APPENDIX C: Lantern: Test Ratios of *Tripneustes ventricosus* taken from the fore reef and back reef at Pear Tree Bottom, Discovery Bay, Jamaica.

Site	Demipyramid length	Test diameter	Lantern:Test Ratio
BR	72	14	0.194444
	88	17	0.193182
	96	21	0.21875
	87	16.5	0.189655
	90	16	0.177778
	80.5	16.5	0.204969
	111	21	0.189189
	95	17	0.178947
FR shallow	68	15	0.220588
	85	18	0.211765
	64	15.5	0.242188
	77	18.5	0.240260
	70	15.5	0.221429
	70	17	0.242857
	72	18.5	0.256944
	79.5	19	0.238994
FR deep	71	18	0.253521
	70	16	0.228571
	85	21	0.247059
	86.5	19	0.219653
	64	17	0.265625
	76.5	18	0.235294
	74	18	0.243243
	78	18	0.230769

INTERACTIONS BETWEEN BLUE CHROMIS AND HERBIVOROUS MIXED SPECIES SCHOOLS

ANA I. BAPTISTA, DANIELLE L. POULIN, AND REESA C. YALE

Abstract. Previous studies have shown that schooling benefits fish by: 1) enabling them to swarm territorial competitors to take advantage of otherwise inaccessible food resources, 2) confusing predators, and 3) pooling sensory capabilities to increase vigilance and increase foraging time of individuals. We hypothesized that both planktivorous blue chromis (*Chromis cyanea*) and herbivorous mixed species schools would benefit from increased feeding efficiency when associated with each other. Using transects and focal samples, we determined that feeding rates of mixed species schools were higher when they were associated with blue chromis schools, but chromis feeding rates were not affected by the presence of mixed species schools. Mixed species schools may feed more efficiently when associated with blue chromis schools because they can spend more time feeding and less time being vigilant. Also, since chromis schools were found to be relatively sedentary, they may be enriching the area with their feces making it an optimal place for mixed species schools to forage.

Key Words: Chromis cyanea, *feeding rates, foraging efficiency, predator confusion, vigilance*

INTRODUCTION

Past studies have shown that herbivorous fish may benefit from forming mixed species schools that are able to swamp and subsequently feed on algae in damselfish territories which would be unavailable to individual fish (Robertson et al. 1976). Schooling has also been shown to reduce the risk of predation to group members by (a) reducing the per capita attack rate, (b) pooling sensory capabilities and maintaining cooperative vigilance, and (c) causing "predator confusion" by making it difficult for a predator to single out and track individual prey in a group (Landeau and Terborgh 1986).

We observed mixed species schools of herbivorous fish associated with schools of planktivorous blue chromis (*Chromis cyanea*) in the fore reef of Discovery Bay, Jamaica. We hypothesized that blue chromis and herbivorous mixed species schools experience increased feeding efficiency when they occur together. Chromis may benefit from zooplankton stirred up by feeding herbivores, and herbivores may benefit from a reduced need for predator vigilance and increased time available for foraging, due to the presence of blue chromis schools. We predicted that blue chromis and mixed species schools would be found associated with each other more often than by chance, and that both chromis and herbivorous fish would have higher feeding rates when associated.

While mixed species schools appeared to be relatively mobile, we were uncertain about the mobility of blue chromis schools. We documented chromis school mobility to determine if it could affect their association with mixed species schools.

METHODS

We conducted our study at three fore reef sites: Mooring 1 and the Long Term Study Site in Discovery Bay, and Pear Tree Bottom near Runaway Bay, Jamaica, West Indies on 6 to 10 March 1998. Data were collected by SCUBA diving and snorkeling. We ran four 100 m transects, three at depths of 0-6 m; and one at a depth of 12 m; these were then broken down into twenty 5 m segments. Presence or absence of chromis schools and mixed species schools, and whether the two were found together or separately, were recorded for each segment. Presence or absence of damselfish territories at the location of each school was also noted. Transect data were analyzed using Chi-square tests to determine whether chromis schools and mixed species schools were found together and in damselfish territories, more often than expected by chance.

We haphazardly chose focal individuals in both chromis and mixed species schools in order

to measure their feeding efficiencies when found separately and in association. We followed focal chromis for 5 min and focal fish in mixed species schools for 2 min 30 sec, recording their feeding rates (number of nips per minute), the number of individuals per school, whether chromis and mixed species schools were found separately or together, and presence or absence of damselfish territories in the area. Additionally, we watched three chromis schools and one mixed species school for 30 minutes each, noting the species and number of individuals, time spent in chromis-mixed species school interactions, substrate (including damselfish territories), and movement. We marked three chromis schools with buoys and went back 24 h later, and 48 h later in one case, to determine how sedentary chromis schools are. We used one-way ANOVAs to compare feeding rates of fish in mixed species schools in the presence and absence of chromis and chromis feeding rates in the presence and absence of mixed species schools.

RESULTS

We found 39 chromis schools and 49 mixed species schools in four transects. Chromis schools ranged from 8 to over 100 individuals, while mixed species schools varied from 5 to 30 fish. The mixed species schools observed during our study consisted primarily of striped parrotfish (*Scarus iserti*), stoplight parrotfish (*Sparisoma viride*), redband parrotfish (*Sparisoma aurofrenatum*), blue tangs (*Acanthurus coeruleus*), and doctorfish (*Acanthurus chirurgus*).

Chromis and mixed species schools were not found together more often than expected by chance ($\chi^2 = 0.581$, $P > 0.05$). Feeding rates for individuals in mixed species schools were significantly higher in the presence of chromis schools than when they were found alone ($F_{1, 20} = 7.34$, $P = 0.014$, Figure 1). The feeding rate for chromis found with mixed species schools was 3.59±0.46 (mean±1SE) nips per minute which was not significantly greater than the feeding rate of 2.88±0.47 nips per minute of chromis found separately from mixed species schools ($F_{1, 28} = 1.13$, $P = 0.30$). Chromis and mixed species schools were found together in damselfish territories more often than would be expected by chance ($\chi^2 = 4.46$, $P < 0.03$).

Observations of chromis schools made after 30 min, 24 h and 48 h showed that the schools had the same number of individuals and remained within 1 m of where they were

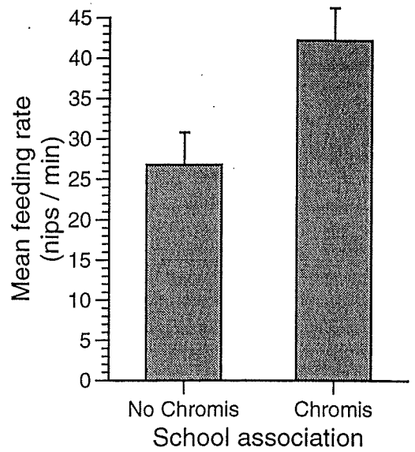

FIG. 1. Differences in feeding rates of focal individuals of mixed species schools when associated and not associated with chromis schools (mean ± 1 SE).

originally observed. During a 30 min observation of one mixed species school, individuals moved among 10 patches of algae, ranging 4 to 5 m from their starting point. Other mixed species schools, particularly schools of larger fish, seemed even more mobile, sometimes swimming 10 m between patches of algae.

DISCUSSION

As hypothesized, increased feeding rates of mixed species schools in the presence of chromis schools suggest that they may be benefiting from the presence of blue chromis by lowering the risk of predation. Trumpetfish, bar jacks, barracuda, and other predatory fish were observed in sample areas, indicating that in spite of recent overfishing, these predators probably remain influential in determining the formation, distribution, and behavior of mixed species schools. Herbivorous fishes feeding below schools of hovering chromis may be able to spend more time feeding and less time vigilant since the greater number of individuals will help to detect and confuse predators. It is also possible that by remaining sedentary, blue chromis repeatedly defecate in an area, enriching the growth and nutritional value of the algae beneath them which attracts herbivorous fish.

An alternative explanation for the higher feeding rates exhibited by herbivorous

fishes in the presence of blue chromis schools is that both schools are associated with areas of high algal cover and structural complexity. We found that associated chromis and mixed species schools were found together in damselfish territories more often than would be expected by chance. Blue chromis schools may be located above structurally complex damselfish territories to take advantage of substrate that provides them with nocturnal refuge, while herbivorous fish are attracted to damselfish territories to feed on their rich algal lawns (Hixon and Brostoff 1983).

We did not find an effect of mixed species schools on blue chromis feeding rates. This may be due to the continuous flow of zooplankton into the reef by currents (Hamner et. al., 1988). Zooplankton may be so abundant on the reef that blue chromis are not food-limited and any zooplankton stirred up by feeding herbivorous fish would be insignificant. In addition, if blue chromis defecation enhances algal growth it may also encourage the aggregation of zooplankton beneath chromis schools, since zooplankton are often concentrated in areas of high vegetation (D Chiavelli, pers. comm.).

It may not be optimal for herbivores to increase their search and travel time to seek out blue chromis schools since food does not appear to be a limiting factor, in light of the plethora of macroalgae and damselfish territories currently present on the reef. However, it is possible that since herbivorous fish experience higher feeding rates in association with blue chromis, they spend a longer time feeding in areas where blue chromis are present when they come across a blue chromis school by chance. An examination of predation rates, zooplankton densities, algal cover, and herbivore preferences in algal species is necessary to more fully understand the interaction between damselfish, blue chromis schools, and mixed species schools of herbivorous fish.

LITERATURE CITED

Hamner et. al., 1988. Zooplankton, planktivorous fish, and water currents on a windward reef face: Great Barrier Reef, Australia. Bulletin of Marine Science, **42**(3): 459-479.

Hixon, M. A. and Brostoff W. N. 1983. Damselfish as keystone species in reverse: intermediate disturbance and diversity of reef algae. Science **220**: 511-513.

Itzkowitz, M. 1977. Social dynamics of mixed-species groups of Jamaican reef fishes. Behavioral Ecology and Sociobiology **2**: 361-384.

Landeau, L. and Terborgh, J. 1986. Oddity and the 'confusion effect' in predation. Animal Behavior **34**: 1372-1380.

Robertson, D. R. et al. 1976. Schooling as a mechanism for circumventing the territoriality of competitors. Ecology **57**: 1208-1220.

Shaw, E. 1978. Schooling fishes. American Scientist **66**: 166-174.