and the subsequent maturation or abortion of their eggs. Two sites in the San Onofre area (0.4 km N and 6.5 km N) and one site farther away (65 km S, La Jolla) were selected for study.

Although this work has not received MRC authorization (two of the surveys were funded by the MRC), MEC successfully completed the weekly field sampling for the 1984 reproductive season. Samples have yet to be analyzed. Preliminary spot checks of the samples indicate that the question regarding the spent condition can be answered with these samples.

Footnotes

1

The June survey was designed to sample only patches of sand crabs at a beach site because the MRC had not yet decided that abundance should be estimated. Once that decision was made, samples from the interpatch areas were also needed for abundance estimates. Therefore, the original sampling design was changed to that of sampling random positions at each beach site. Further conferences between MEC and Keith Parker, statistician, led K. Parker to strongly recommend (memo dated 5 July 1983) the stratified random sampling design, which was presented in the 18 July 1983 Final Statement of Work and was used in the July and August surveys. In this design, four randomly selected patches and two randomly selected interpatch areas were sampled. Contingency schemes were worked out for beach sites having less than four sand crab patches.

2

The size results were not based on direct measurements of growth by following individuals or controlled groups of sand crabs through time. That effort was outside the scope of the statement of work.

Table 1. Biological attributes proposed for study and the relevance to their selection and/or potential use. Asterisks (*) indicate attributes previously studied by Wenner.

Biological Attribute	Relevance
Population density	Establish natural range of abundance values; place SONGS values in perspective
Population dispersion-patchiness a) distribution of patches on beach b) size of patches c) size of space between patches d) between-patch differences of sex, size, etc.	How the patches are described quantitatively determines the precision of the abundance estimates for a beach.
Size frequencies-sexes separate *a) % of total number in a mode b) seasonal shifts of modes *c) mean size of males *d) mean maximum size of males *e) mean size of females with eggs *f) mean minimum size of females with eggs *g) % of larger females with eggs *h) % of females with eggs according to size	Past MRC reports have indicated that some of these attributes are different at San Onofre than at other beaches and that trends exist at San Onofre
Reproductive patterns *a) % females with eggs b) size distribution of females with eggs c) clutch size, egg condition d) sex ratio by size e) histology of gonads and eggs	Reproduction is a vital biological function; Wenner reported aberrant values near SONGS; different processes or aspects of reproduction may relate to different environmental factors.
Parasites & diseases	Can infect eggs; may lead to low viability and/or egg count; may or may not relate to the potential for SONGS-induced stress.
Population genetics	Identify genetic pools; may help determine longshore migration patterns.
Metals & Non-metallic pollutants in eggs and tissue	Metals and non-metallics have been suggested by Wenner as a mechanism of disruption of reproduction.

Table 2. Environmental variables proposed for study and the relevance to their selection and/or potential use.

Environmental Variable	Relevance
Food Stomach contents Plankton/detritus in wave wash Chlorophyll/phaeophytin	Wenner suggested lack of upwelling, i.e., lack of food, as an explanation of small size of females at UCSB.
Gross physical characteristics Beach aspect (direction faced) Beach slope, profile Beach width Wave regime Recent weather effects Length of beach & position of sampling site on the beach State of tide during sampling Water turbidity Time of day in relation to dawn/dusk	Describe study sites, attempt to relate these characteristics to the abundance, condition, etc. of crabs sampled.
Sediment characteristics Grain size Moisture content Organic content Nearshore (0.5 m depth) pebble coverage Interstitial salinity	Describe patches sampled, attempt to relate these characteristics to the abundance, condition, etc. of crabs sampled.
Chemical characteristics Metals Non-metallic pollutants	Wenner suggested that metals or organic pollutants may disrupt female reproduction near SONGS
Turbidity of Water Seston in wave wash	Particulates from past beach excavations and diffuser discharge could tend to direct sand crab activity from feeding to cleaning antennae.

Table 3. Number of replicates collected from each beach in June, July, and August 1983 for potential analyses of metals and organic compounds in sediment and water samples. NS = not sampled.

	SEDIMENT		
Beach site	June	July	August
450 km N	NS	NS	3
115 km N	3	3	3
100 km N	3	3	3
79 km N	3	3	3
15.5 km N	3	3	3
12 km N	3	3	3
6.5 km N	3	3	3
1.5 km N	3	3	3
0.4 km N	3	3	3
1.5 km S	2	3	3
6.5 km S	3	3	3
12 km S	3	3	3
18 km S	3	3	3
25 km S	3	3	3
45 km S	3	3	3
65 km S	3	3	3

	WATER AND SEDIMENT		
Beach site	June	July	August
Doheny Creek-15.5 km N	NS	2 + 2*	2 + 2
San Mateo Creek-6.5 km N	NS	2 + 2	2 + 2
Santa Margarita River-18 km S	NS	2 + 2	2 + 2
San Luis Rey River-25 km S	NS	2 + 2	2 + 2
Moonlight Creek-45 km S	NS	2 + 2	2 + 2

* 2 + 2 = two water replicates plus two sediment replicates.

Table 4. Number of sand crab replicates (with estimated sufficient material for analysis) available from each beach surveyed in July and August 1983 for potential analyses of metals and organic compounds. * = crabs collected but probably not enough tissue available for analyses; - = no crabs available; NS = not sampled.

	July 1983				August 1983			
Beach site	metals in females with eggs	organics in females with eggs	metals in females without eggs	organics in females without eggs	metals in females with eggs	organics in females with eggs	metals in females without eggs	organics in females without eggs
450 km N	NS	NS	NS	NS	2	2	2 or 3	*
115 km N	1	1	3	3	-	-	-	-
100 km N	3	-	3	3	3	3	3	3
79 km N	1	1	2	1	1	1	1	1
15.5 km N	-	-	-	-	1	*	*	*
12 km N	*	-	3	3	-	-	1	1
6.5 km N	1	-	3	3	1	-	3	3
1.5 km N	*	-	1	1	-	-	-	-
0.4 km N	1	-	3	3	3	3	3	3
1.5 km S	*	-	3	3	*	-	3	3
6.5 km S	3	3	4	4	*	-	3	3
12 km S	3	3	3	3	2 or 3	*	3	3
18 km S	2	2	3	3	-	-	-	-
25 km S	3	3	3	3	3	3	3	3
45 km S	3	3	3	3	3	3	2	1
65 km S	3	3	3	3	3	3	3	2 or 3