Evaluation of Spillover Using Lobster, *Panulirus argus*, Size and Catch Rates from Commercial Traps Fished Near and Distant from Marine Protected Areas in the Lower Florida Keys

DAVID B. HAWTOF[1] and DOUGLAS R. GREGORY[2]
[1]1037 United Street, Key West, Florida 33040 USA , [2]University of Florida Sea Grant Extension, 1100 Simonton Street, Key West, Florida 33040 USA

ABSTRACT

Ten years after establishment of marine protected areas (MPAs) in the Florida Keys we sampled a commercial fisherman's catch from traps close to and at a distance from the MPAs to determine if spillover occurs. During the latter part of the 2006 lobster fishing season and the beginning of the 2007 fishing season we recorded lobster size and catch rates from 1341 sampled traps; 325 traps within 0.25 nm an MPA and 1016 traps were farther than 0.25 nm from an MPA. An ANOVA of lobster size indicated no significant interaction effects between season and distance from an MPA as well as a non-significant season effect. We did find that the size of lobsters differed significantly relative to their distance from an MPA with lobsters close to an MPA being larger. Catch rates, in number of lobsters per day of soak time, did not exhibit a significant interaction or distance effect but did exhibit a significant season effect with catch rates being greater at the beginning of the season. It appears spillover effects are easier to detect with lobster size than with catch rates and spillover effects become more evident as the fishing season progresses.

KEY WORDS: Marine protected area, lobster, spillover, Florida Keys

Evaluación de desplazamiento Usando los Tamaños de Langostas y Tasas de Captura de Trampas Comerciales Pescadas Cerca y Lejano de Áreas Marinas Protegidas en los Cayos de la Florida

Diez años después del establecimiento de áreas marinas protegidas (AMPs) en los Cayos de la Florida, probamos la captura de trampas de un pescador comercial cerca y lejano de AMPs para determinar si desplazamiento ocurre. Durante la última parte de la temporada de pesca de langosta en 2006 y al principio de la temporada de la pesca en 2007, anotamos los tamaños de langostas y tasas de captura 1341 trampas; 325 trampas dentro de 0,25 nm de un AMP y 1016 fueron más de 0,25 nm de un AMP. Un ANOVA de tamaño de langosta indicó que no habia interacción significativo entre temporada y distancia de un AMP; temporada no tenia un efecto significativo tampoco. Encontramos que el tamaño de langostas fue diferente significativamente relativo a su distancia de un AMP; las langostas fueron más grande cerca de un AMP. Las tasas de captura (número de langostas por el número de días que la trampa estuvo en el agua), no exhibió un efecto de interacción significativo ni un efecto de distancia pero exhibió un efecto significativo de temporada con las tasas de captura más altas al principio de la temporada. Parece que desplazamiento es más fácil de discernir con los tamaños de langostas que con tasas de captura y desplazamiento es más evidente más tarde durante la temporada de pesca.

PALABRAS CLAVES: Área marina protegida, langosta, desplazamiento, Cayos de la Florida

Évaluation D'exportation Utilisant la Taille de Homard Utilisante et Taux de Prises des Pièges Commerciaux Pêchés et Loin des Aires Protegees Marines dans les Florida Keys

Dix ans après l'établissement d'Aires marines protégées (MPAs) dans les Florida Keys nous avons échantilloné la prise d'un pêcheur commercial des pièges près et à distance de MPAs pour déterminer si l'exportation se produit. Pendant la dernière partie de la saison de pêche du homard en 2006 et le début de la saison de pêche en 2007 nous avons enregistré la taille de homard et les taux de prise à partir de 1341 pièges échantillonnés; 325 pièges dans 0.25 nm un MPA et 1016 étaient plus grands que 0.25 nm d'un MPA. Un ANOVA de taille de homard n'a indiqué aucun effet d'action réciproque significatif entre la saison et la distance d'un MPA aussi bien qu'un effet de saison non-significatif. Nous avons vraiment constaté que la taille des homards s'est différenciée de façon significative par rapport à leur distance d'un MPA avec les homards près d'un MPA étant plus grand. Le sexe a été observé seulement pour les échantillons de saison du début 2007 et dans cette période nous avons trouvé un effet d'action réciproque non-significatif entre le sexe et la distance d'un MPA et, avec curiosité, nous avions aussi un effet de distance non-significatif, mais un effet sexuel significatif avec les mâles étant plus grand que les femelles. Les taux de prise, en nombre de homards par jour de temps de trempage, n'ont pas exposé d'action réciproque significative ou d'effet de distance, mais a vraiment exposé un effet de saison significatif avec les taux de prise étant plus grand au début de la saison. Il semble que les effets d'exportation soient plus faciles à découvrir avec la taille de homard qu'avec les taux de prise et les effets d'exportation deviennent plus évidents alors que la saison de pêche avance.

MOTS CLÉS: Aire marine protégée , pêche commerciale, homard , exportation, Florida Keys

INTRODUCTION

Do marine protected areas (MPA), which provide conservation areas for the environment and fisheries, improve lobster (*Panulirus* argus) catch for the fisherman? One of the most important uses of an MPA is to serve as a refuge from fishing pressure (Bohnsack 1992, 1993, Bohnsack and Ault 1996, Ingram and Patterson 1999). It was anticipated that MPAs would enhance nearby fisheries (Bohnsack 1993, Ault *et al*. 2005, Roberts and Hawkins 1995) and increase the abundance of fished stocks outside the MPA (Appledoorn 1997, Hill 1997). Most of the encouraging reports of spill-over, the movement of adult and sub-adult animals from an MPA to the adjacent waters, involve studies of fish (Abesamis and Russ 2005, Abesamis *et al*. 2006, Johnson *et al*. 1999, McClanahan and Mangi 2000, Roberts *et al.* 2002). Lobsters have been studied as well, especially in the Florida Keys but typically only during the early stages of implementation of an MPA. The increased size and abundance of spiny lobsters (*Panulirus argus*) in an MPA was found in studies by Cox and Hunt (2005). They also found increased size of lobsters in areas near an MPA. Shears *et al*. (2006) observed increased lobster abundance in an MPA. The daily spillover of lobsters from the medium-sized (30 sq km) Western Sambo Ecological Reserve (WSER) was estimated to be approximately 14 lobsters a day during the summer (R.B., unpublished data). A trap-based study) D.R.Gregory Unpubl. data), showed that the size of lobsters decreased with distance from the WSER boundary but there was no similar trend in catch rates. Although fishermen have consistently fished several lines of lobster traps along the boundary of WSER since it was established in 1998, no one has attempted to document how their catches adjacent to an MPA have been affected. This study is the first attempt within the Florida Keys to document MPA effects directly by sampling catches from the commercial fishery.

METHODS

This study was carried out in several areas within the Atlantic waters of the lower Florida Keys, both inside Hawk Channel and outside the adjacent barrier reef, from Western Dry Rocks to Looe Key (Figure 1). The purpose of the study was to compare the catch rates and size of lobsters captured in commercially fished lobster traps near to and distant from an MPA. Areas near an MPA were defined to be those areas that were less than or equal to 0.25 nm (LE 0.25 nm) from an MPA boundary. Areas distant from an MPA were defined to be those areas that were greater than 0.25 nm (GT 0.25 nm) from an MPA boundary. This distance of 0.25 nm is the distance lobsters generally forage when feeding during the night (Rodney Bertelsen, Florida Fish & Wildlife Commission, personal communication). Although it is difficult to determine the areal extent of potential spillover, we surmised that the area outside an MPA but within the typical home range of a lobster living near an MPA would allow us to more directly distinguish between spillover influenced catches and those catches more typical of the fishery.

A commercial fisherman agreed to collaborate with this study by letting us accompany him on fishing trips whenever he fished his traps in the general vicinity of the Atlantic MPAs. On each fishing trip we were able to sample areas both near to and distant from an MPA. Consequently, the data were not collected from a strict experimental design but rather depended on where the fisherman had previously placed his lobster traps. The soak times, in days, of each line of traps that were sampled was taken from the fisherman's records and were used to standardize catch rate as number of lobster per trap per soak day. The catch rate as catch per trap per day of soak time is normally thought to the most appropriate measure of fishing effort in a trap fishery (Gulland, 1976).

Fishermen in this area typically deploy traps in an east -west orientation because that is the normal direction of tidal currents. The sole exception is along the edge of the largest MPA, the Western Sambos Ecological Reserve that extend north-south from the shore to the barrier reef (see Figure 1). The sampled traps typically were placed about 90 meters apart (S. Stafford, personal communication) and in a straight line. The latitude and longitude of the beginning and end of each sampled trap line were recorded. Each trap line was plotted on an electronic chart with the Garmin Mapsource PC program, version 6.14.2. Using chart plotting software we then determined which traps in a trap line were within 0.25 nm of an MPA boundary. All data analyses were conducted with SPSS for Windows.

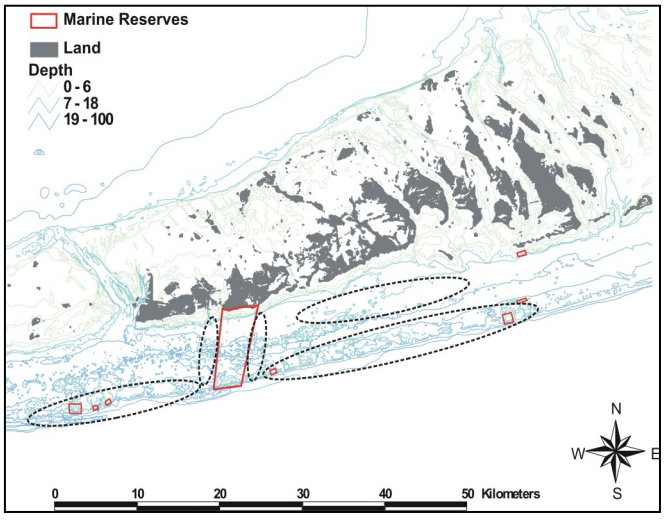

Figure 1. Location of sampled commercial lobster traps and marine protected areas within the Atlantic Ocean side of the lower Florida Keys

Four MPAs were within 0.25 nm of one of the sampled trap lines, the Western Sambos Marine Reserve (30.8 sq km), the Eastern Sambos Research Only Area (0.30 sq km), the Looe Key Sanctuary Protection Area (1.1 sq km), and the Sand Key Sanctuary Preservation Area (1.5 sq km).

The study was conducted during the end of the 2006 - 2007 lobster fishing season (November, January, and February) and during the beginning of the 2007 - 2008 fishing season (August-September). Although the main factor of interest was distance from an MPA, season was included in the analysis because it was possible that size and abundance differences relative to distance from an MPA might differ between the beginning and end of the fishing season because of the continual protection being afforded throughout the fishing season to those lobsters living within the MPA.

Only legal-sized (greater than 76.2 mm carapace length (CL)) lobsters caught in traps were counted and measured. This study focused only on legal-size lobsters, as did Cox and Hunt (2005), "because protection from harvest should be most evident in fishable (legal-sized) lobsters". In addition, we had no knowledge, nor control, over how many undersize lobsters the fishermen had previously put in each of the traps, as attractants which could possibly bias size and catch rate estimates.

RESULTS

A total of 1341 legal-sized lobsters (see Table 1) were measured from 1387 sampled trap pulls (see Table 2). Of the total observations, 325 lobsters from 316 trap samples occurred within 0.25 nautical mile of an MPA.

Size

An analysis of variance of size (natural log transformed) relative to distance from an MPA and fishing season showed no significant interaction between the season and distance factors ($p = 0.134$). Although the season factor alone was not significant ($p = 0.406$) the distance factor was significant with the legal-sized lobsters close to an MPA being 0.89 mm CL larger (Table 1) than those distant from an MPA ($p = 0.008$).

Abundance (Catch Rate per Trap per Day)

An analysis of variance of catch per trap per soak time (natural log +1 transformation) found an interaction effect between distance from an MPA and fishing season at the 0.06 probability level. An examination of the mean catch rate's for each level of distance from an MPA and fishing season (Table 2) shows that the greatest catch rate of 0.11 lobsters per trap per day occurred close to an MPA at the beginning of the fishing season. However, catch rates

Table 1. Mean size of lobster (n) by season and distance from an MPA for the 2006 end of season (Nov 2006-Feb 2007) and the 2007 first of season (Aug). Size in mm carapace length.

Season	Distance from MPA			
	LE 0.25 nm	GT 0.25 nm	Totals	LE – GT Diffs
Beginning	83.71 (217)	83.26 (473)	83.40 (690)	0.45
End	84.61 (108)	83.00 (543)	83.27 (651)	1.61
Totals	84.01 (325)	83.12 (1016)	83.34 (1341)	0.89
First-End Diffs	-0.90	0.26	0.13	

Table 2. Mean catch rate in number of lobsters per soak day (n) by season and distance from an MPA for the 2006 end of season (Nov 2006-Feb 2007) and the 2007 first of season (Aug).

Season	Distance from MPA			
	LE 0.25 nm	GT 0.25 nm	Totals	LE – GT Diffs
Beginning	0.11 (176)	0.08 (522)	0.09 (698)	0.03
End	0.05 (140)	0.05 (549)	0.05 (689)	0.00
Totals	0.08 (316)	0.07 (1071)	0.07 (1387)	0.01
First-End Diffs	0.06	0.03	0.04	

close to an MPA declined to a catch rate of 0.05 by the end of the fishing season. Catch rates more distant from an MPA exhibited a lesser but similar trend with 0.08 and 0.05 lobsters per trap in the beginning and end of the fishing season, respectively.

DISCUSSION

Adjacent trap lines belonging to other fishermen were present during this study. At least two to three other trap lines were consistently located adjacent to the WSER MPA boundary. Wilcox and Pomeroy (2003) have noted that fishermen aggregate around MPAs. However, as many as six nearby trap lines were also observed adjacent to the more distant trap lines (controls) in Hawk Channel but they typically were not as crowded as those adjacent to the WSER MPA.

Size

The analysis of variance model indicated that lobster size differed relative to distance from an MPA. Lobsters close to an MPA were significantly larger than those more distant by a mean size differential of 0.89 mm CL (Table 1). Although this 0.89 mm CL difference in size may seem minimal, we believe the observed size differential is important and would have been greater if we had included the sub-legal sized lobsters in the analysis. A 0.89 mm CL difference is about equal to a half ounce difference in weight (Matthews *et. al* 2003) per lobster. Over a days catch of a few hundred lobsters this size differential can be important to a fisherman.

Although we expected that lobsters more distant from an MPA would become smaller as the fishing season progressed than those closer to an MPA due to the spillover of lobsters, the interaction effect between season and distance was not significant and the season effect alone was not significant. Similarly, Cox and Hunt (2005) also found that seasonal differences in size of lobsters were not statistically significant. However, in a commercial trap based study of the effects of the Western Sambos Ecological Reserve (1998 - 2001) when it was first established, Gregory (Gregory Unpubl. data) found that lobster size did exhibit an interaction effect among the factors, MPA vs. nonMPA and open season vs closed season. In the earlier trap study the differences in lobster size between the MPA and nonMPA areas were found to be greater during the open fishing season than during the closed fishing season.

Our data, although not statistically significant, do follow the same trends seen in the earlier trap study with the mean size of lobsters close to an MPA at the beginning of the season being only 0.45 mm CL greater than those distant from an MPA but, by the end of the fishing season lobsters close to an MPA were larger by 1.61 mm CL, about three and a half times the size differential observed at the beginning of the season. Also, lobster size near an MPA increased from the beginning to the end of the season by 0.9 mm CL whereby lobsters further from an MPA decreased by 0.26 mm CL (see Table 1).

We surmise that lobster movements and intermixing during the four-month lobster season closure resulted in similar sizes of lobster at the beginning of the fishing season both near and distant to an MPA. Conversely, by the end of the fishing season the presence of larger sized lobsters near an MPA was most likely the result of spillover of larger lobsters from the adjacent MPA throughout the fishing season (Cox and Hunt 2005). It would be expected that due to spillover of protected lobsters from an MPA the lobsters closest to an MPA would be subjected to less overall fishing mortality and exhibit greater growth than the lobsters more distant from an MPA that were subject to full extent of in-season fishing mortality and handling throughout the entire fishing season (Hunt and Lyons 1986, Hunt *et al*. 1986).

Abundance (Catch Rate per Trap)

The catch rates of lobster varied both seasonally and relative to distance from an MPA. Catch rates were highest at the beginning of the season closest to an MPA (Table 2). This is consistent with Cox and Hunt (2005) who found the abundance of legal-sized lobsters during the closed season increased significantly in an MPA relative to the exploited areas. By the end of the fishing season lobster catch rates were equivalent regardless of distance from an MPA. The overall higher catch rates at the beginning of the season relative to the end of the season, regardless of distance from an MPA, is most likely the result of abundance increases during the four-month lobster season closure which also gives lobsters both inside and outside an MPA a greater opportunity to intermix without interference from harvest. However, it appears the higher catch rate close to an MPA at the beginning of the season is not only the result of the 4-month closed season but also the result of a spillover effect from lobster moving in and out of an MPA. By the end of the fishing season, it may be that fishing harvest adjacent to the MPAs was substantial enough to mask potential catch rate increases due to the spillover of lobsters.

CONCLUSION

In retrospect, the exclusion of undersize lobsters reduced the power of statistical tests due a reduction in sample size and truncated ranges and variances of sizes and catch rates. The use of undersize lobsters as attractants may not have been as much of a potential bias as we expected if the fishermen baited all traps equally or consistently. Also, the unbalanced nature of the study, whereby the majority of data came from areas more distant from an MPA, may have affected the power of the tests.

Size and catch rate differences observed relative to distance from an MPA did not exhibit similar overall trends. Although it appears that fewer lobsters were coming out of an MPA at the end of the fishing season, they were larger in size than at the beginning of the fishing season. Clearly, MPAs and relative fishing pressure

influence lobster size and catch rate differently probably because they are governed by different biological processes. Catch per trap appears to be more directly affected by competition from nearby traps than is the size of lobsters. Consequently, we suggest that lobster size is an easier measure of spillover than is catch per unit effort. Overall, the data from this study provide evidence of spillover effects from an MPA and benefits to the adjacent fishery.

ACKNOWLEDGEMENTS

We wish to thank Captain Simon Stafford for graciously allowing the senior author aboard his fishing vessel and providing other logistical support. Gabriel Delgado was helpful in providing the Spanish translation for the abstract. Our thanks also to J. Hunt of the Florida Fish and Wildlife Conservation Commission and his staff for valuable comments on an earlier draft. We also especially thank R. Bertelsen for producing Figure 1 from our many trap lines.

LITERATURE CITED

Abesamis, R.A. and G.R. Russ. 2005. Density dependent spillover from a marine reserve: long-term evidence. *Ecological Applicatons* **15**:1798-1812.

Abesamis, R.A., A.C. Alcala, and G.R. Russ. 2006. How much does the fishery at Apo Island benefit from spillover of adult fish from the adjacent marine reserve? *Fishery Bulletin* **104**:360-375.

Appledorn, R.S. 1997. Ecological goals for marine fishery reserve design: workshop summary. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:294-303.

Ault, J.S., J.A. Bohnsack, S.G. Smith, and J. Luo. 2005. Towards sustainable multispecies fisheries in Florida, USA, coral reef ecosystem. *Bulletin of Marine Science* **76**(2):595-622.

Bohnsack, J.A. 1992. Reef resource habitat protection: the forgotten factor. *Marine Recreational Fisheries* **14**:117-129.

Bohnsack, J.A. 1993. Marine Reserves: they enhance fisheries, reduce conflicts, and protect resources. *Oceans* Fall:63-71.

Bohnsack, J.A. and Ault, J.S. 1996. Management strategies to conserve marine diversity. *Oceanography* **9**:73-82.

Cox, C. and J.H. Hunt. 2005. Change in size and abundance of Caribbean spiny lobsters, *Panulirus argus*, in a marine reserve in the Florida Keys National Marine Sanctuary, USA. *Marine Ecology Progressive Series* **294**:227-239.

Gulland, J.A. 1976. Manual of methods for fish stock assessment. Part 1. Fish population analysis. FAD Manuals in Fisheries Science No. 4 (FRS/M4). 154 pages.

Hill, R.L. 1997. Using knowledge of microhabitat selection to maximize recruitment to marine fishery reserve (MFR). *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:417-426.

Hunt, J.H. and W.G. Lyons. 1986. Factors affecting growth and maturation of spiny lobsters, *Panulirus argus*, in the Florida Keys. *Canadian Journal of Fisheries and Aquatic Sciences* **43**:2243-2247.

Hunt, J.H., W.G. Lyons, and F.S. Kennedy, Jr. 1986. Effects of exposure and confinement on spiny lobsters, *Panulirus argus*, used as attractants in the Florida trap fishery. *Fishery Bulletin* **84**:69-75.

Ingram, Jr., G.W. and W.F. Patterson, III. 1999. Movement patterns of red snapper (*L. campechanus*), greater amberjack (*Seriola dumerili*), and gray triggerfish (*Balistes capriscus*) in the Gulf of Mexico and the utility of marine reserves as management tools. *Proceedings of the Gulf and Caribbean Fisheries Institute* **52**:686-699.

Johnson, D.R., N.A. Funicelli, and J.A. Bohnsack. 1999. Effectiveness of an existing estuarine no-take fish sanctuary within the Kennedy Space Center, Florida. *North American Journal of Fisheries Management* **19**:436:453.

Kelly, S., D. Scott, and A.B. MacDiarmid. 2003. The value of spillover fishery for spiny lobsters around a marine reserve in Northern New Zealand. *Coastal Management* **30:**153-166.

Matthews, T. R., J. H. Hunt, and D.W. Heatwole. 2003. Morphometrics and management of the Caribbean spiny lobster, *Panulirus argus*. *Proceedings of the Gulf and Caribbean Fisheries Institute* **54**:156-174.

McClanahan, T.R. and S. Mangi. 2000. Spillover of exploitable fishes from a marine park and its effect on the adjacent fishery. *Ecological Applications* **10**:1792-1805.

Roberts, C.M., J.A. Bohnsack, F. Gell, J.P. Hawkins, and R. Goodridge. 2002. Zoological effects of marine reserves on adjacent fisheries. *Science* **294**:1920-1923.

Roberts, C.M. and J.P. Hawkins. 1995. Marine fisheries reserves for the Caribbean. *Caribbean Park Protected Area Bulletin* 5:58.

Shears, N.T., R.V. Grace, N.R. Usmar, V. Kerr, and R.C. Babcock. 2006. Long-term trends in lobster populations in a partially protected vs. no-take marine park. *Biological Conservation* **132**:222-231.

Wilcox, C. and C. Pomeroy. 2003. Do commercial fisheries aggregate around marine reserves? Evidence from Big Creek Marine Ecological Reserve, Central California. *North American Journal of Fisheries Management* **23**:241-250.