Site Fidelity and Movement of Reef Fishes Tagged at Unreported Artificial Reef Sites off NW Florida

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ABSTRACT

Data were analyzed from an ongoing reef fish tagging study to examine species-specific site fidelity to and movement from unpublished artificial reefs in the northern Gulf of Mexico. Fish were captured at reefs (n = 9) located between 15 and 20 miles south of Pensacola, Florida, USA. A total of 2,678 fish was tagged with internal anchor tags on quarterly tagging trips from March 2005 to June 2007. The most frequently tagged species were red snapper (n = 1,765), red porgy (n = 368), gray triggerfish (n = 256), gag (n = 101), and vermillion snapper (n=66). Eighty-one tagged individuals were recaptured at tagging reefs on subsequent tagging trips, with red snapper, gray triggerfish and grouper recaptures being 41, 28, and 9, respectively. Fishers reported a total of 187 fish caught away from tagging sites, with 133 red snapper, 20 gray triggerfish, and 19 grouper recaptures reported. Mean distance moved among all recaptured red snapper was 28.4 km, while lower mean distances were estimated for gray triggerfish (10.4 km) and groupers (16.6 km). Size of fishes present at reef sites was estimated with a laser scaler attached to a remotely operated vehicle with which study sites were video sampled quarterly. Few red snapper (< 5%) observed at study sites were above the recreational fishery's legal size limit (406 mm total length), while more than half (52%) of the gray triggerfish measured were above that species' legal size limit (305 mm fork length). Overall, results indicate that red snapper displayed lower site fidelity to and greater movement from unreported artificial reef sites than did gray triggerfish; grouper site fidelity and movement were intermediate to red snapper and gray triggerfish parameters. It appears higher movement observed in red snapper made that species vulnerable to high recreational fishing mortality at artificial and natural reefs in the region, hence the lack of larger, older red snapper observed at our study sites. Therefore, unreported artificial reef sites may not serve as effective harvest refugia for species that display low site fidelity and move between fished and unfished areas.

KEY WORDS: Artificial reefs, tagging, site fidelity

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Los datos se analizaron de forma permanente los peces de arrecifes de etiquetado en estudio para examinar sitio específico de la especie y de la fidelidad al movimiento de los no publicados arrecifes artificiales en el norte del Golfo de México. Los peces fueron capturados en los arrecifes (n = 9), situada entre 15 y 20 millas al sur de Pensacola, Florida, EE.UU. Un total de 2.678 peces se etiquetados con etiquetas de anclaje interno trimestral de etiquetado en los viajes a partir de marzo de 2005 a junio de 2007. Las especies con mayor frecuencia fueron etiquetados pargo rojo (n = 1.765), rojo porgy (n = 368), de color gris triggerfish (n = 256), la mordaza (n = 101), y el pargo bermellón y adornado (n = 66). Ochenta y una personas fueron etiquetados capturados en el etiquetado de los arrecifes de etiquetado en viajes posteriores, con el pargo rojo, gris triggerfish y grouper recaptures ser 41, 28, y 9, respectivamente. Pescadores notificado un total de 187 peces capturados fuera de los sitios de etiquetado, con 133 pargo rojo, 20 de color gris triggerfish, y 19 grouper recaptures. La media distancia movido entre todos los capturados pargo rojo era 28,4 km, mientras que las distancias son menores en la vía estimado para gris triggerfish (10,4 km) y meros (16,6 km). Tamaño de los peces presentes en los sitios de arrecifes se calculó con un láser escalador conectada a un vehículo controlado a distancia con el que estudiar los sitios de video se muestra trimestral. Pocos pargo rojo (<5%) observados en los sitios de estudio fueron superiores a la pesca recreativa legal del límite de tamaño (406 mm de longitud total), mientras que más de la mitad (52%) de la gris triggerfish medidos fueron superiores que las especies jurídica de límite de tamaño (305 mm de longitud de la mesa). En general, los resultados indican que el pargo rojo que aparece más bajo sitio y de una mayor fidelidad a la circulación incontrolada de los sitios de arrecifes artificiales que hizo gris triggerfish; Grouper sitio de la fidelidad y la circulación se intermedios a pargo rojo y gris triggerfish parámetros. Parece mayor movimiento observado en pargo rojo hecho de que las especies vulnerables a la alta mortalidad de la pesca recreativa en los arrecifes artificiales y naturales en la región, de ahí la falta de grandes, de más edad pargo rojo observado en nuestros sitios de estudio. Por lo tanto, no declarada arrecife artificial sitios no pueden servir como eficaz cosecha de refugios para las especies que se muestran bajo sitio de la fidelidad y moverse entre pescados y unfished zonas.

PALABRAS CLAVES: Filones artificiales, marcando con etiqueta, fidelidad del sitio

INTRODUCTION

Artificial reefs are manmade structures typically built with a goal of promoting growth of aquatic life in areas of limited hardbottom habitat and/or to enhance fishing opportunities. Increased catch rates usually follow new reef creation, which user groups and fishery managers have typically assumed indicates that reefs increase fish production (Lindberg 1997). However, there is an ongoing debate as to whether artificial reefs function to enhance production of aquatic species or if they are more likely to aggregate individuals from surrounding areas, thus making them more susceptible to fishing mortality. Recent scientific studies have shown that artificial reefs likely do not function exclusively as either attractors or producers, but rather their location on a continuum between those two end points is a function of several factors (e.g., site fidelity, reef dependency, habitat limitation, and degree of exploitation) (Bohnsack and Sutherland 1985, Lindberg 1997, Powers *et al.* 2003). Among the more important factors for evaluating the ecological function of artificial reefs is whether fishes associated with reefs display high site fidelity and limited movement (Bohnsack 1989). Fishes that display low site fidelity and have limited reef dependency are less likely to display an enhancement effect with the creation of artificial reefs. Furthermore, fishes that display greater movement may actually have increased exposure to fishing mortality as they move between less and more targeted areas (Crowder *et al*. 2001, Hampton and Fournier 2001, Kaunda-Arara and Rose 2004).

The preponderance of data from studies aimed at examining the ecological function of artificial reefs suggests they generally function more as fishing tools than as enhancers of reef fish productivity (Bohnsack 1989, Grossman *et al.* 1997, Pitcher and Seaman 2000). Polunin and Saki (1989) did report production was enhanced by artificial reefs for habitat-limited octopuses in Japanese waters, but enhancement was not demonstrated for fishes. Likewise, Butler and Herrnkind (1997) reported that adding small-scale (m^3) artificial reefs to 0.05-ha sites in Florida Bay decreased mortality on habitat-limited juvenile spiny lobster, *Panulirus argus*, thus relaxing a recruitment bottleneck. There is not much evidence for an enhancement effect beyond those two specific examples, which may simply be due to fishing mortality (F) being so high for many targeted species that any enhancement of production is more than offset by fishing. For example, Polovina (1994) estimated new fish production at artificial reefs was 0.02 - 0.5 $kg/m^3/yr$, but fish catches at reefs were 5 - 20 $kg/m^3/yr$. Grossman *et al*. (1997), in a review of several studies, reported fish production varied greatly at the scale of individual artificial reef sites, but no evidence existed to indicate artificial reefs increased fish production regionally.

Minimizing F appears to be key if reef fish production is to be enhanced by the creation of artificial reefs (Patterson and Cowan 2003, Powers *et al*. 2003, Strelcheck *et al*. In press). As such, artificial reefs have been deployed to rehabilitate reef habitat within marine protected areas (e.g., Pitcher *et al*. 2000, 2002), while another approach has been to build artificial reefs but not disclose their location to the public (e.g., Lindberg *et al*. 2006). Following this second model, the Florida Fish and Wildlife Conservation Commission (FWC) constructed 525 unpublished artificial reefs equally divided among four designated Large Area Artificial Reef Sites (LAARS) off northwest Florida in spring 2003 (Figure 1). Reefs consist of one or two pre-fabricated concrete or concrete and rebar structures (Table 1). The main objective of the program was to build reef sites that might serve as harvest refugia, thus mitigate against high fishing mortality rates for reef fishes in the region. In fall 2005, we began a study to examine the ecological function of a subset of these unpublished, hence unfished, reef sites within the Escambia East LAARS (EE-LAARS; 260 km^2) off Pensacola, Florida (Figure 1). One aspect of the larger project is examining site fidelity and movement among fishes tagged at unpublished artificial reef sites. The objective of the ongoing work presented here has been to assess site fidelity and estimate movement of fishes associated with unpublished artificial reef sites, as well as to estimate species-specific size distributions from concurrent remotely operated vehicle (ROV) video sampling at study reefs.

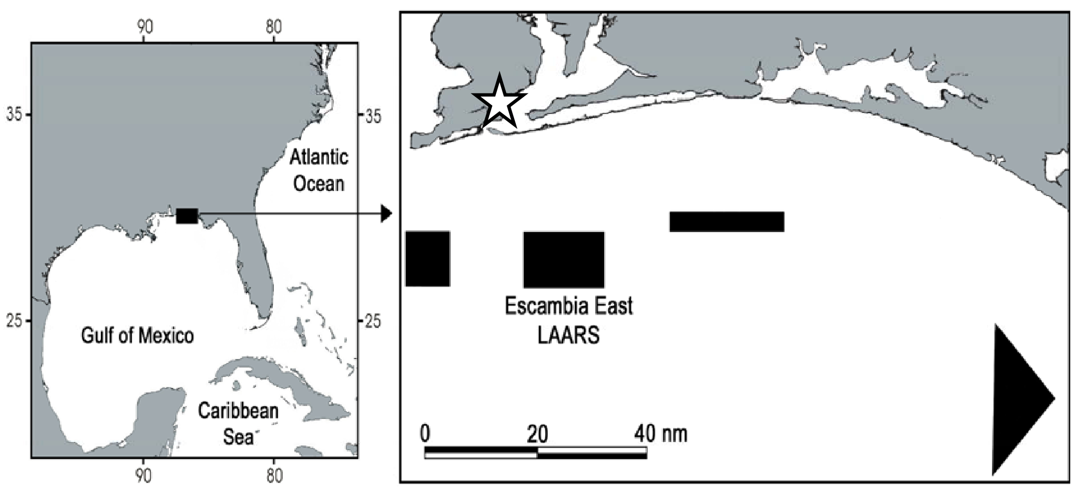
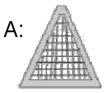
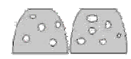


Figure 1. Location of four Large Area Artificial Reef Sites (LAARS) off the coast of northwest Florida in which 525 unreported artificial reefs were deployed in 2003; study reefs are located in the Escambia East LAARS. Star indicates Pensacola, Florida.

Table 1. Dimensions of three artificial reef types deployed by the FWC in the Escambia East LAARS in spring 2003.

Reef Parameters	Type A: 	Type B: 	Type C: 
construction material	concrete and rebar	concrete	concrete
modules per site	1	2	2
module height m	3.05	1.83	1.45
module base m	3.05	3.05	1.83
reef volume m^3	4.09	4.90	2.84

METHODS

Quarterly sampling trips were conducted from March 2005 to June 2007 to tag reef fishes at nine artificial reef study sites (n = 3 of each design; Table 1). Reefs were located in the southwest quadrant of the EE-LAARS and ranged in depth between 28 - 38 m. Quarterly tagging effort was standardized among reefs. Once over a given site, 5 fishermen targeted fish to be tagged for 30 minutes. Four anglers used two-hook bottom rigs (3/0 J hooks each tied to a 0.5-m leader) baited with squid and cut mackerel, and a fifth angler fished in the water column above the reef using a sow rig (two 5/0 J hooks snelled 10 cm apart to the end of a 1.5-m leader) baited with a whole mackerel scad. Fish were brought to the surface at an approximate rate of 1 m/sec. Fish were immediately removed from hooks and placed into a 475-L cooler filled with constantly recycling seawater. Fish were removed from the holding tank and measured to the nearest mm fork length (FL) and/or total length (TL). Fish were tagged with an internal anchor tag inserted into a small (< 5 mm) incision in the abdominal cavity, and then released. Anchor tags were marked with the word "REWARD", an identifying tag number, and a toll free number to report tag recoveries. The tagging study was advertised in several media outlets to the recreational and commercial fishing communities, encouraging fisherman to report tag recoveries. Those who reported a tag recovery received a $10 reward per tag and were entered into a $500 annual lottery of all tag returnees. Tag recovery information was obtained from those who called the toll-free number: tag number, location of recapture (GPS or LORAN-C coordinates if available), date of catch, and fish length.

Recapture location was plotted in a geographic information system (GIS) for tag recoveries for which sufficient detail in recapture location was reported by fishermen. Fish movement was estimated from the straight-line distance between site of tagging and reported location of fish recapture. Species-specific movement distributions (including zeros for fish recaptured at tagging sites) were plotted to visualize movement patterns. Given high numbers of zero movement and log-normal distributions of positive movement observations, the delta method was employed to estimate unbiased taxa-specific estimates of mean distance moved and its standard deviation (SD) (Aitchison 1955, Pennington 1983). Movement of recoveries reported by fishermen as being caught within the EE-LAARS but without accompanying GPS coordinates was estimated using a random number generator to randomly assign distance moved based on taxa-specific movement distributions of fish recaptured within the EE-LAARS but for which fishermen did report GPS coordinates of recapture location.

Sizes of reef fishes resident at study artificial reef sites were estimated with a laser scaler observed striking fishes during quarterly video sampling conducted with a Video-Ray Pro III® micro remotely operated vehicle (ROV). The scaler consists of two red lasers mounted at a fixed width 100 mm apart. Fish length was estimated from the lasers by multiplying the distance measured between laser spots on fish observed with a high resolution monitor during video playback by the actual distance between lasers (100 mm), and then dividing that product by the fish length measured on the monitor.

RESULTS

A total of 2,678 fish was tagged on 10 tagging trips between March 2005 and June 2007. An additional 335 fish were caught at tagging sites but not tagged due to small size or being non-targeted species. The most frequently tagged fish was red snapper, *Lutjanus campechanus*. However, groupers (Family: Serranidae) and other snappers (Family: Lutjanidae) and, as well as red porgy, *Pagrus pagrus*, and gray triggerfish, *Balistes capriscus*, also were well represented (Table 2). To date, 81 tagged individuals have been recaptured at tagging sites on subsequent tagging trips, and fisherman have reported an additional 187 fish caught away from tagging sites (Table 2).

Overall, red snapper displayed the lowest site fidelity and highest dispersion, with 80.8% of recaptures made away from tagging sites and a mean distance (SD) moved of 28.4 (5.1) km (Figures 2A and 3A). The farthest movement observed among all fishes was 319.9 km for a red snapper free for 792 days, while the longest time free was for a red snapper recaptured 11.7 km to the northeast of its tagging site 807 days after being tagged. Four tagged gray triggerfish were free for longer than a year. Three of those fish were recaptured at their tagging sites, while the one free the longest (616 days) was recaptured 70.3 km to the east southeast of its tagging site. Overall, gray triggerfish displayed the highest site fidelity (58.3% of recaptures made at tagging sites) and lowest dispersion [mean distance (SD) = 10.4 (3.6) km] among tagged fishes (Fiures 2C and 3C). Collectively, groupers (gag, *Mycteroperca microlepis*, scamp, *Mycteroperca phenax*, and red grouper, *Epinephelus morio*) displayed site fidelity (33.3% of recaptures made at tagging sites) and movement [mean distance (SD) = 16.6 (8.9) km] intermediate to red snapper and gray triggerfish. The high SD of grouper distance moved resulted from one gag that moved much farther (299.0 km) than all the rest of grouper recaptures. That fish was free for 806 days and was recaptured just west of the mouth of the Mississippi River (Figure 2B).

Size of 4,894 fish associated with tagging sites was estimated from laser observations in ROV-collected video. Of the more abundant species observed, red snapper (n = 2,563) size distribution was conspicuous due to the lack (< 5%) of fish that were above the recreational fishery's legal size limit (406 mm TL; Figure 4A). Gray triggerfish (n = 461) displayed the opposite trend in that 52.5% of measured individuals were above gray triggerfish's recreational size limit (305 mm FL; Figure 4C). Recreational size limits differ among the predominant grouper species observed (gag, scamp, and red grouper), but overall 19.0% of measured groupers (n = 472) were above their respective size limits (Figure 4B).

DISCUSSION

Tagged reef fishes recaptured in this study displayed a range of site fidelity and movement. Of the more frequently recaptured species, red snapper clearly displayed the lowest site fidelity and greatest movement, which has important implications for the ecological and fishery functions of artificial reefs with regard to that species. It appears red snapper movement away from the study reefs exposed them to high fishing mortality (F) rates in the region (Strelcheck *et al*. In press, Turpin and Bortone 2002). This inference is supported by the lack of legal-sized red snapper at study sites yet the abundance of legal-sized gray triggerfish. Triggerfish displayed much higher site fidelity to and limited dispersion from study reefs, thus were likely not as exposed to F as red snapper. Groupers displayed movement that was intermediate to that of red snapper and triggerfish. Likewise, the percentage of groupers above the legal size that were present at study sites also was intermediate to that of red snapper and gray triggerfish.

Table 2. The most frequently tagged reef fishes captured at artificial reef study sites in the Escambia East Large Area Artificial Reef Site off Pensacola, Florida from March 2005 through July 2007. Lengths are total length for all species except gray triggerfish, *Balistes capriscus*, for which fork length is reported. SD = standard deviation.

Species	Number Tagged	Mean Length at Tagging (SD)	Reported by Fishermen (% total tagged)	Recaptures at Study Sites (% total recaptures)	Mean Days Free among all Recaptures (SD)
Lutjanus campechanus	1,765	355.4 (57.7)	133 (7.5)	41 (23.7)	270.0 (178.2)
Pagrus pagrus	368	300.5 (26.9)	12 (3.3)	2 (14.2)	53.4 (96.2)
Balistes capriscus	256	343.6 (50.4)	20 (7.8)	28 (58.3)	161.6 (126.0)
Mycteroperca microlepis	101	519.6 (82.2)	13 (12.9)	5 (27.8)	199.5 (208.8)
Rhomboplites aurorubens	66	329.4 (32.0)	3 (4.5)	1 (25.0)	309.7 (233.0)
Seriola spp.	55	388.0 (80.9)	0 (0)	0 (0)	na
Epinephelus morio	34	516.6 (84.8)	2 (5.9)	4 (66.7)	92.7 (66.0)
Mycteroperca phenax	20	410.0 (61.0)	3 (15.0)	0 (0)	204.7 (10.7)
Lutjanus synagris	10	332.4 (68.4)	1 (10)	0 (0)	275

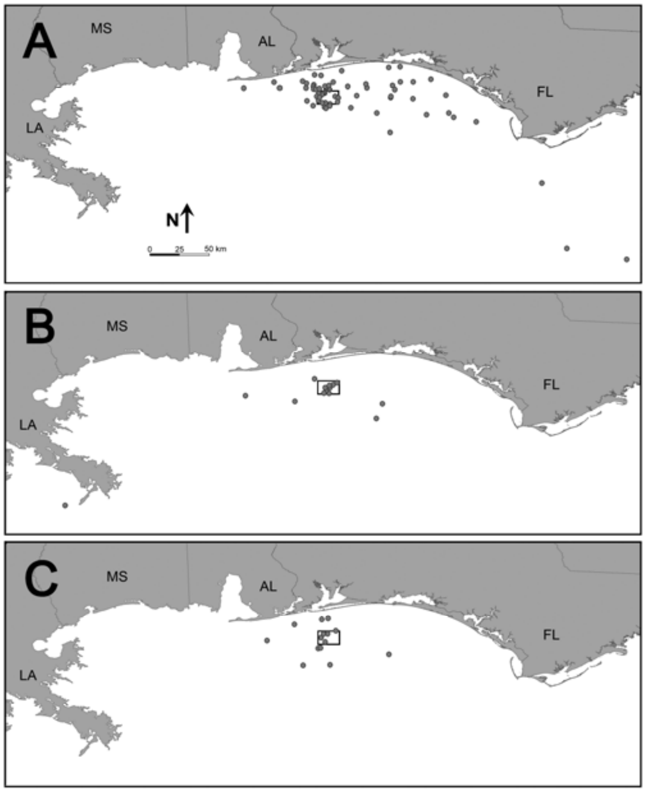


Figure 2. Recapture locations reported by fishermen for A) red snapper, B) groupers, and C) gray triggerfish. Black polygons depict the Escambia East LAARS where tagging reefs were located.

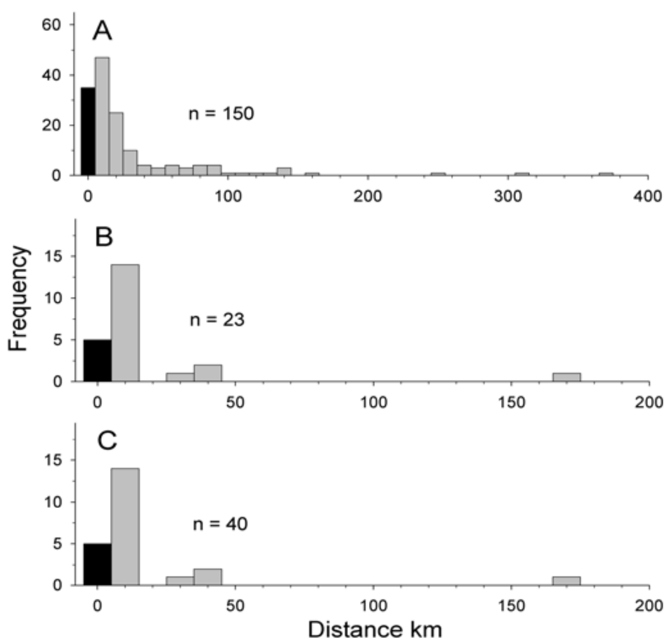


Figure 3. Frequency distributions of movement observed in A) red snapper, B) groupers, and C) gray triggerfish. Recaptures made on subsequent tagging trips are shown black (zero movement). Movement of recoveries reported by fishermen as being caught within the Escambia East LAARS but without accompanying GPS coordinates was estimated using a random number generator and based on the movement distribution of fish recaptured within the LAARS but for which fishermen did report GPS coordinates of recapture location.

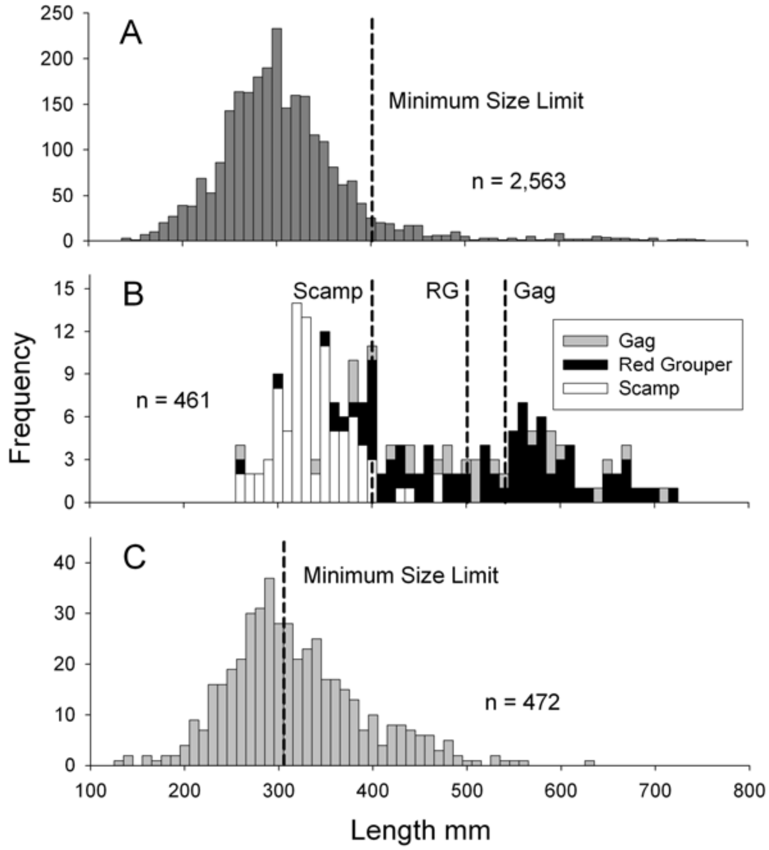


Figure 4. Length frequencies of A) red snapper, B) groupers, and C) gray triggerfish estimated at study artificial reef sites with laser scales attached to a remotely operated vehicle. Data are composites of the ten quarters (March 2005-July 2007) over which tagging occurred. Dashed vertical lines indicate species-specific minimum size limits for recreational fishermen. Sample sizes are given.

Reef fish movement estimates reported here are consistent with results from previous studies conducted elsewhere in the Gulf of Mexico (GOM). While there has been some debate with regard to the interpretation of red snapper movement data, the pattern has been repeated in several studies that most tagged red snapper have been recaptured near their release sites with a logarithmic decline in numbers of fish that moved greater distances (reviewed in Patterson In press). Red snapper movement on the scale of 100s of km also has been observed repeatedly in results of various tagging studies (Beaumariage 1969, Patterson *et al*. 2001b, Strelcheck *et al*. In press). Patterson *et al*. 2001b reported a mean distance moved of 29.6 km, which is nearly identical to the 28.4 km we observed. Similarly, site fidelity estimates reported in other studies also have been low for red snapper, especially considering the species can live greater than 50 years and mostly small, young fish have been tagged (Patterson In press). Patterson and Cowan (2003) and Strelcheck *et al*. (In press) reported direct estimates of red snapper site fidelity to individual artificial reef sites between 25 - 50%/year for fish tagged over artificial reefs off Alabama. Ultrasonically tagged fish in the same area also displayed only a 50% probability of remaining at their tagging reef after one year free (Schroepfer and Szedlmayer 2006).

Collectively, grouper movement data we report suggest gag, scamp, and red grouper display higher site fidelity and lower movement than red snapper. However, an important caveat to that general statement is that others have shown that movement in these shallow grouper species increases ontogenetically and fish we tagged were mostly small, young individuals (Beaumariage 1969, Lindberg *et al*. 2006, McGovern *et al*. 2005, Wilson and Burns 1996). Several authors have reported significant movement (*e.g.*, > 100 km) often occurs in larger individuals of these species. McGovern *et al.* (2005) reported 23% of recaptured gag that were originally tagged in the U.S. south Atlantic moved > 185 km, with several individuals moving from the Atlantic into the GOM. Lindberg *et al.* (2006) reported sub-adult gag that were ultrasonically tagged at artificial reef sites in the northeastern GOM displayed high site fidelity for up to a year. However, several fish moved significant distances once they left that habitat, with one individual being recaptured in the southern GOM off Vera Cruz, Mexico. Fewer movement data have been reported for scamp and red grouper than gag, but Wilson and Burns (1996) reported 11.2% of recaptured red grouper that were tagged west of Tampa, Florida moved >25 km away from their tagging sites. They also reported 52.6% of recaptured scamp moved >9 km, with one individual being recaptured 255 km away from its tagging site.

Few data on gray triggerfish movement existed prior to the current study. Beaumariage (1969) reported a 36.9% recovery rate of tagged gray triggerfish by investigators in the approximate area of initial capture and tagging. Ingram (2001) estimated gray triggerfish annual site fidelity to artificial reefs off Alabama ranged from 63 - 87%/year, while the greatest movement he observed was 23.6 km. Although we report a tagged gray triggerfish moved 70.3 km in this study, fish we tagged generally showed movement and site fidelity similar to that reported by Ingram (2001). Ingram and Patterson (2001) concluded high site fidelity and low dispersion made gray triggerfish a better candidate for stock rehabilitation via creation of marine protected areas than either red snapper or greater amberjack, *Seriola dumerili*, which displayed much greater movement.

Inter-species differences in site fidelity and dispersion have significant implications for fisheries management, especially in the context of artificial reefs. Bohnsack (1989) hypothesized that artificial reefs would be more likely to increase net production of fishes that were obligatory reef residents, or otherwise displayed high site fidelity to reefs, while fishes that had higher dispersion rates and were only partially reef-dependent would be less likely to experience enhanced production following reef creation. However, in the presence of high fishing mortality, even artificial reefs that enhance reef fish productivity may serve as net sinks of reef fish biomass (Strelcheck *et al*. In press). Artificial reefs can increase fish production by decreasing natural mortality (M), therefore total mortality (Z, which equals M + F), or by increasing growth (G). If F is too high, however, the ratio G:Z will be less than one, resulting in a sink scenario (Houde 1989). Strelcheck *et al*. (In press) indicated that at current fishing mortality rates, artificial reefs off Alabama serve as net sinks of red snapper biomass (G:Z <1). In the eastern GOM, Lindberg *et al*. (2006) reported gag productivity increased on unpublished artificial reefs, but gag biomass decreased to 77% of its pre-fished level after reef coordinates were released to the fishing public.

There is a general concern that many marine artificial reef programs may be functioning more as reef fish production sinks rather than sources in heavily fished areas (Grossman *et al.* 1997, Pitcher and Seaman 2000, Polovina 1991, Polovina and Sakai 1989). If this is the case, then continued deployment of artificial reefs may exacerbate rather than mitigate overfishing (Lindberg 1997, Strelcheck *et al*. In press). The establishment of no-take marine protected areas (MPAs), including ones containing artificial reefs, has been proposed as a management tool to alleviate overfishing of reef fishes and rebuild spawning stock biomass of heavily exploited fish stocks (Pitcher and Seaman 2000). However, marine reserves must be designed and placed thoughtfully because of the many factors that may affect their likelihood for success (*e.g.*, ecosystem source/sink dynamics, area fishing intensity, ecology of targeted species, and habitat health). Crowder *et al*. (2000) explained that poor MPA design may contribute to a lack of evidence for MPA benefit. Marine reserves functioning as mitigation for overfishing of reef species must take into account design (size and placement) and fish behavior (movement and fidelity). Smaller MPAs might function well for obligatory reef species, such as gray triggerfish, that display high site fidelity and low movement (Ingram and Patterson 2001). However, our results suggest MPAs designed to protected partially reef dependent species that display high site fidelity and high dispersion, such as red snapper, would need to be expansive in order to achieve the goals of protecting and rebuilding spawning stock biomass. Clearly, these same parameters will effect the efficacy of unpublished artificial reef sites as harvest *refugia* for reef fishes.

In the end, data presented here and inferences we draw from them should be viewed as preliminary. Our research involves a much more intensive and quantitative modeling effort to examine the ecological function of additional reefs (n = 27) off the coast of northwest Florida. Additional tag and recapture data will used to directly estimate site fidelity and dispersion (e.g., Patterson and Cowan 2003, Strelcheck *et al.* In press), which in turn will sure as inputs to community dynamics models. Our central goal to be able to quantitative estimate ecological function of artificial reefs off northwest Florida, and to be able to predict under what type of scenarios they are likely to accomplish the management goal of increasing reef fish biomass.

ACKNOWLEDGEMENTS

We thank the Florida Fish and Wildlife Conservation Commission Artificial Reef Section for funding and Jon Dodrill and Keith Mille at FL FWC for support. We thank Capt. Jeff Thiery for field support onboard the *F/V Dorado*. We thank volunteer anglers for help in tagging fish, as well as the many fishermen who reported tag recoveries.

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