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Proceedings of the

FORTY- SEVENTH ANNUAL

Gulf and Caribbean Fisheries Institute

ISLA DE MARGARITA
NUEVA ESPARTA , VENEZUELA

NOVEMBER 1994

Library of Congress Catalog Card Number
52-033783

Edited by:
Mel Goodwin & Alejandro Acosta

FORT PIERCE, FLORIDA 2005

FISH ASSEMBLAGES ASSOCIATED WITH AN ESTABLISHED (> 10 YEARS OLD) ARTIFICIAL REEF AND AN ADJACENT NATURAL REEF

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ABSTRACT

In 1984 an artificial reef consisting of four large marine vessels was deployed on sand bottom in 12 - 33 m depth within 100 m of a shallow (6 11 m depth) natural coral reef. Beginning in February 1994 three of the vessels comprising the artificial reef and the adjacent natural reef were visually censused via SCUBA at two-week intervals. Findings are reported for February - September 1994. A total of 86 species were observed; 67 species each on the artificial and natural reefs. Mean species richness varied by sample site; species richness was higher on the natural reef sites. Mean abundance also varied by site; mean abundance was lower on two of the three artificial reef sites, and was higher on the natural reef sites and the third artificial reef site. Mean abundance and water temperature varied by date, but there was no significant relationship between these variables. The most abundant family on the artificial reef was pomacentridae, while labridae was most abundant on the natural reef. The most abundant recreationally targeted species on the artificial reef represented the families mullidae, pomadasyidae and scaridae. Scaridae, pomadasyidae and holocentridae were most abundant on the natural reef.

INTRODUCTION

Artificial reefs are used in many regions to enhance fishing opportunities, but there is limited information on artificial reef ecology (Bohnsack and Sutherland, 1985; Bohnsack, 1989; Seaman et al., 1989). When compared to natural reefs, most artificial reefs differ in species composition, species richness and abundance (reviewed in Bohnsack and Sutherland, 1985). As more fisheries management agencies utilize artificial reefs as management and mitigation tools, it is important to determine the suitability of artificial habitats for target species, and to understand the effects of newly placed artificial reefs on established natural communities.

Many comparisons of natural and artificial reefs have revealed higher values of species richness and abundance on artificial reef material (Bohnsack, 1989). However, many of these studies focus on relatively new reefs, when it may be ten years or more before a fish assemblage associated with an artificial reef reaches a relatively steady state (Bohnsack and Sutherland, 1985). Many artificial reefs exhibit high species richness and abundance values immediately after placement, followed by a decrease over an extended period (Bohnsack and Sutherland, 1985). Therefore, data from studies focusing on "aged" artificial reefs are more applicable to fisheries management than data on "new" reefs.

The Butler Bay Artificial Reef Site on St. Croix, U.S.V.I., was designated as an artificial reef site in 1974. Material placed within site boundaries includes automobile bodies, tires, an old aquarius habitat, and four large marine vessels; a tanker at approximately 33 m depth, a freighter (Suffolk Maid) at 21 m, a barge (barge) at 15 m, and a tugboat (tug) at 13 m. This material was placed at the site from the mid-1970's to the early 1980's. Adjacent to the site are two natural reefs; a moderate- size continuous reef system inshore at 10 m depth, and a well developed patch-reef system to the south at 10 m to > 15 m depth.

Quantitative data are lacking for the artificial reef and the adjacent natural reef. Although designated as an artificial reef site for 19 years, there was only a preliminary trapping study conducted in the 1970s, and that report is unavailable. There has been no research on artificial reefs on St. Croix since that study. The fish assemblages associated with the natural reefs adjacent to the artificial reef site have never been studied.

The objective of this research was to collect and analyze quantitative data from natural reef and artificial reef communities to determine the ecological impacts and potential benefits or disadvantages of artificial reefs to Virgin Islands fisheries. This study will be continued through 1995.

METHODS AND MATERIALS

The Butler Bay Artificial Reef Site is located off the northwest corner of St. Croix on a sand plain which extends from an inshore reef at 10 m depth to a steep reef slope at 45 m depth. The artificial reef structures are separated by open sand; 21 m between the Suffolk Maid and barge, 41 m between the barge and tug, and approximately 150 m between the tug and the inshore natural reef.

Diver census of the artificial reef and natural reef began in February 1994. Two census dives were completed by two divers on each sample date. On the first

dive complete-count census were conducted on the Suffolk Maid, barge, and tug (the tanker at 33 m depth was not sampled due to no-decompression time limitations).

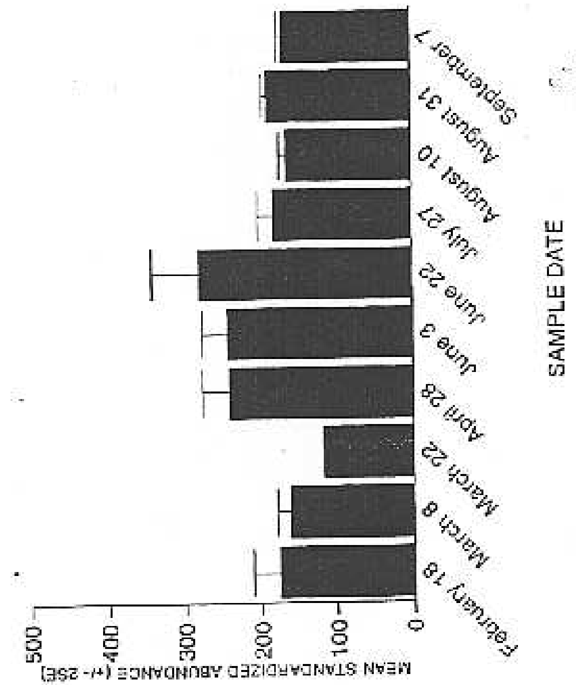

Figure 1. Mean standardize total abundance by sample date

The complete-count census were conducted as follows: Each structure was divided into two sample areas, the dividing line running along the middle of each vessel from bow to stern: two divers swam parallel from one end of the structure to the other, with each diver recording fish observed in his sample area (half of the vessel). The sample areas for each vessel extended 10 meters above the deck, and 3 meters from the sides and ends. Total sample volume for the Suffolk Maid was 8193.06 m^3, for the Barge 15060.62 m^3, and for the Tug 4572.30m^3.

Four stationary point census (Bohnsack and Bannerot, 1991) (two by each diver) were completed on the inshore natural reef on the second dive. For each diver, one sample was conducted along the reef wall (a 3 m drop-off to a reef/sand interface) and one sample on the reef platform (level reef area above and inshore of the wall. Each stationary point census had a sample radius of 7 meters, with sample height equal to water depth. Total sample volume varied due to differences in water depth at the wall and platform sample areas; wall sample volume = 1943.86 m^3 per sample, and platform sample volume = 1449.06 m^3 per sample.

Species richness and abundance values were standardized to account for differences in sample volume prior to data analyses. Total abundance and species richness data were log transformed and analyzed with a two-way ANOVA, with site and sample date as independent variables. The relationship between water temperature and total abundance and species richness data were examined with least squares regression. The total abundance of recreationally targeted species was summarized by site for qualitative comparisons of abundance. Recreational species were defined as those species recorded in Division of Fish and Wildlife Recreational Port Sampling Program interviews.

RESULTS

A total of 86 species, representing 34 families, were observed over ten sample dates; 67 species on the natural reef, and 67 species on the artificial reef (Table 1). When examined by sample site, the total number of species was; Suffolk Maid - 53, barge - 50, tug - 42, reef wall - 61, and reef platform - 51. Mean species richness was significantly different between all sites, but not by date (Table 2). Mean total abundance was significantly different among sites and by date (Table 3, Fig. 1). The most abundant family overall on the artificial reef site was pomacentridae, while labridae was most abundant family on the natural reef. When examined by sample site, the most abundant families were; labridae on the Suffolk Maid, barge and reef platform, and pomacentridae on the tug and reef wall. The most abundant recreationally targeted families for all sites combined were scaridae,

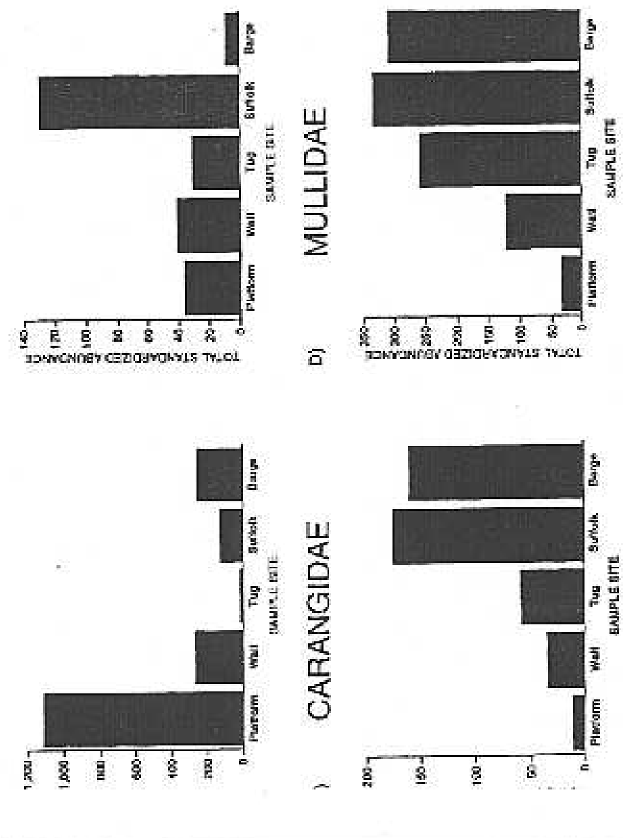

Figure 2. Total standardized abundance of abundant recreationally targeted families

pomadasyidae, mullidae, holocentridae, carangidae, serranidae, and lutjanidae. Scarids were in highest abundance on the natural reef (Fig. 2a), serranids (Fig. 2b), carangids (Fig. 2c), and mullids (Fig. 2d) were most abundant on the artificial reef, while pomadasyids (Fig. 3a), lutjanids (Fig. 3b), and holocentrids (Fig. 3c) were in similar abundance in both habitat types. There was no significant relationship between water temperature and total abundance ($R2 = 0.018$, $F = 1.766$, $df = 1, 98$, $p > 0.10$), or water temperature and species richness ($R2 = 0.024$, $F = 2.361$, $df = 1,98$, $p > 0.10$).

DISCUSSION

The size and isolation of a reef are important in determining species composition and abundance (Diamond and May, 1976). In general, reefs which are further from a source of colonization generally have fewer species, and reef size limits the number of species and individuals which inhabit the island. Mean species richness was a minimum of 1.6 times and a maximum of 5.2 times higher on the natural reef than on the artificial reef material. Mean abundance was also lower on two of the three artificial reef sites than on the natural reef. The artificial reef sites are located on sand bottom, and are the only structures on an open sand plain. Each structure is separated from other structures by a minimum of 20 m of open sand. The natural reef sample site is part of a larger continuous reef system extending along shore for a considerable distance, and is considerably greater in area than the artificial reefs. The greater area provided by the natural reef increases the chance of recruitment (Schroeder, 1987), and provides more habitat than the artificial reefs.

Habitat complexity is also an important factor influencing reef-associated fish assemblages. More heterogenous habitats generally have greater species richness and abundance (Chandler et al., 1985), and refuge size influences reef-associated fish assemblage characteristics (Hixon and Beets, 1989). Divers' qualitative observations indicated that the natural reef habitat was more heterogeneous than the artificial reefs. The outer hull of the Suffolk Maid is smooth, solid metal, and the superstructure was removed, resulting in a predominantly level deck surface. The exterior surface of the barge is smooth, with only small (<40 cm x 40 cm), sparsely scattered holes in the side and top. Both the Suffolk Maid and the barge have relatively low vertical profiles. The majority of fishes on the Suffolk Maid and barge were located primarily in two places; under the shadows of the bows or propellers, and above the structure (planktivores). The tug, which is closest to the natural reef in species richness and abundance levels, provides a comparatively more heterogeneous habitat. the superstructure is intact, with a higher vertical profile (vertical profile is greater than half the water depth) than the other artificial structures. Most fishes observed on the tug were within the

superstructure and above the structure (planktivores). The high vertical profile of the tug provided refuge within the feeding area of the planktivores, and allowed these species to take advantage of a previously inaccessible location. On the natural reef, fishes were observed in all portions of the sample area.

Among-site variation in the abundance of some recreationally targeted families was likely due to food and habitat requirements. Their was very limited invertebrate growth on the artificial reef structures, which was likely a limiting factor for scarids. The serranids were in comparatively high abundance only on the Suffolk Maid (primarily *Cephalopholis fulva*). There were no notable characteristics to explain serranid preference of the Suffolk Maid over the other sites. The majority of the carangids were *Caranx latus*, which were observed in large schools around and above the Suffolk Maid and barge. *C. latus* were transients in that they were present only sporadically, and quickly left a site when divers approached and did not return for the duration of the one hour dive. *C. latus* were not observed within any structure, and possibly utilized the reefs as points of orientation, similar to carangids in the southeastern United States (Adams, 1993; Stephan and Lindquist, 1989). Mullids, primarily *Mulloidichthys martinicus*, were observed almost exclusively in large schools feeding in the open sand surrounding the artificial reef structures, and used the structures for shelter when approached by divers. Although in smaller schools, similar *M. martinicus* behavior was observed on the sand adjacent to the reef wall. Mullidae presence in the reef platform was sporadic, and was primarily only individuals. Pomadasyids were most often in schools under coral heads or overhangs on the natural reef. The Suffolk Maid provided similar habitat to the natural reef in the overhangs of the bow and stern, and also had a high abundance of pomadasyids. Lutjanidae abundance was primarily due to schools of *Lutjanus mahogoni* which were resident on the reef wall and on the tug.

The *L. mahogoni* on the tug site were mixed with a school of *M. martinicus*, and were feeding on the open sand. On the reef wall, *L. mahogoni* were in schools taking refuge in overhangs and caves. Finally, holocentrids were abundant in any area they were able to find suitable shelter for day-time refuge. These were the only species to utilize the interiors of the artificial reef structures. They were in lowest abundance on the barge, which had limited access to the interior.

CONCLUSIONS AND FUTURE RESEARCH

The initial findings of this continuing study indicate that the Butler Bay artificial reef site provides habitat for many species. However, species richness and abundance were generally higher on the natural reef. Qualitative observations indicate that the lack of spatial heterogeneity and isolation of the artificial reef structures were likely factors contributing to these differences.

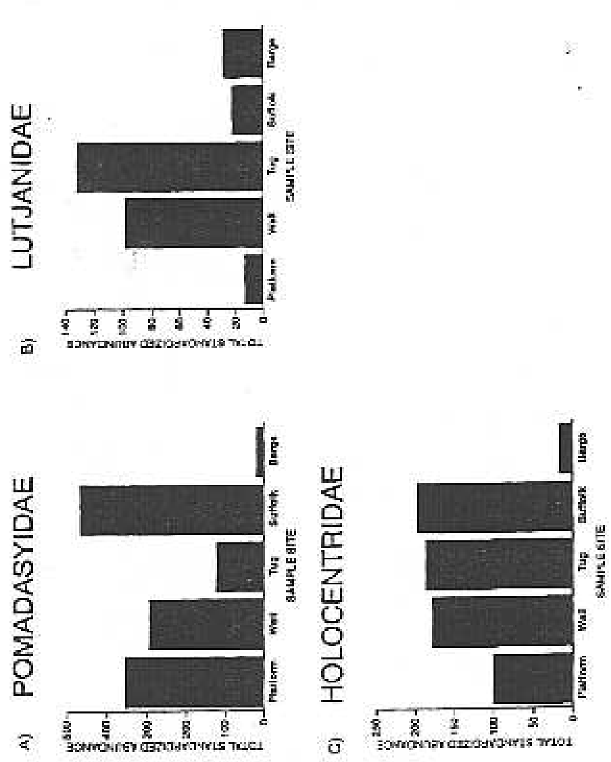

Figure 3. Total standardized abundance of abundant recreationally targeted families

Species-specific requirements likely contributed to the differences in species abundance among sites. This was most evident among recreationally targeted species. For example, scarids were in low abundance on the artificial reef due to a limited food source, while mullids were able to feed in areas previously unavailable due to lack of shelter areas.

If artificial reefs are to be deployed in the future, a number of steps should be completed prior to deployment:

1. determine the target species, and use material that mimics that specie's natural habitat
2. consider the effect of isolation and reef size on the target species
3. determine which materials will promote epifaunal growth.

Future research on artificial reefs on St. Croix should incorporate long term monitoring of pier demolition rubble which was deployed in June 1994 south of the current study site. The majority of this material is concrete rubble, which provides habitat different from the structures currently under study. Analysis of stomach contents of fishes on the artificial and natural reefs may provide information on factors contributing to artificial reef colonization. Finally, tagging of fishes on the artificial and natural reefs may help determine residence time of species, sources of colonization, and movement between reef sites.

LITERATURE CITED

Adams, A.J. 1993. Dynamics of fish assemblages associated with an offshore artificial reef in the southern Mid-Atlantic bight. M.S. Thesis. College of William and Mary, Virginia Institute of Marine Science. 98 pp.

Bohnsack, J.A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation or behavioral preference? Bulletin of Marine Science. 44(2):631-645.

Bohnsack, J.A. and D.L. Sutherland. 1985. Artificial reef research: a review with recommendations for future priorities. Bulletin of Marine Science. 37(1):11-39.

Chandler, C.R., R.M. Sander, Jr., and A.M. Landry, Jr. 1985. Effects of three substrate variables on two artificial reef fish communities. Bulletin of Marine Science. 37(1):129-142.

Diamond,J.M. and R.M. May. 1976. Island biogeography and the design of natural reserves. Pages 163-186 in R.M. May, ed. Theoretical ecology: principals and applications. W.B. Saunders Co., Philadelphia, PA.

Hixon, M.A. and J. P. Beets. 1989. Shelter characteristics and Caribbean fish assemblages: experiments with artificial reef. Bulletin of Marine Science. 44(2):666-680.

Schroeder, R.E. 1987. Effects of patch reef size and isolation on coral reef fish recruitment. Bulletin of Marine Science. 41(2):441-451.

Seaman, W., Jr., R.M. Buckley and J.J. Polovina. 1989. Advances in knowledge and priorities for research, technology and management related to artificial aquatic habitats. Bulletin of Marine Science. 44(2):527-532.

Table 1. Total species abundance by site for all sample dates (N = 10). Totals are for each site without standardization for differences in site size.

	Artificial reef			Natural reef		
Species	Barge	Suffolk	Tug	Wall	Flata form	total
Acanthurus bahianus	127	191	61	57	79	515
A. coeruleus	219	167	205	25	28	644
Aulostomus maculatus	0	0	0	24	11	35
Melichthys niger	0	0	0	1	2	3
Bothus lunatus	3	0	3	1	0	7
Caranx latus	741	419	0	0	0	1160
Caranx ruber	42	35	80	47	11	215
Decapterus punctatus	47	40	12	0	0	99
Trachinotus falcatus	0	2	0	0	0	2
Chaetodon aculeatus	0	1	1	0	0	2
C. capistratus	0	0	6	16	22	44
C. sedentarious	0	7	1	0	0	8
C. striatus	1	1	0	7	8	17
Dasyatis americana	0	0	0	0	1	1
Diodon hystrix	1	1	1	1	0	4

Hemiramphus brasiliensis	0	0	0	100	30	130
Gerres cinereus	1	0	0	7	1	9
Gramma loreto	0	0	0	20	0	20
Rypticus saponaceus	0	0	1	3	1	5
Holocentrus adscensionis	14	9	14	14	21	72
Myripristis jacobus	65	504	280	221	74	1144
Neoniphon marianus	14	49	0	3	5	71
Kyphosus sectatrix	1	0	8	4	0	13
Bodianus rufus	10	69	211	15	11	316
Ciepticus parrai	429	1007	835	268	9	2549
Halichoeres bivittatus	0	1	0	3	0	4
H. garnoti	19	0	45	39	13	116
H. radiatus	0	0	0	2	3	5
Thalassoma bifasciatus	1234	1299	1795	2830	3825	10938
Lutjanus analis	4	0	1	1	0	6
L. apodus	0	0	1	0	0	1
L.cyanopterus	1	0	0	0	0	1
L. jocu	0	4	0	0	0	4
L. mahogoni	105	27	183	53	11	379

L. synagris	5	3	23	6	0	37
Ocyurus chrysurus	32	29	0	9	2	72
Malacanthus plumieri	0	0	0	15	0	15
Aluterus scriptus	0	0	0	0	3	3
Cantherhines macroceros	0	0	0	1	3	4
Mulloidichthys martinicus	1607	947	411	153	24	3142
Pseudopeneus maculatus	0	0	0	11	9	20
Gymnothorax moringa	2	0	0	0	0	2
Lactophrys bicaudalis	2	0	1	0	2	5
L. polygonia	1	5	0	1	1	8
L. quadricornis	0	0	0	1	0	1
L. triqueter	15	14	8	4	1	42
Holacanthus tricolor	0	31	0	8	12	51
Pomacanthus paru	10	0	7	4	3	24
Abudefduf saxatilis	83	294	100	105	30	612
Abudefduf taurus	0	13	8	0	0	21
Chromis cyanea	0	18	80	92	12	202
C. multilineata	435	433	5423	2665	871	9827

Microspathodon chrysurus	0	0	0	15	12	27
Stagastes fuscus	0	0	0	34	25	59
S. partitus	15	263	116	514	478	1386
S. planifrons	0	0	0	6	0	6
Anisotremus surinamensis	1	0	0	0	0	1
Haemulon album	5	7	0	0	0	12
H. carbonarium	23	425	151	1	0	600
H. chrysargyreum	19	731	0	363	190	1303
H. flavolineatum	39	123	42	30	161	445
H. melanurum	1	1	0	0	0	2
H. plumieri	0	11	0	0	0	11
H. sciurus	2	16	0	0	3	21
Priacanthus arenatus	0	9	0	0	0	9
Sparisoma aurofrenatum	106	131	6	133	115	491
S. chrysopterum	0	1	2	5	35	43
S. viride	10	17	10	26	162	225
Scarus guacamaia	1	5	1	4	0	11
S. iserti	2	11	0	4	16	33
S. taeniopterus	1187	179	2	182	729	2279
S. vetula	0	0	0	3	48	51

Equetus punctatus	0	0	0	0	2	2
Scomberomorus regalis	1	0	1	1	0	3
Scorpaena spp.	0	0	0	1	0	1
Cephalopholis cruentata	2	1	6	15	3	27
Epinephelus adscensionis	0	1	1	0	0	2
Cepahalopholis fulvus	40	291	42	35	33	441
Epinephelus guttatus	4	1	0	4	0	9
Hypoplectrus nigricans	0	0	0	1	0	1
Mycteroperca venenosa	0	1	0	0	0	1
Paranthias furcifer	0	71	0	0	0	71
Calamus spp.	9	0	0	0	0	9
Sphyraena barracuda	1	1	0	0	2	4
Synodus intermedius	0	1	0	4	2	7
Canthigaster rostrata	4	11	52	12	11	90

Table 2. Effect of site and date on log-transformed mean standardized species richness.

A) Two-way ANOVA.

Source	SS	df	MS	F	p
Site	34.567	4	8.624	409.22	0.000
Date	0.158	9	0.018	0.833	0.589
Site*Date	0.791	36	0.022	1.040	0.443
Error	1.056	50	0.021		

B) Tukey-Kramer multiple comparison test for log-transformed mean standardized species richness by site. Treatments that are not significantly different at the 0.05 level share and underline. Values are non-transformed means.

3.67	8.80	10.86	17.35	19.01
Barge	Suffolk Maid	Tug	Reef wall	Reef plataform

Table 3. Effect of site and date on log-transformed mean standardized total abundance.

A) Two-way ANOVA.

Source	SS	df	MS	F	p
Site	42.428	4	10.607	53.588	0.000
Date	5.081	9	0.565	2.852	0.009
Site*Date	5.380	36	0.149	0.755	0.810
Error	9.897	50	0.198		

B) Tukey-Kramer multiple comparison test for log-transformed mean standardized total abundance by site. Treatments that are not significantly different at the 0.05 level share and underline. Values are non-transformed means.

56.79	138.88	304.43	308.09	352.67
Barge	Suffolk Maid	Tug	Reef wall	Reef plataform

C) Tukey-Kramer multiple comparison test for log-transformed mean standardized total abundance by date. Treatments that are not significantly different at the 0.05 level are denote by an (*). Dates are listed by month/day.

	2/18	3/8	3/22	4/28	6/3	6/22	7/27	8/10	8/31	9/7
2/18	*									
3/8	*	*								
3/22	*	*	*							
4/28	-	-	-	*						
6/3	-	-	-	*	*					
6/22	-	-	-	*	*	*				
7/27	*	*	-	*	*	-	*			
8/10	*	*	-	-	-	-	*	*		
8/31	*	-	-	*	*	-	*	*	*	
9/7	*	*	-	-	-	-	*	*	*	*