# Predation in Marine Protected Areas: Preliminary Results of the Effects on Growth and Survivorship of Newly-settled Coral Reef Fishes

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ABSTRACT

Substantial attention has been paid to the implementation and efficacy of marine protected areas. As a result, data are available on the increased abundance of large piscivorous and commercially-important fishes within marine protected areas. Fewer studies have evaluated the indirect effects of this build-up, such as the influence on recruitment and survivorship of young fishes. Higher predation pressures in marine protected areas should lead to lower post-settlement survival rates of newly-recruited fishes as well as higher selective mortalities. For example, surviving recruits in these areas may exhibit traits such as faster growth rates and larger sizes-at-age than elsewhere. Due to the constraints of testing these hypotheses in marine protected areas (e.g. permit restrictions, confounding environmental variables), mesocosm tanks were constructed in order to run experimental trials in a controlled setting. Recruits of the bluehead wrasse, *Thalassoma bifasciatum,* were collected from the field, transplanted in natural densities to replicate experimental tanks and then subjected to three treatments—high predation or SPA (reflecting predator densities in marine protected areas), lower predation or NSP (reflecting predator densities in non-protected areas) and control treatments (CON) with no predators. Survivorship of recruits was recorded and compared among treatments to evaluate differential predatioan rates. To evaluate selective mortality, growth rates of individual recruits (as recorded in otoliths) were compared between the initial population of recruits and the survivors of each treatment. Differences in post-settlement survival and selective mortality among treatments will enhance our understanding of ecological processes occurring within marine protected areas by shedding light on factors affecting successful recruitment of fishes to these areas.

KEY WORDS: MPAs, predation, larval fish

# Depredacion en las Areas Marinas Protegidas: Efecto sobre el Crecimiento y la Superviviencia de Larvas de Peces de Arrecifes Coralinos Recientemente Asentados

La implementación y la eficacia de las áreas marinas protegidas han sido objeto de mucha atención. Consecuentemente, ahora hay datos sobre el incremento en abundancia de grandes piscívoros y de peces de importancia comercial dentro de dichas áreas, pero pocos estudios han evaluado el efecto indirecto de esta acumulación, así como su influencia sobre la supervivencia y el reclutamiento de los peces juveniles. Una mayor presión de depredación en áreas marinas protegidas debería reducir las tasas de supervivencia post-asentamiento de peces recién reclutados y aumentar la mortalidad selectiva. Por ejemplo, los reclutas que sobreviven en estas áreas podrían mostrar tasas de crecimiento más rápidas y talla-por-edad más grande que en otros sitios. Debido a limitaciones para poder probar esas hipótesis en áreas marinas protegidas (e.g. restricción de licencias, variables ambientales que confunden los resultados), se construyeron acuarios mesocosmos para realizar experimentos en un medio controlado. Reclutas del limpiador cabeza azul, *Thalassoma bifasciatum*, se recolectaron en el campo, se pusieron en densidades naturales en los aquarios experimentales replicados, y luego se sometieron a tres tratamientos diferentes – depredación alta (reflejando la densidad de depredadores en áreas marinas protegidas), depredación baja (reflejando la densidad de depredadores en zonas no protegidas), y tratamiento de control sin depredadores. La supervivencia de los reclutas se midió y se comparó entre los tratamientos para evaluar tasas de depredación diferenciales. Para la evaluación de mortalidad selectiva, el crecimiento de reclutas individuales (interpretado de los otolitos) se comparó entre la población inicial de los reclutas y los que sobrevivieron cada experimento. Las diferencias entre la supervivencia post-asentamiento y la mortalidad selectiva entre tratamientos, mejorará nuestro entendimiento de los procesos ecológicos que ocurren en las áreas protegidas, al identificar los factores que afectan el reclutamiento exitoso de los peces en esas zonas.

PALABRAS CLAVES: Areas Marinas Protegidas, depredacion, larvas de peces

## INTRODUCTION

Though substantial attention has been paid to the increase in densities of larger, commercially-important species in marine protected areas, relatively fewer studies have focused on the possible indirect impacts of this increase. Since larger fishes tend to be piscivorous, we would expect that an increase in their density would lead to an increase in predation pressure for their prey. Higher predation pressures would lead not only to decreased survivorship of prey species, but also to a possible higher level of selective mortality. For newly-settled coral reef fishes, which are particularly vulnerable to predation, an increase in predation pressure could have an impact on the post-settlement processes influencing their survival and growth. As densities of recruits decrease and selective mortality increases, survivors should exhibit relatively larger sizes-at-age and higher levels of condition (e.g. higher lipid content, faster swimming speeds, behavioral advantages). We hypothesize that recruits settling to marine protected areas will indeed be subjected to higher predation pressures, leading to decreased survivorship, larger mean size-at-age and faster larval or juvenile growth rates.

## METHODS

All field research was conducted in the upper Florida Keys, USA within the Florida Keys National Marine Sanctuary (FKNMS). Within the reserve, sites are defined by varying degrees of protection. Sanctuary Preservation Areas (SPAs) are considered "no-take" zones, in which all collection is prohibited. Other areas are restricted to general size limits, bag limits, and gear restrictions, with all forms of collection permitted except spearfishing.

Due to the prohibition of scientific collection in the SPAs of the FKNMS, an in-situ study was not possible. To isolate the effect of predation pressure on new recruits while controlling for as many variables as possible, mesocosm manipulations were necessary. The bluehead wrasse *Thalassoma bifasciatum* was chosen as the study species for this experiment due to the high abundance of recruits on the reef, ease of recruit collection and large amount of information available on its life history.

To determine the effect of various piscivores on the recruitment and post-settlement survival of *T. bifasciatum*, recruits were subjected to different densities of predators in large aquaria to estimate survival and selective mortality under varying levels of predation pressure. Using survey data of piscivore density from both protected and unprotected areas of the FKNMS, three treatments were established: SPA, with a higher density of predators reflecting protected area densities; NSP, with a lower piscivore density reflecting natural densities outside protected areas; and Control (CON), with no predators. An equal number of recruits, also reflecting natural densities in the field, were transplanted to each treatment. Each treatment was replicated, resulting in a total of six experimental tanks, two of each treatment.

The most abundant predators in the FKNMS, the yellowtail snapper, *Ocyurus chrysurus,* and the gray snapper, *Lutjanus griseus,* were caught using hook and line and transported to the mesocosm facility. Predators were immediately fed and then starved for a period of two days in order to standardize their level of hunger. Recruits also were collected from the field by SCUBA divers and transported to the mesocosms. They were transplanted in equal densities ($n = 30$) to each of the six tanks and then left to acclimate in the tanks for 24 hours. At the end of this period, predators were introduced to the SPA and NSP treatments ($n = 5$ and $n = 2$, respectively) and control tanks received no predators. Predation trials ran for 48 hours post-predator introduction. At the end of the experiment, predators were captured and released while recruits were caught and preserved for further analysis.

Recruits were measured for standard length and then dissected to obtain their otoliths. These structures, the "ear bones" of the fish, serve as a record of both the age and growth of the recruit throughout its life history. By counting the increments deposited along the otolith as well as measuring the width of each increment, we are able to obtain measures of larval and juvenile age and otolith growth during these periods. Since standard length of these fishes and otolith length are significantly correlated (Figure 1), we can use the otolith measurements as a proxy for understanding the somatic growth of the fish. Half of the fish from each treatment tank were randomly selected for otolith analysis.

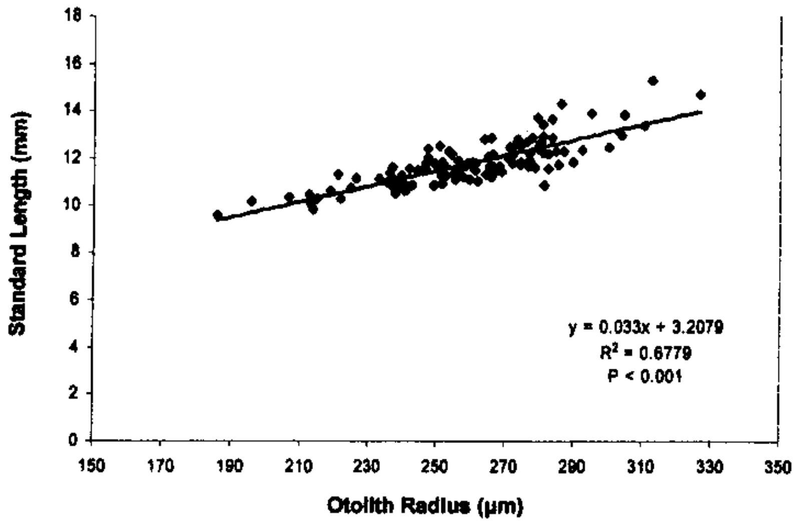


**Figure 1.** The relationship between otolith radius and standard length

## RESULTS AND DISCUSSION

Mean numbers of survivors recovered from each experimental treatment show that fishes subjected to higher levels of predation (SPA treatment) do have lower levels of survivorship than those not subjected to predation pressure (CON treatment) (Figure 2). Levels of survivorship were similar between the CON and NSP treatments, but error bars indicate higher survivorship may be more frequent for those fish free from predation in the control treatments.

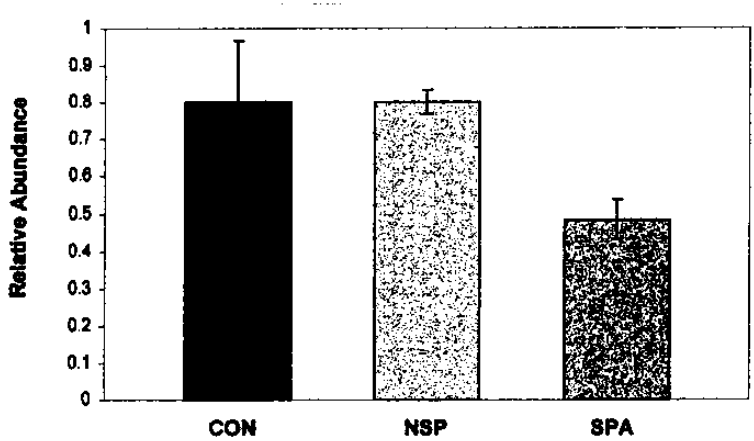


**Figure 2.** Survivorship of fish subjected to high levels of predation pressure (SPA), lower levels (NSP), and fish free from predation (CON)

Analysis of larval growth rates of survivors from each of the treatments indicated that recruits subjected to predation pressure in both the SPA and NSP treatment have a higher rate of larval growth than do recruits in the CON treatment (Figure 3). This corroborates the predictions of our working hypothesis—recruits subjected to predation may show higher selective mortality, indicating those with some selective advantage will survive. In this case, this advantage may be conferred through faster growth rates during larval life. The data also show that these differences in growth rates translate into larger mean otolith length-at-age.

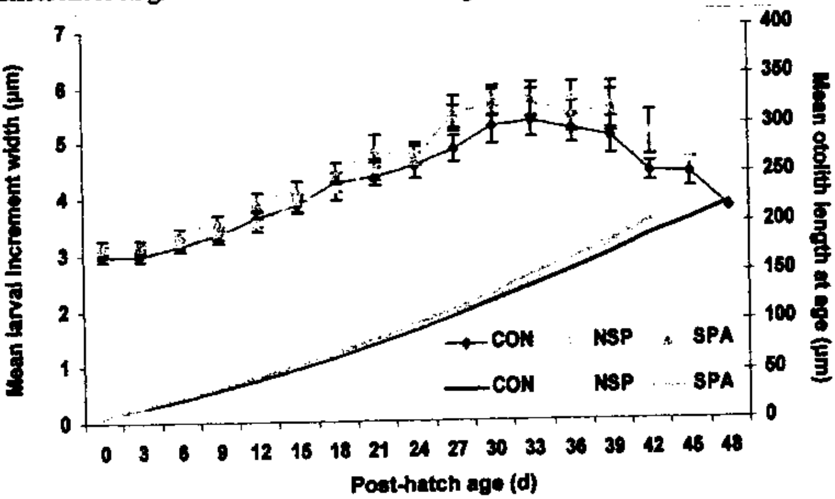


Figure 3. Larval otolith growth of fish subjected to high levels of predation pressure (SPA), lower levels (NSP), and fish free from predation (CON)

Due to these faster larval growth rates, recruits in the SPA and NSP treatments were able as larvae to achieve a minimum level of condition or size required for settlement more quickly. They settled to the reef earlier, resulting in a shorter mean pelagic larval duration relative to those recruits not subjected to selective mortality in the CON treatment (Figure 4).

While this trend continued during the first three days of juvenile life, this difference was likely insignificant (Figure 5).

In order to ascertain that the trends exhibited were a natural phenomenon and not merely an artifact of the mesocosm manipulations, recruits from the field were collected and compared to the experimental survivors. Recruits from the initial population were collected just after emergence onto the reef, and recruits from the same population were collected a week later. We would assume that during this week, recruits were exposed to natural levels of predation on the reef. By comparing the larval growth rates of the two collections, we see that larval growth rates were faster for those recruits surviving to the final collection than those initially collected (Figure 6). This is consistent with our mesocosm findings: the final population, exposed to more predation, shows evidence of selective mortality based on larval traits. Only those faster growing fishes survived. Similarly, the survivors had a lower mean pelagic larval duration (Figure 7).

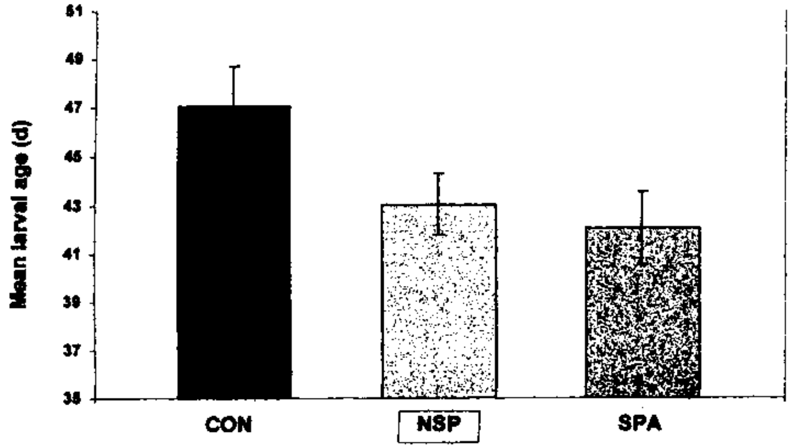


Figure 4. Pelagic larval duration of fish subjected to high levels of predation pressure (SPA), lower levels (NSP), and fish free from predation (CON)

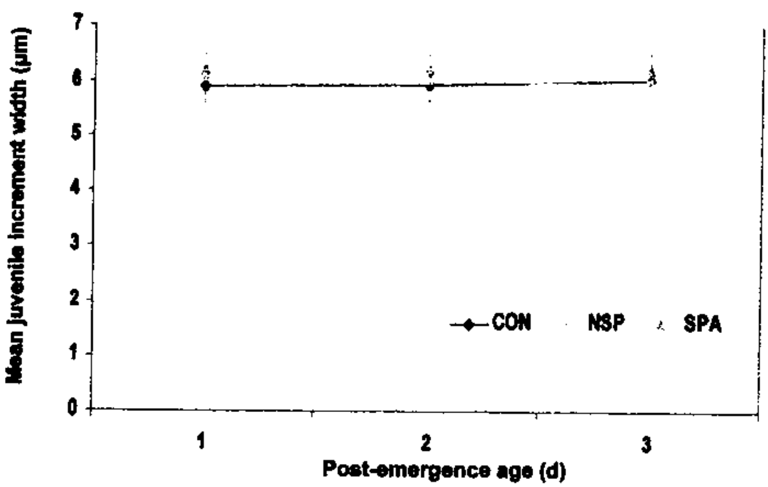


Figure 5. Juvenile otolith growth of fish subjected to high levels of predation pressure (SPA), lower levels (NSP), and fish free from predation (CON)

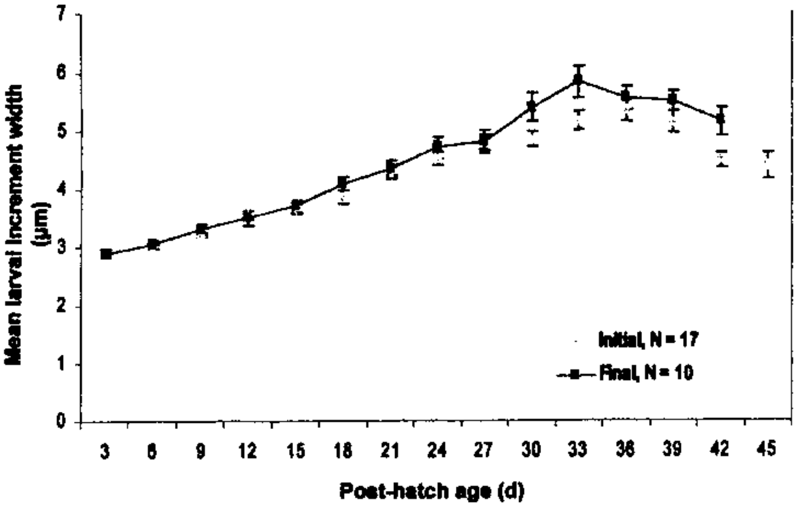


Figure 6. Larval growth rates of recruits surviving to the final collection versus those initially collected

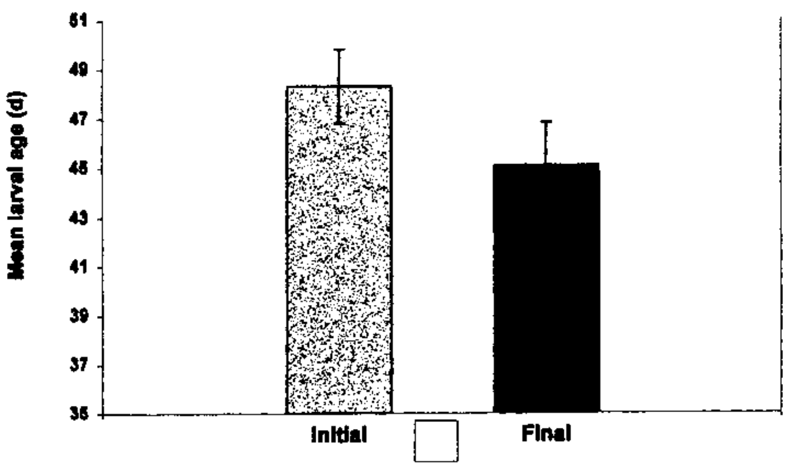


Figure 7. Pelagic larval duration of recruits surviving to the final collection versus those initially collected

## IMPLICATIONS

Preliminary analyses show trends in the data that will require further analysis to indicate the importance of indirect effects acting in marine protected areas. If fishes recruiting to these areas are indeed subject to higher predation pressures that limit their survivorship and exert selection on survivors, repercussions for the protected population as a whole may occur. By decreasing the number of newly-settled coral reef fishes, there would be a subsequent decrease in recruitment success and overall diversity. Selective mortality also may potentially change the traits of the surviving population as a whole. Indirect effects of protection such as these potential mechanisms should be considered when attempting to manage fish populations using marine protected areas.