Seasonally-Closed Spawning Aggregation Sites for Red Hind (*Epinephelus guttatus*): Bermuda's Experience over 30 years (1974 – 2003)

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ABSTRACT

Following the confirmation of two red hind (*Epinephelus guttatus*) spawning aggregation sites on the Bermuda reef platform in the early 1970s, legislation was enacted to seasonally close these two areas to all fishing for four months (May-August). Following early enforcement problems, there appears to have been general compliance by the fishing industry to the area closures, although periodic poaching continued to occur. Reported landings from the commercial fishery showed a large decline from 1975 (almost 70,000 kg) to 1981 (about 22,000 kg) which was assumed to reflect a decline in population abundance. This was followed by a slower declining trend through the 1980s and in 1990, the use of fish pots was banned. This resulted in reduced catchability as only line fishing was permitted and landings since the Fish Pot Ban have stabilized at a lower level and oscillated in a small range (6,000 – 10,000 kg). Examination of size-frequency distributions over a 30 year period indicate a 13 cm fork length (FL) increase in mean size (1973-74 = 34.9 cm FL; 2001-03 = 47.9 cm FL). Modal size increased from 31 cm FL to 49 cm FL during this same period. Although it is not possible to demonstrate cause and effect, the correlation between the number of years of seasonal area closure and the increase in mean and modal sizes is suggestive of a positive impact of the management action initiated in the 1970s. Some comments about elements of successful management of area closures are included.

KEY WORDS: Red hind, *Epinephelus guttatus*, spawning aggregation, seasonal area closure, management, Bermuda

Según la Temporada-cerrado de las Agregaciones de Desove para Mero Colorado (*Epinephelus guttatus*): La Experiencia de Bermuda más de 30 Años (1974 – 2003)

Siguiente la documentación de dos agregaciones de desove para mero colorado (*Epinephelus guttatus*) comienzos de los años setenta, la legislación fue decretada para cerrar según la temporada estas áreas a toda pesca. Siguiente los problemas tempranos de la aplicación, allí parecen haber sido la conformidad general por la industria pesquera a los cierres de la área aunque pescar furtivamente periódico haya continuado ocurrir. Los reportes de los desembarcos de la pesquería comercial mostraron un descenso grande en 1975 de (casi 70,000 kg) a 1981 (22,000 kg) el cual fue asumido como un descenso en la abundancia de la población. Este fue seguido por una lenta disminución en las tendencias atreves de 1980 y en 1990 el uso de las nasas fue prohibid. Esto resulto en una reducción de la captura debido a que solamente la pesca de cordel fue permitida y los desembarcos desde la prohibición de las nasas se estabilizo a niveles más bajos que oscilaban en un rango menor (6,000 – 10,000 kg). El examen de las distribuciones de las frecuencias de tallas a lo largo de un periodo de 30 años indica un aumento de 13 cm en el promedio de la longitud de horquilla (FL) (1973-74 = 34.9 cm FL; 2001-03 = 47.9 cm FL). El tamaño de la moda aumento de 31 cm FL a 49 cm FL durante el mismo periodo. Aunque no sea posible demostrar la causa y el efecto, la correlación entre el número de años de la protección estacional y el aumento en el tamaño promedio y el tamaño de la moda sugiere un impacto positivo de la acción de manejo iniciada en los años 70. Algunos comentarios acerca de los elementos de manejo exitosos en el cierre de aéreas son incluidos.

PALABRAS CLAVES: Mero colorado, *Epinephelus guttatus*, agregacion de desove, temporada de area cerrada, manejo, Bermuda

Saisonnierèment-fermé Frayant les Sites D'agregation pour Mérou Couronne (*Epinephelus guttatus*): L'éxperience des Bermudes plus de 30 Ans (1974 - 2004)

Suivre la documentation de deux frayant les sites d'agrégation de merou couronne(*Epinephelus guttatus*) dans le début des années 70, la législation a été saisonnièrement promulguée pour fermer ces secteurs à toute pêche. Suivre tôt les problèmes d'exécution, apparaît avoir été là la conformité générale par l'industrie de pêche aux fermetures de secteur bien que braconner périodique a continué à arriver. Les atterrissages rapportés de la pêche commerciale ont montré un grand déclin de 1975 - 1981 et ont oscillé alors dans une gamme limitée, mais à un niveau plus bas, depuis cette période. L'examen de taille-relations en fréquence et signifie que la taille sur cette période de 30 ans indique de grandes différences avec augmenter de taille moyen de 39 longueur de fourchette de cm (FL) dans les mi-années 70 à 48 cm FL en 2001. Les estimations de mortalité totale (Z) utilisant l'analyse de prise-courbe indique un déclin dans Z sur la période d'étude. Bien que ce n'est pas possible de démontrer la cause et l'effet, la corrélation entre le nombre d'ans de protection saisonnière et l'augmentation dans la taille moyenne est suggestive d'un impact positif de l'action de direction a reçu les années 70. Les taux de mortalité par ailleurs, en baisse indiquent au même effet positif.

MOTS CLÉS: Merou couronne, agrégation

INTRODUCTION

Anecdotal evidence indicated that spawning aggregations of red hind were heavily fished in the late 1960s and early 1970s. There was poor documentation of landings due to the lack of a formal statistical reporting program, but fishermen reported catching "boatloads" of fish. Red hind was not a preferred market fish during these years because larger groupers, e.g. Nassau grouper (*Epinephelus striatus*), were still abundant and dominated the market.

As a consequence, it was reported that some of the landings were not marketed as food fish. In response to this wasteful practice, a lobby of commercial fishermen asked the Bermuda government to seasonally protect the red hinds at the aggregation sites. In 1972, the Fisheries Act came into force and provided for the systematic collection of fisheries catch and effort data. It took several years to establish the program and the first year of reliable information in the statistical program was 1975. Research on two red hind spawning aggregation sites well-known to fishermen began in 1973 and the information collected from this work (Burnett-Herkes 1975) was used to formulate legislation which afforded protection to these sites - they were seasonally closed to all fishing for four months (May – August) starting in 1975. The aggregation areas were spatially defined in the legislation by latitude/ longitude coordinates and marker buoys were used to define the boundaries of the areas. There was reportedly reasonable compliance by fishermen to the closures but there was poor enforcement capability at the time of implementation of the legislation. Because of the difficulty in accurately fixing the positioning of a poaching vessel (before GPS was available), there were few successful prosecutions. As a consequence, some poaching continued, mainly by night fishing. Fishermen could still use landmarks and triangulation to determine their position when the marker buoys were not visible.

With the demise of the larger groupers from 1975 - 1981 (Luckhurst 1996), the market value of red hind increased and provided an additional economic incentive for fishermen to fish illegally at the aggregation sites. A third red hind spawning aggregation site was discovered by a commercial fisherman on the northeast edge of the reef platform in 1988. This area was added to the existing two areas for seasonal closure in 1989. In the legislation which enabled a ban on fish pots in 1990 (hereafter called the Fish Pot Ban), the three red hind aggregation sites were incorporated into two expanded closed areas, one at each end of the reef platform, providing a larger buffer area around the sites (Figure 1).

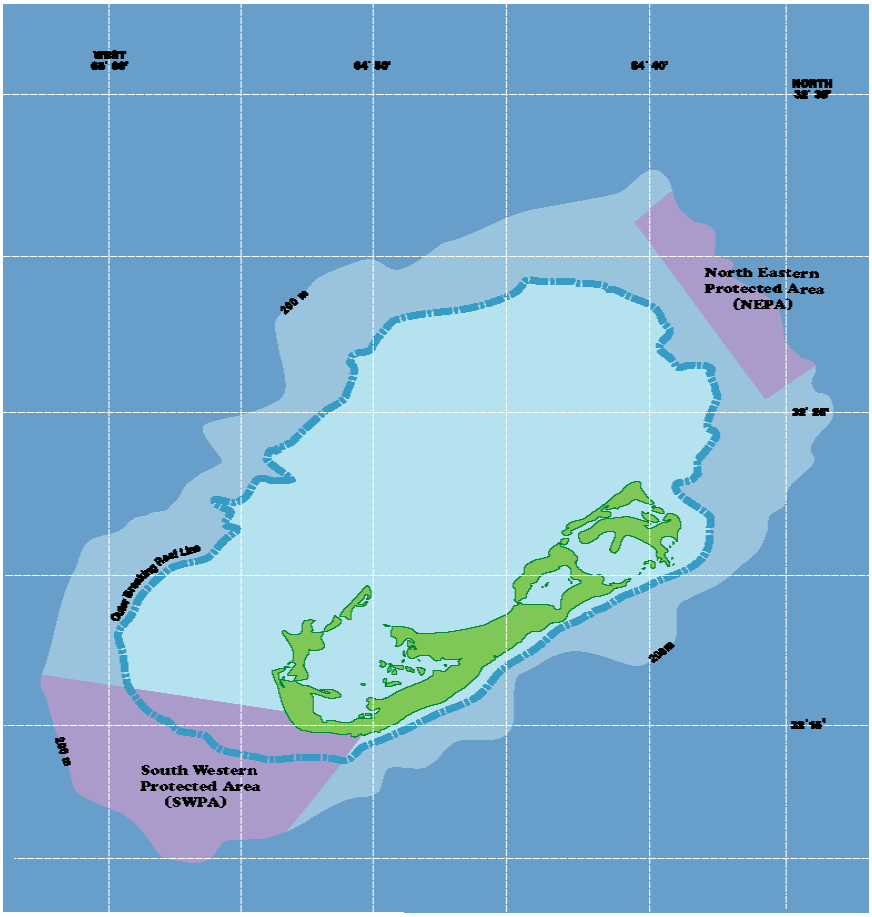

Figure 1. Map showing the two seasonally closed areas on the Bermuda Reef Platform (modified from a map designed by Terence Madeiros, TM Design, Bermuda).

In the Caribbean region, there have been evaluations of the closure of red hind aggregation sites in St. Thomas, U.S. Virgin Islands and in Puerto Rico. In St. Thomas, a spawning aggregation site (Red Hind Bank Marine Conservation District - RHBMCD) was seasonally closed to fishing in 1990 after heavy fishing pressure. In 1997, the average size of red hind had increased 10 cm (Beets and Friedlander 1998). This same site (RHBMCD) was permanently closed to all fishing in 1999. Further studies conducted at this site up until 2004 indicated that the maximum total length of male red hind had increased substantially following permanent closure (Nemeth 2005). In addition, average density and biomass of spawning red hind had also increased (Nemeth 2005).

Following a decline in red hind landings in Puerto Rico, a seasonal closure of three red hind spawning aggregation sites on the west coast was enacted in 1995 (Matos-Caraballo 2002, Matos-Caraballo *et al*. 2006). The average fork length (FL) of red hind from the west coast only, increased by a small but statistically significant amount (Matos-Caraballo 2002).

MATERIALS AND METHODS

The fishery landings figures presented are taken from the Bermuda Fishery Statistical Database starting in 1975. This is a compulsory self-reporting system for all holders of commercial fishing licences. The first size-frequency sample (1973 - 1974) used data recalculated from Burnett-Herkes (1975) and all remaining size-frequency data were collected by the authors and Fisheries staff.

All fish samples were taken by handlining using the same hook sizes throughout this study thereby eliminating the possibly of gear bias that might arise from using fish pots. Virtually all of the specimens used in the size-frequency analyses presented here were taken from a single spawning aggregation site in the South Western Protected Area (Figure 1) at the southwest edge of the Bermuda platform. For various logistical reasons, the sample sizes in different years were highly variable and, in some instances, we pooled the data from consecutive years to achieve an adequate sample size.

RESULTS

Landing Statistics

The first reliable landings statistics in 1975 provided a benchmark against which to evaluate changes in landings. In this first year of the program, red hind had the highest reported landings of any species in the fishery at almost 70,000 kg, but by 1981, only six years later, landings had declined to just over 22,000 kg (Figure 2). Following a brief increase, landings then showed a declining trend through the 1980s. Since 1990 when the Fish Pot Ban was imposed (Luckhurst and Ward 1996), red hind landings have oscillated in a relatively small range, mostly between 6,000 and 10,000 kg (Figure 2). A clear demonstration of the impact of fish pots on the reported landings of red hind is shown in the analysis of landings by gear type (Figure 3). In the three years (1987 - 1989) before the Fish Pot Ban, the reported landings by fish pots ranged from 19,413 – 25,100 kg which represented between 78.6% and 90% of total landings of red hind. In April 1990, the Fish Pot Ban came into effect and red hind landings dropped to only 9,900 kg. Although there are no reliable measures of line fishing effort, anecdotal evidence suggests that there was a significant increase in line fishing effort for red hinds after the Fish Pot Ban as fishermen attempted to maintain catch levels of groupers. Despite this apparent increase in effort, the fishery was unable to increase landings back to previous levels (Figure 2) and landings in 1991, the first full year without fish pots, reached just over 13,300 kg. In subsequent years, landings declined back to lower levels (Figure 2).

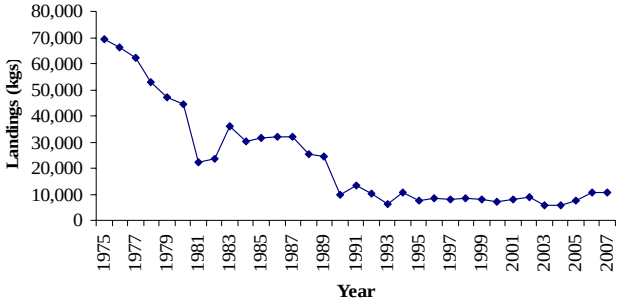

Figure 2. Reported landings (kg) of red hind from 1975-2007 from the Bermuda Fishery Statistical Database. The Fish Pot Ban came into effect in 1990.

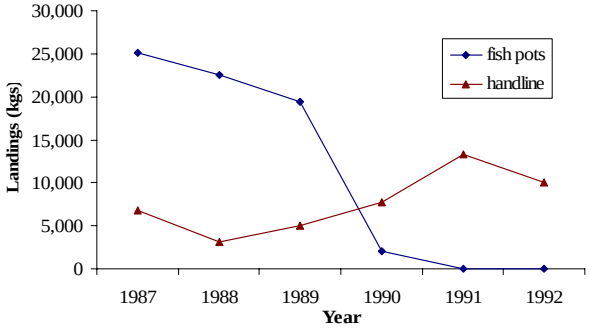

Figure 3. Reported landings (kg) of red hind by fish pots and handline from 1987-1992. As the Fish Pot Ban was implemented in April 1990, the landings from fish pots in that year represent the total from the first quarter (January – March).

Size-frequency Analysis

The data collected over approximately 30 years are presented from six time periods where there were adequate data available. Data were pooled when the sample size from a single year was considered inadequate. The size-frequency distributions for these six time periods (Figure 4) clearly illustrate the changes in the population size structure over time. A summary of mean and modal sizes derived from these size-frequency distributions (Table 1) indicates a marked increase in mean fork length (FL) from 34.9 to 47.9 cm during the referenced period. An analysis of variance (ANOVA) comparing the size-distributions across the six time periods was highly significant ($F = 356.5$, $p < 0.0001$) as were all pair-wise comparisons by time period. The large increase in modal size (mid-point of the size class) from 31 cm FL to 49 cm FL was also noteworthy (Table 1).

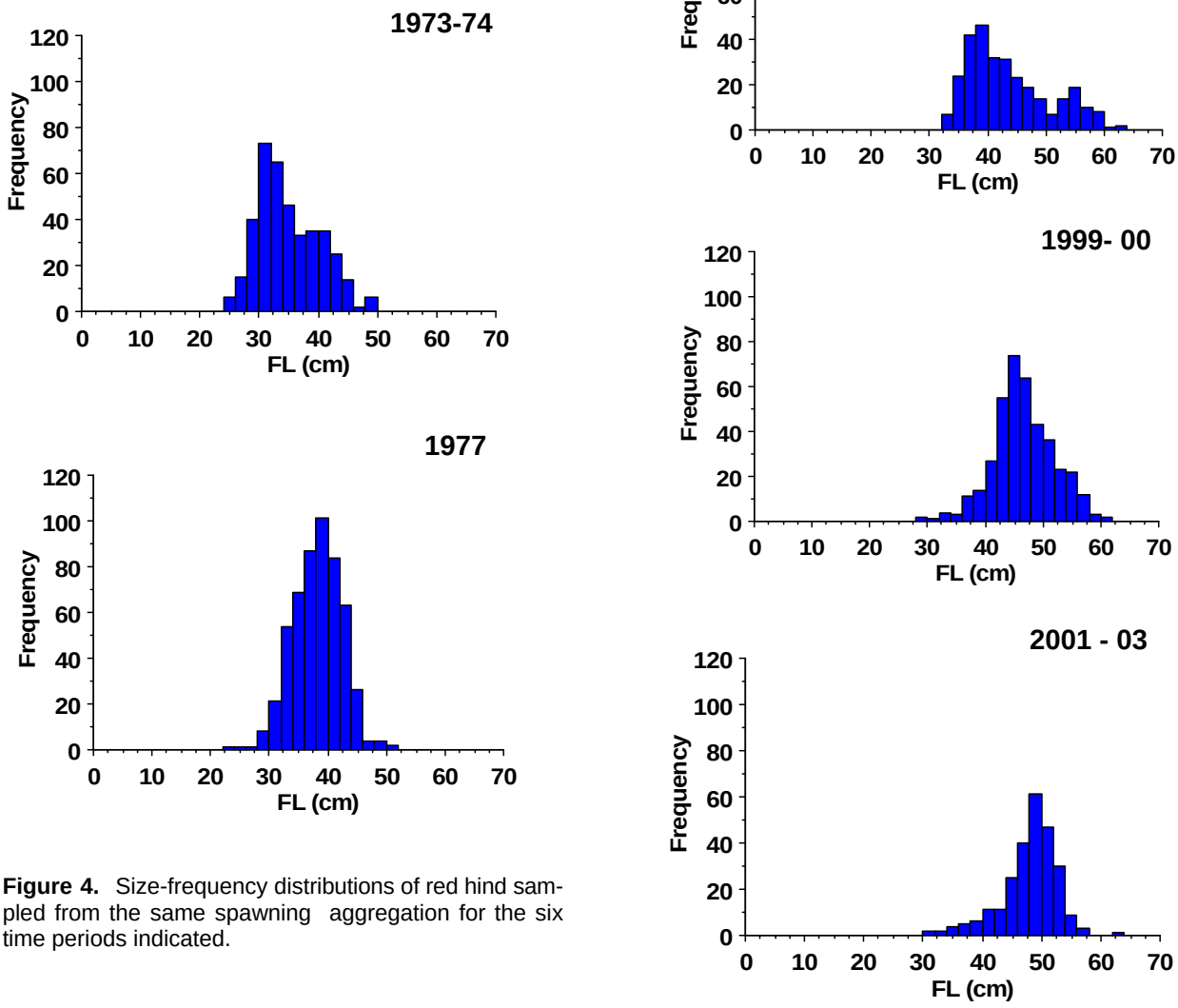

Figure 4. Size-frequency distributions of red hind sampled from the same spawning aggregation for the six time periods indicated.

A simple extrapolation from the mean lengths (Table 1) to mean weight using the relationship determined by Bohnsack and Harper (1988), indicates that the mean weight of the red hinds in the first time period (1973 - 1974) was 703 g whereas the mean weight in the last time period (2001 - 2003) was 1,885 g, an increase of almost 270%. This represents a substantial increase in biomass over time. In addition, as the size-fecundity relationship of females is exponential (Burnett-Herkes 1975) this suggests that the number of eggs available to be fertilized during the spawning period should be greatly increased. This potential increase in spawning output will only likely be realized if there are a sufficient number of males available for spawning. If a spawning aggregation is heavily fished, it is possible that the larger males are caught differentially thus skewing the population sex ratio towards females (e.g. Beets and Friedlander 1998) and reducing reproductive output.

Table 1. Summary of red hind size-frequency samples for six time periods from the same spawning aggregation site. Analysis of variance (ANOVA) of mean size (FL) indicated a highly significant difference across all time periods.

Time period (years)	Sample size (N)	Mean FL (cm)	Standard Deviation (SD)	Modal size (cm)
1973-74	395	34.9	5.2	31
1977	526	38.0	4.1	39
1982-83	388	39.2	4.4	39
1997	299	43.5	7.1	39
1999-00	396	46.5	5.3	45
2001-03	257	47.9	4.8	49

DISCUSSION

The marked decline in the landings of red hind as illustrated in Figure 2 was likely the result of a combination of seasonal closures of spawning aggregations (which limited access to the population during the period of highest vulnerability), a probable population decline in the first half of the time series and the shift to line fishing after the Fish Pot Ban with a subsequent decline in catchability. This shift from using a passive gear type (fish pot) to an active gear (handline) can have significant consequences for the fishery as more time and effort are required to catch red hinds and poor sea conditions can be a limiting factor in terms of the fishing effort which can be expended. A combination of the above factors, along with better enforcement in recent years, appears to have limited (and stabilized) red hind landings over the past 15 years.

The increase in mean size (13 cm FL) as summarized in Table 1 provides clear evidence that substantial increases in size can occur when aggregations are protected but it is not possible to demonstrate that there is a cause and effect relationship between this size increase and the seasonal closures of spawning aggregations. The highly significant difference when comparing these six size-distributions (Figure 4) is however, strongly suggestive of a positive impact of this management measure on the population. In St. Thomas, U.S. Virgin Islands, a spawning aggregation site (RHBMCD) was seasonally closed in 1990 after heavy fishing pressure reduced the average length of red hind to 295 mm with a highly skewed sex ratio (15 F:1 M). Under seasonal protection, the average size increased 10 cm to 395 mm by 1997 and the sex ratio was reduced to 4 F:1 M (Beets and Friedlander 1998). We have no comparable data concerning changes in population sex ratio because the majority of the red hinds that we sampled were tagged and released (Luckhurst 1998). However, the 10 cm increase in average size corresponds well with our results. On the basis of their findings, Beets and Friedlander (1998) concluded "that protection of spawning aggregations is a sound management strategy … for aiding the sustainable use of reef fish resources".

This same site in St. Thomas was permanently closed to all fishing in 1999 and studies conducted from 1999-2004 indicated that the maximum total length of male red hind increased by nearly 7 cm following permanent closure (Nemeth 2005). In addition, average density and biomass of spawning red hind increased by over 60% following the permanent closure and maximum spawning density more than doubled (Nemeth 2005). These results indicate further the potential benefits of the active management of spawning aggregations.

The seasonal closure of three red hind spawning aggregation sites on the west coast of Puerto Rico was enacted in 1995 (Matos-Caraballo 2002, Matos-Caraballo *et al*. 2006). The average fork length (FL) of red hind (west coast only) increased after the closures by 1.3 cm FL (Matos-Caraballo 2002). Although this increase was small in comparison to other regional studies of red hind spawning aggregations, it was statistically significant. Several years later, the effectiveness of these seasonal closures on the western platform of Puerto Rico was evaluated to infer recovery of the red hind population (Marshak 2007). There was an initial increase in Catch-per-Unit-Effort (CPUE) within spawning aggregations as well as an increase in average length. However, the length increase was found to result from limited recruitment and proportional contributions of a few remaining larger females (Marshak 2007). Although initially effective in slowing stock decline, changes in strategy by the fishing industry have diminished the impact of this seasonal closure and appear to have hindered stock recovery. Overall, these limited studies clearly demonstrate the benefits of the active management of spawning aggregations.

CONCLUDING THOUGHTS ABOUT ELEMENTS OF AREA PROTECTION OF SPAWNING AGGREGATIONS

In the wider Caribbean region, area closures of spawning aggregations appear to be the most widely used management measure for protecting them. Area closures are a relatively simple and effective means for protecting spawning aggregations, however, the success of using area closures can only be demonstrated when a systematic and long term monitoring program provides the data necessary to evaluate their effectiveness (Luckhurst 2007).

i) The support of the fishing industry is critical in the success of establishing area closures. Outreach needs to penetrate throughout the different sectors of the fishing industry. The goal is to have fishermen agree that protection of the resource is necessary and that it will benefit them in the longer term. Positive dialogue between scientists and fishermen is an important element in achieving this goal.

ii) Enforcement of area closures must be effective and meaningful sanctions must be imposed to discourage fishermen from poaching in these areas. Similarly, sales bans in the marketplace should be considered to deter fish vendors from dealing with illegally-caught fish from aggregations which invariably show up as short-term gluts in the market.

iii) Fishery management agencies should provide regular feedback to the fishing industry regarding the impact of the area closure on the status of the population. Using data collected from monitoring programs, fishery agencies need to demonstrate the benefit and sensibility of the closure to fishermen to maintain their support and interest.

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LITERATURE CITED

Beets, J. and A. Friedlander. 1998. Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Environmental Biology of Fishes* **55**:91-98.

Bohnsack, J.A. and D.E. Harper. 1988. Length-weight relationships of selected marine reef fishes from the southeastern United States and the Caribbean. NOAA Tech Memo NMFS-SEFC-215:31

Burnett-Herkes, J. 1975. *Contribution to the Biology of the Red Hind Epinephelus guttatus, a Commercially Important Serranid Fish from the Tropical Western Atlantic*. Ph.D. dissertation, University of Miami, Miami, Florida USA. 154 pp.

Luckhurst, B.E. 1996. Trends in commercial fishery landings of groupers and snappers in Bermuda from 1975 to 1992 and associated fishery management issues, Pages 286-297 in: F. Arreguin-Sanchez, J.L. Munro, M.C. Balgos and D. Pauly (Eds.) *Biology, Fisheries and Culture of Tropical Groupers and Snappers*. ICLARM Conference Proceedings 48. 449 pp.

Luckhurst, B.E. 1998. Site fidelity and return migration of tagged red hinds (*Epinephelus gutttatus*) to a spawning aggregation site in Bermuda. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:750-763.

Luckhurst, B.E. 2007. Evaluation of fisheries management and conservation measures taken to protect grouper spawning aggregations in the wider Caribbean: Case studies of Bermuda, Belize and Cayman Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **58**:281-282.

Luckhurst, B.E. and J.A. Ward. 1996. Analysis of trends in Bermuda's fishery statistical database from 1975 to 1990 with reference to fishery management measures implemented during this period. *Proceedings of the Gulf and Caribbean Fisheries Institute* **44**:306 - 324.

Marshak, A.R. 2007. Evaluation of seasonal closures of red hind, *Epinephelus guttatus* (Pisces: Serranidae), spawning aggregations to fishing off the west coast of Puerto Rico, using fishery-dependent and independent time series data. MS. Thesis, University of Puerto Rico, Mayaguez, Puerto Rico 97 pp.

Matos-Caraballo, D. 2002. Portrait of the commercial fishery of the red hind, *Epinephelus guttatus*, in Puerto Rico during 1992-1999. *Proceedings of the Gulf and Caribbean Fisheries Institute* **53**:446-459.

Matos-Caraballo, D., M. Cartagena-Haddock, and N. Pena-Alvarado. 2006. Portrait of the fishery of Red Hind *Epinephelus guttatus*, in Puerto Rico during 1988-2001. *Proceedings of the Gulf and Caribbean Fisheries Institute* **57**:343-356.

Nemeth, R.S. 2005. Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. *Marine Ecology Progress Series* **286**:81-97.

Nemeth, R.S., J. Blondeau, S. Herzlieb, and E. Kadison. 2007. Spatial and temporal patterns of movement and migration at spawning aggregations of red hind, *Epinephelus guttatus*, in the U.S.Virgin Islands. *Environmental Biology of Fishes* **78**:365-381.