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Biological Assessment of Artificial Reef Materials: Concrete Aggregates and Quarry Stone

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**Biological Assessment of
Artificial Reef Materials:
Concrete Aggregates and Quarry Stone**

EXECUTIVE SUMMARY

This is the first annual report of a three year biological assessment of artificial reefs, constructed of three different materials.

Fish and invertebrate assemblages were inventoried bimonthly on 12 artificial reefs constructed of either quarry rock, gravel-concrete aggregate or tire-concrete aggregate, four reefs of each material. The resulting data were used to test the null hypothesis that there are no differences in faunal assemblages amongst the differing reef types.

The reefs were initially deployed 18 June 1998 in approximately 7 m of water offshore Miami Beach at 12 predetermined sites. The reefs lie in two lines of six, separated from each other by approximately 100 m. The four quarry stone reefs were constructed with 50 "4-5" foot boulders in a two layer configuration. The eight concrete reefs were constructed with tetrahedron modules produced by CSR Rinker under license agreement with Stability Reefs Inc. Each of the concrete reefs was composed of a mix of two differing sized modules: 25 large modules (5' edge) and 25 small modules (4' edge) to allow for a mix in interstice sizes. An effort was made to construct all the reefs to a similar size in height and width and this required some post-deployment reconfiguration which was completed in August 1998.

A fish census was accomplished bimonthly by divers using SCUBA and recording data underwater on plastic slates. Species, numbers of fish per species, and total length were recorded. The resulting data were analyzed by non-parametric analysis of variance (ANOVA) techniques. In addition lobsters were censused and a qualitative inventory was taken of other invertebrates.

No statistically significant differences were noted among the three reef types for either total fish (all species combined), total species, or total biomass. In addition, there was no significant differences in the number of lobsters among reef types and all recorded invertebrates were found on all three types of material.

Thus at the end of 12 months of research no biological differences were noted among the reefs composed of the differing materials. It would however be premature to rely heavily on data collected over only a single year and additional data is required to confirm these early results.

INTRODUCTION

Historically, artificial reefs have been constructed of a wide assortment of materials of opportunity (derelict ships, auto bodies, refrigerators, concrete rubble, used tires, and the like). Although materials of opportunity are still in use, in recent years marine structures have been designed specifically to function as artificial reefs. These reefs have been constructed from a variety of materials (e.g. wood, fiberglass, metal, rubber, concrete, shell, coral and rock). However, few studies have examined the suitability of these materials for reef construction in terms of their efficacy in acquiring diverse floral or faunal assemblages (Fitzhardinge and Bailey-Brock 1989, Gilliam et al. 1995, Miller and Barimo 1999).

In South Florida the two most popular reef construction materials are concrete and quarry stone. A third material, a tire-concrete aggregate, has been suggested as an environmentally positive alternative to the usual gravel-concrete aggregate (Gilliam et al. 1995). This study compares the fish and invertebrate assemblages on co-located reefs constructed of these three materials that were deployed on the same day.

METHODS AND MATERIALS

The experimental design of the study is straightforward. Fish and invertebrate assemblages are inventoried bimonthly on 12 artificial reefs constructed of either quarry rock, gravel-concrete aggregate or tire-concrete aggregate, four reefs of each material. The resulting data are used to test the null hypothesis that there are no differences in faunal assemblages amongst the differing reef types.

The reefs were initially deployed 18 June 1998 in approximately 7 m of water offshore Miami Beach at 12 predetermined sites (Figure 1). The reefs lie in two lines of six, separated from each other by approximately 100 m (Figure 2). Four quarry stone reefs were constructed with 50 "4-5" foot boulders (Figure 3) in a two layer configuration. The eight concrete reefs were constructed with tetrahedron modules (Figure 4) produced by CSR Rinker under license agreement with Stability Reefs Inc. Likewise the use of tire-concrete aggregate in artificial reef construction is a propriety technology held by Stability Reefs Inc. Tetrahedrons were selected based on their stability characteristics, demonstrated efficacy in acquiring a diverse faunal assemblage, and potential application for use in shoreline stabilization. Each of the concrete reefs was composed of a mix of two differing sized modules: 25 large modules (5' edge) and 25 small modules (4' edge) to allow for a mix in interstice sizes. An effort was made to construct all the reefs to a similar size in height and width and this required some post-deployment reconfiguration. The reconfiguration was completed in August 1998.

In order to evaluate stability of the reefs through time we attempted to acquire and maintain a photographic record of the reefs. The photos were to include an entire reef and be taken from specific sites, compass headings, and height above the substrate. The resultant photos were to be used to accurately determine movement of any modules on a reef (Figure 5, 6). Regrettably the underwater visibility in the area precluded the use of this technique. As an alternate method to monitor stability, the maximum height and

REFERENCES

- Fitzhardinge, R.C. and J.H. Bailey-Brock. 1989. Colonization of artificial reef materials by corals and other sessile organisms. *Bull Mar. Sci.* 44(2): 567-579.
- Gilliam, D., K. Banks and R.E. Spieler. 1995. Evaluation of a tire-concrete aggregate for artificial reef construction. *ECOSSET Proc.* 1: 345-350.
- Miller, M.W. and J. Barimo, 1999. An Assessment of Juvenile Coral Populations at Two Coral Reef Restoration Sites in the Florida Keys National Marine Sanctuary: Indicators of Success?



Figure 1. Reef deployment 18 June 1998. Photograph shows deployment of a gravel-concrete aggregate Tetrahedron module



Figure 3. Boulder reef module, pre-deployment.



Figure 4. Tetrahedron reef modules, gravel-concrete aggregate, pre-deployment.



Figure 5. Boulder reef #1, West side.



Figure 7. Diver installing stake to gauge potential movement.



Figure 8. Diver counting fish on boulder reef.

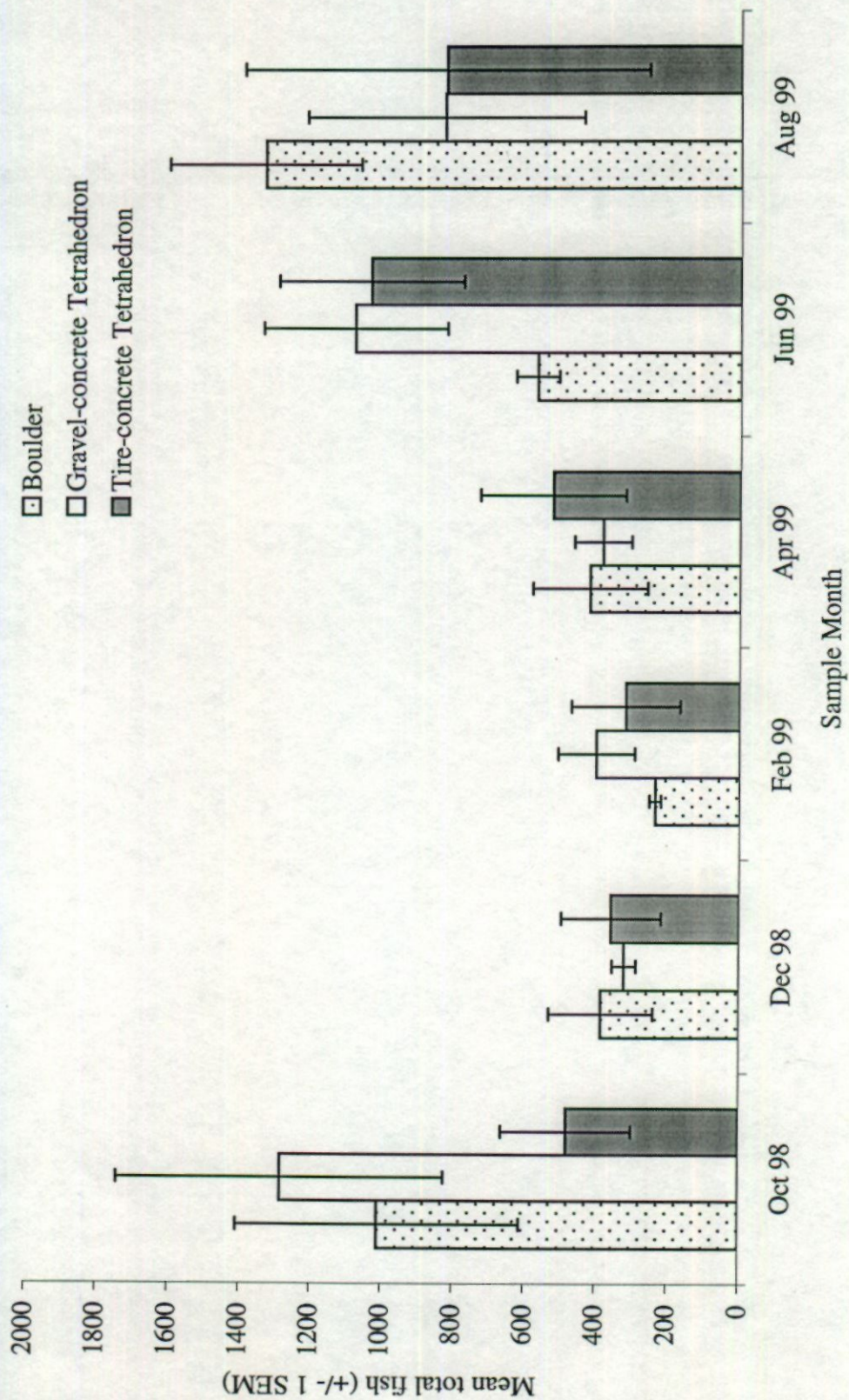


Figure 9. Mean total fish (all species of all sizes combined) on Boulder, Gravel-concrete, or Tire-concrete reefs by month. Vertical lines represent one standard error of the mean (SEM).

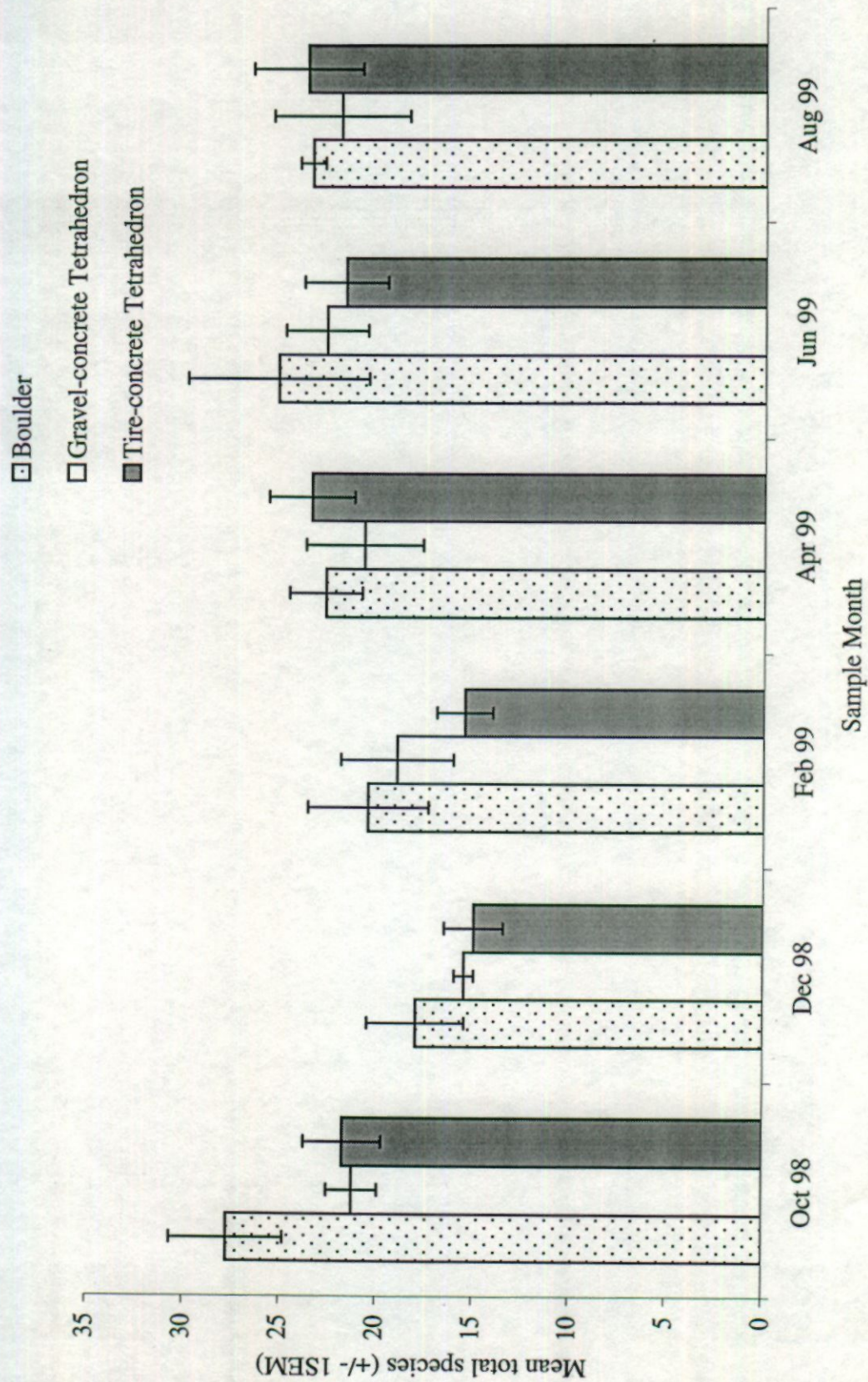


Figure 10. Mean total species (all sizes combined) on Boulder, Gravel-concrete, or Tire-concrete reefs by month. Vertical lines represent one standard error of the mean (SEM).

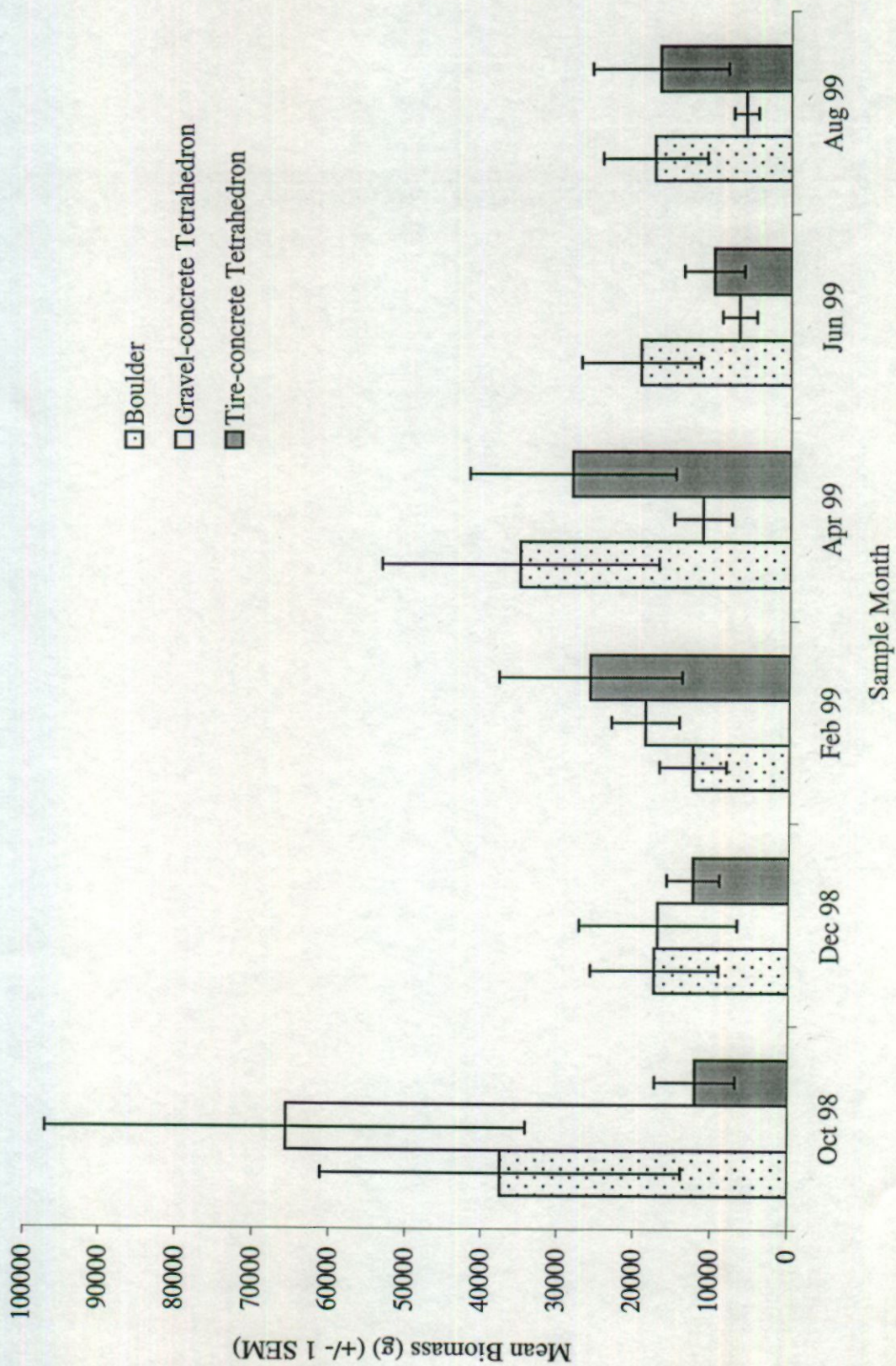


Figure 11. Mean biomass (all species of all sizes combined) on Boulder, Gravel-concrete, or Tire-concrete reefs by month. Vertical lines represent one standard error of the mean (SEM)

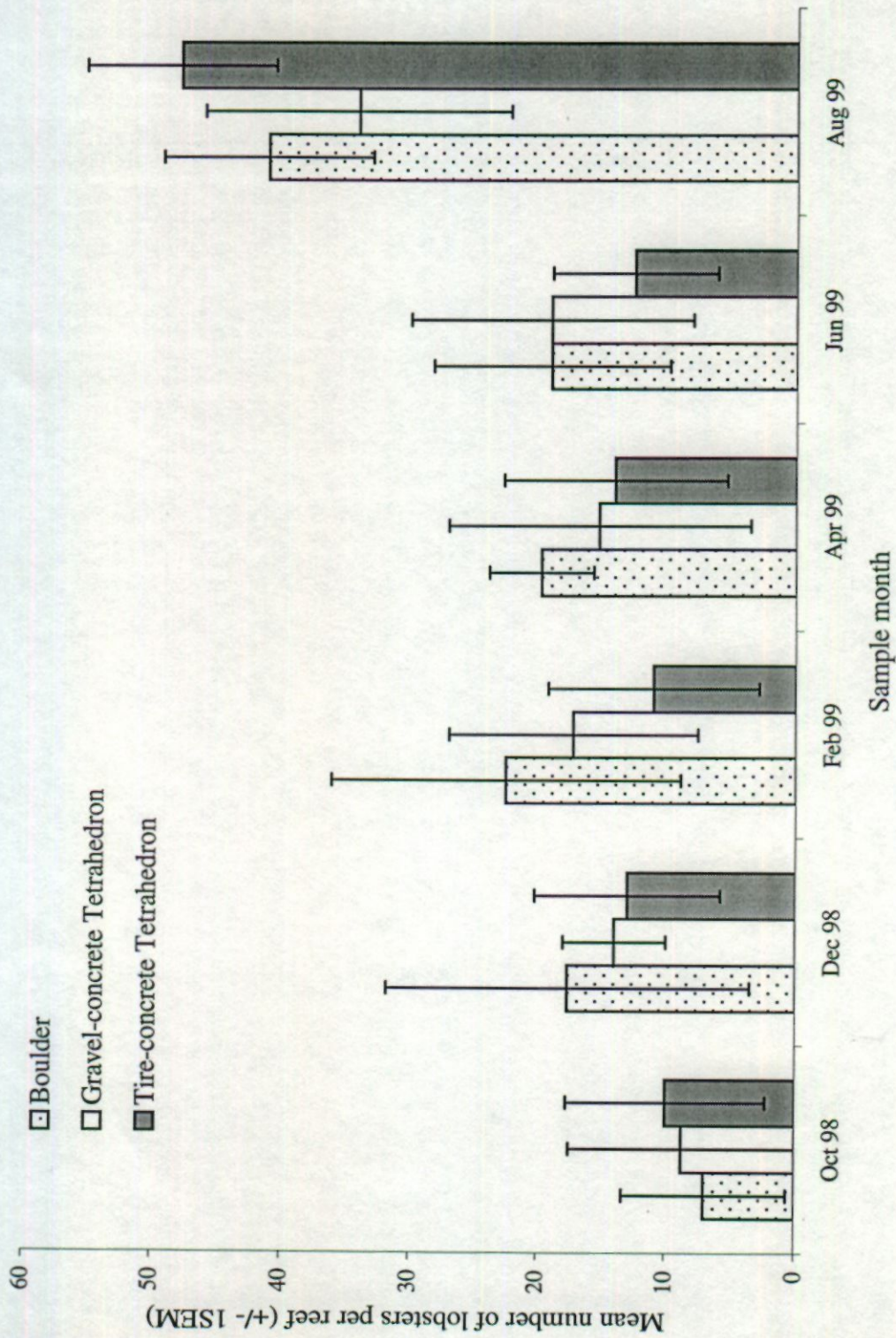


Figure 12. Mean number of lobster (*Panulirus argus*) (all sizes combined) on Boulder, Gravel-concrete, or Tire-concrete reef by month. Vertical lines represent one standard error of the mean (SEM)

Table 1. Measured maximum width and height of Boulder (B1-4), Gravel-concrete aggregate (C1-4) and Tire-concrete aggregate (T1-4) reefs.

Reef	Width	Height
T1	33' 7"	7' 0"
C1	22' 0"	8' 7"
B1	35' 6"	8' 3"
T2	21' 9"	7' 0"
C2	22' 2"	6' 2"
B2	28' 0"	7' 8"
T3	22' 3"	6' 2"
C3	22' 0"	6' 1"
B3	25' 8"	7' 2"
T4	27' 0"	5' 8"
C4	25' 6"	5' 7"
B4	26' 0"	8' 6"

Mean	Width	Height
B	28' 10"	7' 11"
T	26' 7"	6' 6"
C	22' 11"	6' 7"

Table 2. Fish species list for Miami Beach (as of August 1999).

COMMON NAME	SCIENTIFIC NAME	Boulder	Concrete	Tire aggregate
FAMILY: SHARKS	ORECTOLOBIDAE			
Nurse shark	<i>Ginglymostoma cirratum</i>	X	X	X
FAMILY: REMORA	ECHENEIDAE			
Sharksucker	<i>Echeneis naucrates</i>			X
FAMILY: STINGRAY	DASYATIDAE			
Southern stingray	<i>Dasyatis americana</i>	X	X	
Yellow Stingray	<i>Urolophus jamaicensis</i>	X		X
FAMILY: TARPON	ELOPIDAE			
Tarpon	<i>Megalops atlanticus</i>	X	X	
FAMILY: MORAY EELS	MURAENIDAE			
Spotted Moray	<i>Gymnothorax moringa</i>	X		
Purplemouth Moray	<i>Gymnothorax vicinus</i>		X	X
FAMILY: SARDINES	CLUPEIDAE			
False Pilchard	<i>Harangula cluepola</i>	X	X	
FAMILY: LIZARDFISHES	SYNODONTIDAE			
Sand Diver	<i>Synodus intermedius</i>	X		X
Inshore Lizardfish	<i>Synodus foetens</i>			X
FAMILY: TRUMPETFISHES	AULOSTOMIDAE			
Trumpetfish	<i>Aulostomus maculatus</i>	X	X	X
FAMILY: SEA BASSES	SERRANIDAE			
Black Grouper	<i>Mycteroperca bonaci</i>	X		X
Gag	<i>Mycteroperca microlepis</i>	X		
Scamp	<i>Mycteroperca phenax</i>	X		
Red Grouper	<i>Epinephelus morio</i>	X	X	X
Graysby	<i>Epinephelus cruentatus</i>			X
Sand Perch	<i>Diplectum formosum</i>	X	X	X
Belted Sand Bass	<i>Serranus subligarius</i>	X		
FAMILY: CARDINALFISHES	APOGONIDAE			
Flamefish	<i>Apogon maculatus</i>		X	
Twospot Cardinalfish	<i>Apogon pseudomaculatus</i>	X	X	X
FAMILY: JACKS	CARANGIDAE			
Juvenile Jacks	<i>Carangid sp.</i>	X		
Round Scad	<i>Decapterus punctatus</i>		X	X
Amberjack	<i>Seriola dumerili</i>	X	X	X
Blue Runner	<i>Caranx crysos</i>	X	X	X
Bar Jack	<i>Caranx ruber</i>	X	X	X
Yellow Jack	<i>Caranx bartholomaei</i>	X	X	X
FAMILY: SNAPPERS	LUTJANIDAE			
Yellowtail Snapper	<i>Ocyurus chrysurus</i>	X	X	X
Gray Snapper	<i>Lutjanus griseus</i>	X	X	X
Lane Snapper	<i>Lutjanus synagris</i>	X	X	X
FAMILY: MOJARRAS	GERREIDAE			
Yellowfin Mojarra	<i>Gerres cinereus</i>	X	X	

Table 2. contd.

COMMON NAME	SCIENTIFIC NAME	Boulder	Concrete	Tire aggregate
FAMILY: GRUNTS	HAEMULIDAE			
Cottonwick	<i>Haemulon melanurum</i>	X	X	X
White Grunt	<i>Haemulon plumieri</i>	X	X	X
Tomtates	<i>Haemulon aurolineatum</i>	X	X	X
Juvenile Grunts	<i>Haemulon juveniles</i>	X	X	X
Margate	<i>Haemulon album</i>	X	X	
French Grunt	<i>Haemulon flavolineatum</i>	X	X	X
Spanish Grunt	<i>Haemulon macrostomum</i>	X		X
Bluestripe Grunt	<i>Haemulon sciurus</i>	X	X	X
Striped Grunt	<i>Haemulon striatum</i>	X	X	X
Sailors Choice	<i>Haemulon parrai</i>	X	X	X
Smallmouth Grunt	<i>Haemulon chrysargyreum</i>	X	X	X
Black Margate	<i>Anisotremus surinamensis</i>	X	X	X
Porkfish	<i>Anisotremus virginicus</i>	X	X	X
Pigfish	<i>Orthopristis chrysoptera</i>	X	X	X
FAMILY: PORGIES	SPARIDAE			
Pinfish	<i>Lagodon rhomboides</i>	X	X	X
Spottail Pinfish	<i>Diplodus holbrooki</i>	X	X	X
Sea Bream	<i>Archosargus rhomboidalis</i>	X	X	X
Saucereye Porgy	<i>Calamus calamus</i>	X	X	X
FAMILY: DRUMS	SCIAENIDAE			
Highhat	<i>Equetus acuminatus</i>	X	X	X
Reef Croaker	<i>Odontoscion dentex</i>			X
Cubbyu	<i>Equetus umbrosus</i>		X	
FAMILY: GOATFISHES	MULLIDAE			
Yellow Goatfish	<i>Mulloidichthys martinicus</i>	X	X	X
FAMILY: SEA CHUBS	KYPHOSIDAE			
Bermuda Chub	<i>Kyphosus sectatrix</i>	X		X
FAMILY: SPADEFISHES	EPHIPPIDAE			
Spadefish	<i>Chaetodipterus faber</i>		X	X
FAMILY: BUTTERFLYFISHES	CHAETODONTIDAE			
Spotfin Butterflyfish	<i>Chaetodon ocellatus</i>	X	X	X
Banded Butterflyfish	<i>Chaetodon striatus</i>	X		
Reef Butterflyfish	<i>Chaetodon sedentarius</i>	X	X	X
FAMILY: ANGELFISHES	POMACANTHIDAE			
Queen Angelfish	<i>Holocanthus ciliaris</i>	X	X	
Blue Angelfish	<i>Holocanthus bermudensis</i>	X	X	
French Angelfish	<i>Pomacanthus paru</i>	X	X	X
Gray Angelfish	<i>Pomacanthus arcuatus</i>	X	X	X
FAMILY: DAMSELFISHES	POMACENTRIDAE			
Sergeant Major	<i>Abudefduf saxatilis</i>	X	X	X
Dusky Damselfish	<i>Stegastes fuscus</i>	X	X	X
Beaugregory	<i>Stegastes leucostictus</i>	X	X	X
Bicolor Damselfish	<i>Stegastes partitus</i>	X	X	
Cocoa Damselfish	<i>Stegastes variabilis</i>	X	X	X

Table 2. contd.

COMMON NAME	SCIENTIFIC NAME	Boulder	Concrete	Tire aggregate
FAMILY: WRASSES	LABRIDAE			
Hogfish	<i>Lachnolaimus maximus</i>	X	X	X
Clown wrasse	<i>Halichores maculipinna</i>			X
Slippery Dick	<i>Halichores bivittatus</i>	X	X	X
Yellowcheek wrasse	<i>Halichores cyanocephalus</i>			X
Puddingwife	<i>Halichores radiatus</i>	X	X	
Bluehead Wrasse	<i>Thalassoma bifasciatum</i>	X	X	X
FAMILY: PARROTFISHES	SCARIDAE			
Parrotfish	<i>Sparisoma sp.</i>	X		X
Striped Parrotfish	<i>Scarus croicensis</i>	X	X	X
Rainbow Parrotfish	<i>Scarus guacamaia</i>		X	X
Bucktooth Parrotfish	<i>Sparisoma radians</i>	X	X	X
Red tail Parrotfish	<i>Sparisoma chrospterum</i>	X	X	X
Redfin Parrot	<i>Sparisoma rubripinne</i>	X		X
Greenblotch Parrotfish	<i>Sparisoma atomarium</i>	X	X	X
Stoplight Parrotfish	<i>Sparisoma virride</i>	X	X	X
Redband Parrot	<i>Sparisoma aurofrenatum</i>	X	X	X
FAMILY: BARRACUDAS	SPHYAENIDAE			
Barracuda	<i>Sphyraena barracuda</i>		X	X
FAMILY: COMBTOOTH BLEN	BLENNIDAE			
Blenny	Blennidae	X	X	X
Molly Miller	<i>Startella cristata</i>		X	
Barred Blenny	<i>Hypoleurochilus bermudensis</i>	X	X	X
Seaweed Blenny	<i>Parablennius marmoreus</i>	X	X	X
FAMILY: GOBIES	GOBIIDAE			
Neon Goby	<i>Gobiosoma oceanops</i>	X	X	X
Bridled Goby	<i>Coryphopterus glaucofraenum</i>	X	X	X
FAMILY: SURGEONFISHES	ACANTHURIDAE			
Ocean Surgeon	<i>Acanthurus bahianus</i>	X	X	X
Doctorfish	<i>Acanthurus chirurgus</i>	X	X	X
Blue tang	<i>Acanthurus coeruleus</i>	X	X	X
FAMILY: SCORPIONFISH	SCORPAENIDAE			
Spotted Scorpionfish	<i>Scorpaena plumieri</i>	X	X	X
FAMILY: LEATHERJACKETS	BALISTIDAE			
Filefish	<i>Aluterus sp.</i>		X	
Scrawled Filefish	<i>Aluterus scriptus</i>	X	X	X
Planehead Filefish	<i>Monocanthus hispidus</i>	X	X	
Gray Trigger	<i>Balistes capriscus</i>	X	X	X
FAMILY: BOXFISHES	OSTRACIIDAE			
Scrawled cowfish	<i>Lactophrys quadricornis</i>	X	X	X
Spotted trunkfish	<i>Lactophrys trigonus</i>	X		
Honeycomb cowfish	<i>Lactophrys polygonia</i>	X	X	
Smooth trunkfish	<i>Lactophrys triqueter</i>	X	X	
FAMILY: PUFFERS	TETRAODONTIDAE			
Sharpnose Puffer	<i>Canthigaster rostrata</i>	X		X
Bandtail Puffer	<i>Sphoeroides spengleri</i>	X	X	X
FAMILY: SPINY PUFFERS	DIODONTIDAE			
Porcupinefish	<i>Diodon hystrix</i>	X	X	X
Balloonfish	<i>Diodon holocanthus</i>		X	
	Total Species	88	83	80

Table 3. Invertebrate species list for Miami Beach (as of August 1999).

Taxon	Reef												
	B1	B2	B3	B4	T1	T2	T3	T4	C1	C2	C3	C4	
Phylum PORIFERA													
Class DEMOSPONGIAE													
<i>?Monachora unguifera</i>	X	X	X	X	X	X		X	X	X	X	X	
Order POECILOSCLERIDA													
Family Desmacionidae													
<i>Iotrochota birotulata</i>		X						X					
Family Mycalidae													
<i>Mycale</i> sp.	X	X	X	X	X	X	X	X	X	X		X	
Order DICTYOCERATIDA													
Family Thorectidae													
<i>Ircinia strobilina</i>				X			X			X			
Order Dendroceratida													
Family Haliscaridae													
<i>?Halisarca</i> sp.	X	X	X	X	X	X	X	X	X	X	X	X	
Unidentified Sponges													
Green Encrusting	X	X			X								
Tan Encrusting	X												
Red Encrusting	X	X		X	X			X	X		X		
White Encrusting	X	X	X	X	X	X	X	X	X	X	X	X	
Branching Rope Sponge			X										
Dark Rope Sponge		X											
Grey Sponge	X				X					X	X		
Orange Sponge	X	X	X	X	X	X	X		X	X	X	X	
Blue Sponge	X	X	X	X	X	X		X	X	X	X	X	
Tube Sponge		X											
Brown Sponge	X		X		X								
Phylum CNIDARIA													
Class HYDROZOA													
Order THECATA													
Family Milleporidae													
<i>Millepora</i> sp.				X									
Unidentified Hydroids													
Feather Hydroid	X	X	X	X	X	X	X	X	X	X	X	X	
Stalked Hydroid	X	X	X	X	X	X	X	X	X	X	X	X	
Small White Hydroid	X	X	X	X	X	X	X	X	X	X	X	X	
Class OCTOCORALLIA													
Order ALCYONARIA													
Family Plexauridae													
<i>Eunicea</i> sp.			X					X				X	
Family Gorgoniidae													
<i>Pseudopterogorgia</i> sp.	X				X	X	X	X			X		
<i>Pterogorgia</i> sp.			X				X	X	X		X	X	
Family Telestinae													
<i>Carijoa riisei</i>	X	X	X	X	X	X	X	X	X		X	X	

Table 3. contd.

Taxon	Reef				T1	T2	T3	T4	C1	C2	C3	C4
	B1	B2	B3	B4								
Order SCLERACTINIA												
Family Caryophyllidae												
? <i>Eusmilia</i> sp.	X		X	X			X	X		X		
Family Faviidae												
? <i>Montastrea cavernosa</i>								X				
? <i>Solenastrea bournoni</i>	X		X	X	X	X	X	X	X	X	X	X
? <i>Cladocora arbuscula</i>	X		X	X			X		X			
Order ACTINIARIA												
Family Aiptasiidae												
<i>Bartholomea annulata</i>			X	X								
Family Actiniidae												
<i>Condylactis gigantea</i>		X										
? <i>Aiptasia tagates</i>	X	X	X			X	X	X	X		X	X
Phylum ANNELIDA												
Class POLYCHAETA												
Order TERESELLIDA												
Unidentified Feather Duster	X	X	X	X	X	X	X	X	X	X		X
Family Serpulidae												
<i>Filograna huxleyi</i>					X		X	X			X	
Family Terebellidae												
Unidentified Spaghetti Worm	X	X	X	X		X						X
Family Sabellariidae												
<i>Phragmatopoma lapidosa</i>	X	X	X	X	X	X	X	X	X	X	X	X
Order SABELLIDA												
Family Sabellidae												
Unidentified Christmas Tree Worm	X		X	X		X			X	X	X	X
Phylum MOLLUSCA												
Class GASTROPODA												
Order VETIGASTROPODA												
Family Fissurellidae												
Unidentified Keyhole Limpet											X	
Family Cypraeidae												
<i>Cypraea cervus</i>					X							
Family Strombidae												
<i>Strombus gigas</i>										X		
Unidentified Gastropods	X	X		X		X			X		X	X
Class BIVALVIA												
Order PTERIOIDA												
Family Pteridae												
Unidentified Oyster	X		X		X		X	X	X	X	X	X
Family Limidae												
Unidentified Oyster	X	X	X	X	X	X	X	X	X	X	X	X
Family Spondylidae												
? <i>Spondylus americanus</i>							X				X	X

Table 3. contd.

Taxon	Reef												
	B1	B2	B3	B4	T1	T2	T3	T4	C1	C2	C3	C4	
Family Chamidae													
<i>Chama maerophylla</i>	X			X	X	X							
Family Pinnidae													
<i>Pinna carnea</i>	X												
Phylum BRYOZOA													
Unidentified Encrusting Bryozoans	X	X	X	X	X	X	X	X	X	X	X	X	X
Unidentified Branching Bryozoan			X					X					
Phylum ARTHROPODA													
Subphylum CRUSTACEA													
Class MALACOSTRACA													
Order STOMATOPODA													
Unidentified Stomatopod							X					X	
Order DECAPODA													
Unidentified Burrowing Shrimp				X				X				X	
Infraorder STENOPODIDEA													
Family Stenopodidae													
<i>Stenopus hispidus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X
Infraorder CARIDEA													
Family Alpheidae													
<i>Aplpheus armatus</i>			X										
Family Hippolytidae													
<i>Lysmata wurdemanni</i>					X	X	X	X	X	X	X	X	X
Infraorder PALINURA													
Family Panuliridae													
<i>Panulirus argus</i>	X	X	X	X	X	X	X	X	X	X	X	X	
Infraorder ANOMURA													
Unidentified Hermit Crab	X	X	X		X	X	X	X	X	X	X	X	X
Family Porcellanidae													
<i>Petrolisthes armatus</i>	X	X		X	X	X	X	X	X				X
Infraorder BRACHYURA													
Family Majidae													
<i>Stenorhynchus seticornis</i>	X	X	X	X	X	X	X	X	X	X	X	X	X
Unidentified Clinging Crab	X	X	X	X	X	X	X	X	X	X	X	X	X
Family Grapsidae													
<i>Percnon gibbesi</i>	X	X						X		X			
Family Xanthidae													
<i>Menippe mercenaria</i>	X	X	X		X	X		X		X			X
Family Portunidae													
Unidentified Portunid		X						X	X	X			X
Order Thoracica													
Unidentified Barnacle	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3. contd.

Taxon	Reef												
	B1	B2	B3	B4	T1	T2	T3	T4	C1	C2	C3	C4	
Phylum ECHINODERMATA													
Class ECHINOIDEA													
Family Cidaridae													
<i>Eucidaris tribuloides</i>		X				X							
Family Toxopneustidae													
<i>Tripneustes ventricosus</i>													X
Family Echinometridae													
<i>Echinometa lucunter</i>	X												
Class OPHIUROIDEA													
Unidentified Brittlestar						X				X			
Phylum CHORDATA													
Subphylum UROCHORDATA													
Class ASCIDIACEA													
<i>?Polycarpa spongiabilis</i>	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Symplegma viride</i>	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>?Botylloides nigrum</i>	X	X	X		X	X			X				
<i>?Eudistoma sp.</i>			X			X							
<i>Clavelina sp.</i>	X												
Black Solitary Ascidian	X	X	X	X	X	X	X	X	X	X	X	X	X
Red Solitary Ascidian		X							X				
Purple Colonial Ascidian										X			
Taxon Count	45	39	40	35	37	37	34	40	36	35	36	36	

Table 4. Summary statistics

<u><i>Boulder Total Fishes Oct 98</i></u>		<u><i>Concrete Total Fishes Oct 98</i></u>		<u><i>Tire Total Fishes Oct 98</i></u>	
Mean	1010.50	Mean	1284.00	Mean	481.75
Standard Error	398.14	Standard Error	458.62	Standard Error	182.43
Standard Deviation	796.27	Standard Deviation	917.24	Standard Deviation	364.86
Minimum	269.00	Minimum	211.00	Minimum	140.00
Maximum	2130.00	Maximum	2442.00	Maximum	997.00
Sum	4042.00	Sum	5136.00	Sum	1927.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Fishes Dec 98</i></u>		<u><i>Concrete Total Fishes Dec 98</i></u>		<u><i>Tires Total Fishes Dec98</i></u>	
Mean	386.00	Mean	321.50	Mean	357.67
Standard Error	146.04	Standard Error	33.50	Standard Error	139.70
Standard Deviation	252.95	Standard Deviation	47.38	Standard Deviation	241.96
Minimum	106.00	Minimum	288.00	Minimum	87.00
Maximum	598.00	Maximum	355.00	Maximum	553.00
Sum	1158.00	Sum	643.00	Sum	1073.00
Count	3.00	Count	2.00	Count	3.00
<u><i>Boulder Total Fishes Feb 99</i></u>		<u><i>Concrete Total Fishes Feb99</i></u>		<u><i>Tire Total Fishes Feb99</i></u>	
Mean	235.50	Mean	400.00	Mean	317.75
Standard Error	16.46	Standard Error	107.48	Standard Error	152.18
Standard Deviation	32.93	Standard Deviation	214.96	Standard Deviation	304.36
Minimum	205.00	Minimum	145.00	Minimum	60.00
Maximum	275.00	Maximum	582.00	Maximum	717.00
Sum	942.00	Sum	1600.00	Sum	1271.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Fishes Apr99</i></u>		<u><i>Concrete Total Fishes Apr99</i></u>		<u><i>Tire Total Fishes Apr 99</i></u>	
Mean	419.00	Mean	383.25	Mean	523.00
Standard Error	160.81	Standard Error	80.35	Standard Error	203.87
Standard Deviation	321.62	Standard Deviation	160.70	Standard Deviation	407.74
Minimum	66.00	Minimum	208.00	Minimum	104.00
Maximum	846.00	Maximum	542.00	Maximum	923.00
Sum	1676.00	Sum	1533.00	Sum	2092.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Fishes Jun 99</i></u>		<u><i>Concrete Total Fishes Jun99</i></u>		<u><i>Tire Total Fishes Jun99</i></u>	
Mean	567.75	Mean	1079.75	Mean	1034.75
Standard Error	59.68	Standard Error	258.86	Standard Error	260.20
Standard Deviation	119.35	Standard Deviation	517.72	Standard Deviation	520.40
Minimum	437.00	Minimum	626.00	Minimum	267.00
Maximum	706.00	Maximum	1794.00	Maximum	1414.00
Sum	2271.00	Sum	4319.00	Sum	4139.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Fishes Aug99</i></u>		<u><i>Concrete Total Fishes Aug99</i></u>		<u><i>Tire Total Fishes Aug 99</i></u>	
Mean	1333.75	Mean	827.00	Mean	823.75
Standard Error	269.86	Standard Error	388.38	Standard Error	567.93
Standard Deviation	539.73	Standard Deviation	776.76	Standard Deviation	1135.86
Minimum	672.00	Minimum	159.00	Minimum	123.00
Maximum	1840.00	Maximum	1791.00	Maximum	2509.00
Sum	5335.00	Sum	3308.00	Sum	3295.00
Count	4.00	Count	4.00	Count	4.00

Table 4. Summary statistics cont.

<u><i>Boulder Total Species Oct 98</i></u>		<u><i>Concrete Total Species Oct 98</i></u>		<u><i>Tires Total Species Oct 98</i></u>	
Mean	27.75	Mean	21.25	Mean	21.75
Standard Error	2.93	Standard Error	1.31	Standard Error	2.02
Standard Deviation	5.85	Standard Deviation	2.63	Standard Deviation	4.03
Minimum	19.00	Minimum	19.00	Minimum	17.00
Maximum	31.00	Maximum	25.00	Maximum	26.00
Sum	111.00	Sum	85.00	Sum	87.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Species Dec 98</i></u>		<u><i>Concrete Total Species Dec 98</i></u>		<u><i>Tires Total Species Dec98</i></u>	
Mean	18.00	Mean	15.50	Mean	15.00
Standard Error	2.52	Standard Error	0.50	Standard Error	1.53
Standard Deviation	4.36	Standard Deviation	0.71	Standard Deviation	2.65
Minimum	15.00	Minimum	15.00	Minimum	12.00
Maximum	23.00	Maximum	16.00	Maximum	17.00
Sum	54.00	Sum	31.00	Sum	45.00
Count	3.00	Count	2.00	Count	3.00
<u><i>Boulder Total Species Feb99</i></u>		<u><i>Concrete Total Species Feb99</i></u>		<u><i>Tire Total Species Feb99</i></u>	
Mean	20.50	Mean	19.00	Mean	15.50
Standard Error	3.12	Standard Error	2.92	Standard Error	1.44
Standard Deviation	6.24	Standard Deviation	5.83	Standard Deviation	2.89
Minimum	14.00	Minimum	11.00	Minimum	12.00
Maximum	28.00	Maximum	25.00	Maximum	19.00
Sum	82.00	Sum	76.00	Sum	62.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Species Apr 99</i></u>		<u><i>Concrete Total Species Apr99</i></u>		<u><i>Tire Total Species Apr 99</i></u>	
Mean	22.75	Mean	20.75	Mean	23.50
Standard Error	1.89	Standard Error	3.04	Standard Error	2.22
Standard Deviation	3.77	Standard Deviation	6.08	Standard Deviation	4.43
Minimum	18.00	Minimum	15.00	Minimum	20.00
Maximum	27.00	Maximum	26.00	Maximum	30.00
Sum	91.00	Sum	83.00	Sum	94.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Species Jun 99</i></u>		<u><i>Concrete Total Species Jun99</i></u>		<u><i>Tire Total Species Jun99</i></u>	
Mean	25.25	Mean	22.75	Mean	21.75
Standard Error	4.70	Standard Error	2.14	Standard Error	2.17
Standard Deviation	9.39	Standard Deviation	4.27	Standard Deviation	4.35
Minimum	18.00	Minimum	17.00	Minimum	18.00
Maximum	39.00	Maximum	26.00	Maximum	28.00
Sum	101.00	Sum	91.00	Sum	87.00
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Species Aug99</i></u>		<u><i>Concrete Total Species Aug 99</i></u>		<u><i>Tire Total Species Aug 99</i></u>	
Mean	23.50	Mean	22.00	Mean	23.75
Standard Error	0.65	Standard Error	3.54	Standard Error	2.84
Standard Deviation	1.29	Standard Deviation	7.07	Standard Deviation	5.68
Minimum	22.00	Minimum	17.00	Minimum	16.00
Maximum	25.00	Maximum	32.00	Maximum	28.00
Sum	94.00	Sum	88.00	Sum	95.00
Count	4.00	Count	4.00	Count	4.00

Table 4. Summary statistics cont.

<u><i>Boulder Total Biomass Oct 98</i></u>		<u><i>Concrete Total Biomass Oct 98</i></u>		<u><i>Tires Total Biomass Oct 98</i></u>	
Mean	37492.44	Mean	65670.65	Mean	12062.08
Standard Error	23669.58	Standard Error	31458.81	Standard Error	5230.62
Standard Deviation	47339.17	Standard Deviation	62917.62	Standard Deviation	10461.25
Minimum	7842.15	Minimum	8954.15	Minimum	2924.53
Maximum	107705.65	Maximum	155551.35	Maximum	27082.20
Sum	149969.75	Sum	262682.58	Sum	48248.33
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Biomass Dec 98</i></u>		<u><i>Concrete Total Biomass Dec98</i></u>		<u><i>Tires Total Biomass Dec 98</i></u>	
Mean	17424.87	Mean	16975.12	Mean	12409.71
Standard Error	8350.67	Standard Error	10286.84	Standard Error	3407.81
Standard Deviation	14463.79	Standard Deviation	14547.79	Standard Deviation	5902.50
Minimum	5563.04	Minimum	6688.27	Minimum	6914.41
Maximum	33537.82	Maximum	27261.96	Maximum	18648.88
Sum	52274.62	Sum	33950.23	Sum	37229.14
Count	3.00	Count	2.00	Count	3.00
<u><i>Boulder Total Biomass Feb99</i></u>		<u><i>Concrete Total Biomass Feb99</i></u>		<u><i>Tire Total Biomass Feb99</i></u>	
Mean	12512.80	Mean	18714.60	Mean	25943.00
Standard Error	4339.22	Standard Error	4416.59	Standard Error	11990.67
Standard Deviation	8678.45	Standard Deviation	8833.17	Standard Deviation	23981.33
Minimum	4408.22	Minimum	9175.55	Minimum	4543.98
Maximum	24704.72	Maximum	26925.63	Maximum	51077.00
Sum	50051.20	Sum	74858.40	Sum	103772.01
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Biomass Apr99</i></u>		<u><i>Concrete Total Biomass Apr 99</i></u>		<u><i>Tire Total Biomass Apr 99</i></u>	
Mean	35242.99	Mean	11334.14	Mean	28380.79
Standard Error	18197.83	Standard Error	3738.01	Standard Error	13515.66
Standard Deviation	36395.65	Standard Deviation	7476.03	Standard Deviation	27031.32
Minimum	4399.38	Minimum	2499.59	Minimum	7550.27
Maximum	87800.06	Maximum	20576.44	Maximum	66529.98
Sum	140971.96	Sum	45336.54	Sum	113523.15
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Biomass Jun 99</i></u>		<u><i>Concrete Total Biomass Jun99</i></u>		<u><i>Tire Total Biomass Jun99</i></u>	
Mean	19478.10	Mean	6711.62	Mean	9973.47
Standard Error	7738.66	Standard Error	2219.52	Standard Error	3906.04
Standard Deviation	15477.31	Standard Deviation	4439.05	Standard Deviation	7812.07
Minimum	6316.18	Minimum	1904.30	Minimum	4277.51
Maximum	41472.12	Maximum	11928.03	Maximum	21061.97
Sum	77912.41	Sum	26846.47	Sum	39893.88
Count	4.00	Count	4.00	Count	4.00
<u><i>Boulder Total Biomass Aug 99</i></u>		<u><i>Concrete Total Biomass Aug 99</i></u>		<u><i>Tire Total Biomass Aug 99</i></u>	
Mean	17673.18	Mean	5846.28	Mean	16973.46
Standard Error	6801.04	Standard Error	1571.88	Standard Error	8833.14
Standard Deviation	13602.08	Standard Deviation	3143.75	Standard Deviation	17666.29
Minimum	5454.51	Minimum	2472.20	Minimum	1411.42
Maximum	37012.64	Maximum	9961.95	Maximum	35475.76
Sum	70692.71	Sum	23385.11	Sum	67893.84
Count	4.00	Count	4.00	Count	4.00