Spedicato, M.T.; Lembo, G.; Marmulla, G. (eds.)
Aquatic telemetry: advances and applications. Proceedings of the Fifth Conference on Fish Telemetry held in Europe. Ustica, Italy, 9-13 June 2003.
Rome, FAO/COISPA. 2005. 295p.

Insight into the homing behaviour of the dusky grouper (*Epinephelus marginatus* Lowe, 1834) around the island of Ustica, Italy

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Key words: *Epinephelus marginatus*, juvenile/pre-adult migrations, homing behaviour, hydroacoustic telemetry, marine protected areas.

Abstract

Knowledge about the migratory behaviour of a threatened nearshore fish, *Epinephelus marginatus*, is critical for the effective conservation and management of the species, particularly in terms of designing and regulating Marine Protected Areas (MPAs). Homing and site fidelity of adult dusky groupers (2-17 kg) were already documented using a hydroacoustic telemetry study. In addition, site fidelity of juveniles (less than 1 kg) was also demonstrated using a wireless communication system combined with manual tracking events. However, the life stage at which homing behaviour becomes established remains unknown, as well as the duration of the home memory when the fish is kept far (e.g. in captivity) and then re-introduced in its environment. Indeed, these aspects are particularly relevant when re-stocking is envisaged as a possible management option. The objective of our study was to determine the homing and migratory behaviour of two age categories of the dusky grouper. Four juveniles (343-679 g) and three pre-adult individuals (1350-1450 g) were captured in a no-take zone of a marine protected area and outfitted with acoustic transmitters. Juveniles were released within two months after capture, while the pre-adults were kept in captivity for about 15 months. The releasing sites for both groups were about 5 km far from the capture site. One juvenile precisely homed within four days, other two were found moving towards the capture site and the fourth one disappeared. Among the pre-adult groupers, two fish were remained in the vicinity of the release site for two successive months, while the third individual disappeared few days after being released. These preliminary results suggest that homing behaviour is likely established in juvenile dusky groupers and prolonged captivity may affect homing ability.

Introduction

Over the past two decades Marine Protected Areas (MPAs) have been established worldwide for species, habitat and biodiversity conservation (e.g. Agardy, 1997). More recently, MPAs have also been proposed as a valuable tool for mitigating the effects of mismanagement of fishery resource (e.g. Lauck *et al*., 1998) and for providing additional benefits to those obtained from simple fishing effort control (Apostolaki *et al*., 2002). The benefits of MPAs are related to their ability to act as harvesting refugia and sources of recruits to fisheries (Nowlis and Roberts, 1999), although their effectiveness mainly relies upon size, location, designing (i.e. subdivision in zones with different degree of protection), (Côté *et al*., 2001), habitat quality (Rodwell *et al*., 2003) and movement pattern of the species. For example, species typically exhibiting small home ranges may be well protected by small harvest refugia (Holland *et al*., 1993). Thus, studies on movement dynamics of overexploited, long-living and top-predator species, such as rockfishes (e.g. Soh *et al*., 2000; Starr *et al*., 2002) and groupers (Zeller, 1998; Lembo *et al*., 1999a; Bolden, 2000; Sala *et al*., 2001; Whaylen *et al*., 2004), have increased in the last years, focusing on the implication of managing MPAs targeting these fish.

Hydroacoustic telemetry proved to be a powerful technique for generating complete information on

individual fish movements over time, including in and out protected areas, thus providing data on home range and site fidelity that are crucial for species conservation and designing/management of MPAs (O'Dor *et al*., 2001).

Along the Mediterranean coasts, several MPAs have been established and the dusky grouper (*Epinephelus marginatus*, Lowe, 1834) has been considereded the key-species. (e.g. Ustica Island, Italy; Medes Islands, Spain; Straits of Bonifacio, France). Knowledge about the movement dynamics of this threatened nearshore fish is critical for the effective conservation and management of the species, particularly as it applies to the regulation of marine reserves.

Homing and site fidelity of adult dusky groupers (2-17 kg) were documented using a hydroacoustic telemetry study (Lembo *et al*., 1999a; 1999b). In addition, site fidelity of juveniles (less than 1 kg) was also demonstrated using a wireless communication system combined with manual tracking exercises (Lembo *et al*., 2002). However, the life stage at which homing behaviour becomes established remains unknown, as well as the duration of the homing behavioiur when the fish are kept in captivity and then re-introduced. These aspects are particularly relevant to the restoration of the species through re-stocking and re-location events within MPAs.

To address these issues, preliminary experiments were conducted within a MPA on the island of Ustica (Italy) using two age groups of the dusky grouper: four juveniles (343-679 g) and three pre-adult specimens (1350-1450 g), to determine their homing and migratory behaviour.

Materials and methods

Study area

The study was conducted in Ustica, a volcanic island (area 8.7 km^2 and circumference 9 km) situated in the Mediterranean Sea, 60 km north off the Sicilian coast of Italy (38° 42' N, 13° 10' E) (Fig. 1), where a MPA has been established since 1986. Coastline is rocky and uneven and the core area of the marine reserve (A zone), which is fully protected, is located on the northwest side of the island. It stretches ca. 1.5 km along the coastline and ca. 400 m out from the shore, covering an area of ca. 0.5 km^2. In the B zone commercial fishing is permitted only with special authorisation, while in the C Zone fishing is permitted with some limitations.

Tagging and tracking

Two age categories: four juveniles (mean total length = 31.1±3.5 cm; mean total weight = 470.5±147.7 g, Table 1) and three pre-adult specimens (mean total length = 43.7±1.5 cm; mean total weight = 1400±50 g, Table 1), the former for homing experiment and the latter for testing home memory were used.

The transmitters (CAFT 8_6, Lotek Wireless, Inc., Canada) used for the juveniles were cylindrical in shape and operated at 76.8 kHz with a pulse rate of 5 s. Power output, as specified by the manufacturer, was 148 dB and nominal longevity 35 days. Transmitter length was 38.0 mm, diameter 8.5 mm and the weight in air and salt water was 5.0 and 3.3 g, respectively.

Also the transmitters employed for pre-adult dusky groupers operated at 76.8 kHz (CAFT 16_4s, 12 hours on, 12 hours off), but pulse rate was 10 s, power output 161 dB and nominal longevity 270 days. Transmitter length, diameter, weight in air and salt water were 62 mm, 16 mm, 29 and 14 g, respectively. All the transmitters employed a digital coding scheme.

The dusky groupers were captured by hook and line in the no take area (A zone) of the MPA at Ustica (at 5-7 m depth the juveniles and at 5-12 m depth the pre-adults) and surgically implanted with acoustic transmitters, following the technique reported in Økland *et al*. (1999).

The fish of the juvenile group were kept in tanks almost 2 months between catch and surgery, and 1-4 days between surgery and release (Table 1) that took place about 5 km far from the capture site at 9 m depth. Pre-adult dusky groupers were kept in captivity at COISPA Experimental Station, based on the mainland, for about 15 months. The three dusky groupers were transported (about 20 hours trip duration) using a 400 l tank continuously supplied with

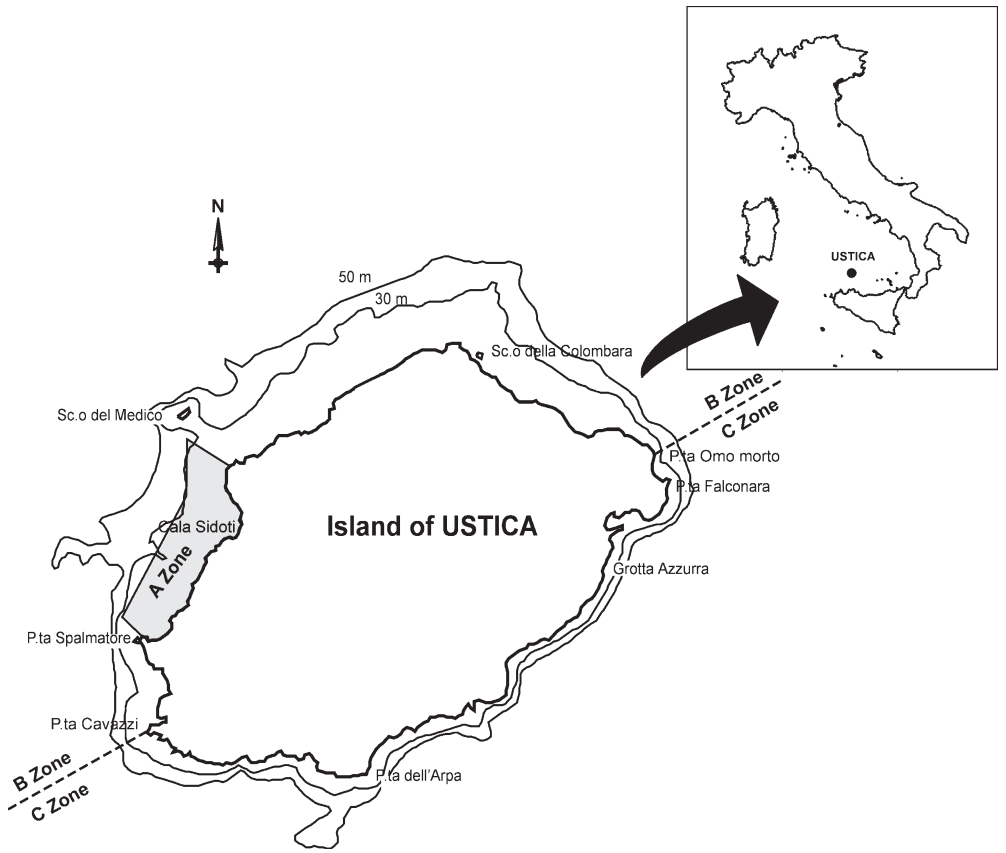

Fig. 1 – Ustica Island depicting areas with different degrees of protection (A zone=core area of the MPA-all activities forbidden; B zone=commercial fishing permitted only with special authorisation; C Zone=fishing permitted with some limitations).

Table 1 – Transmitter code, fish length and weight, transmitter/body weight ratio (weight of transmitter in air), capture, surgery and releasing dates of the two groups of dusky grouper used for the homing tests.

	Transmitter Code	Total length (cm)	Total weight (g)	Transmitter /body weight ratio	Capture date	Surgery Date	Releasing Date
Group 1 juveniles	5	36.0	679	0.74	06.06.01	29.07.01	30.07.01
	6	29.5	395	1.27	07.06.01	29.07.01	30.07.01
	11	28.0	343	1.46	11.06.01	29.07.01	03.08.01
	12	31.0	465	1.08	10.06.01	29.07.01	03.08.01
Group 2 pre-adults	154	42	1350	1.86*	23.10.00	31.01.02	01.02.02
	161	45	1400	1.07*	23.10.00	31.01.02	01.02.02
	167	44	1450	1.37*	30.10.00	31.01.02	01.02.02

*calculated on the final weight of 1570 (code 154), 2700 (code 161) and 2120 (code 167) g.

oxygen. When at the rearing facilities, the fish were maintained at density of 4-5 kg$(m^3)^{-1}$, water renewal of 5-6 volumes(day^{-1}), natural photoperiod and fed fresh food (mainly cephalopods) *ad libitum*. The fish growth was monitored and the weight before releasing was 1570, 2700, 2120 g for the fish code 154, 161 and 167 (Table 1). Thus their gain in weight was respectively 15, 92 and 46%. Once again at Ustica the fish were implanted with acoustic transmitter and released about 5 km far from the capture site at 16 m depth.

Manual tracking of juveniles was carried out from a boat during daylight in the period 1-9 and 23-28 August 2001. Tracking of pre-adults was conducted on the following dates: 2, 7, 8, 9, 10 February; 1-2 March, 20-23 April, 20-22 May and from 29 June to 4 July 2002. A receiver (Lotek SRX_400A with W5 CODE_LOG software), an ultrasonic upconverter to radio signals (Lotek UUC-142) and an omni-directional hydrophone (Lotek HPA-D-2) were used. Tracking accuracy was estimated as the mean distance between the exact position of a reference transmitter (determined by GPS Model: Garmin 12 XL; precision ±5 m) and the position determined by a naive tracker during six trials. The accuracy of positioning, for the same person that conducted manual trackings, was 18 m (sd=4.6; C.V.=25.6%).

Results

One juvenile dusky grouper (code 5) precisely homed within four days after releasing (August 3, 2001), covering a distance of 5119 m, calculated as shortest route between the capture and releasing site (Fig. 2). During the subsequent 6 days (4÷9 August, 2001) this individual moved on average 63±14 m from the capture site in a depth range of 7-14 m. The second fish (code 6) was found 2080 m

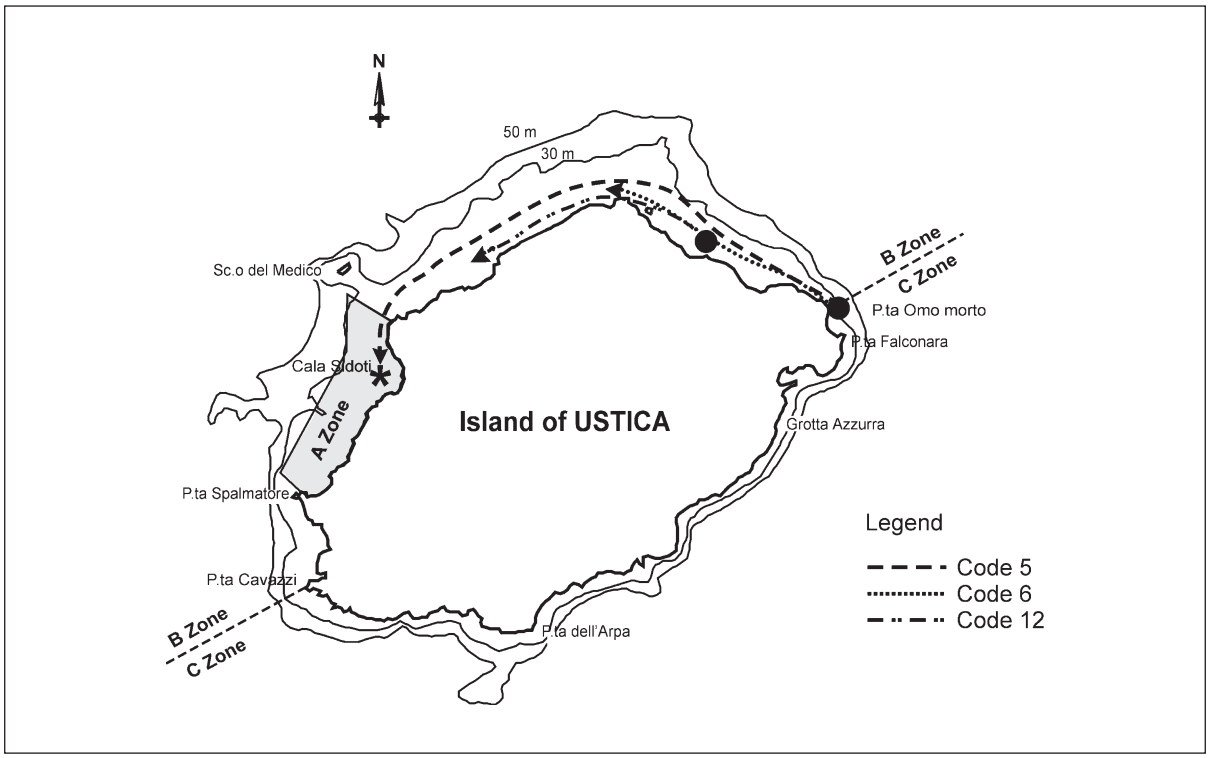

Fig. 2 – Movements of the fish code 5, 6 and 12 (*) Capture site and releasing sites (●) are indicated. The dotted lines represent the possible shortest routes followed by the fish.

far from the releasing site after 24 days at liberty (23 August, 2001) and it moved on average 59±17 m in the following 5 days (24÷28 August, 2001) in a depth range of 15-17 m. The third juvenile (code 12) showed a displacement of 767 m two days after releasing (5 August, 2001) and travelled 1000 m further on the 3rd day, while in the successive 3 days (7÷9 August, 2001) it moved on average 63±15 m in a depth range of 8-14 m. At the end of August we could no longer locate the individual. The fourth fish (code 11) never was found after release. All tracked fish moved north-westward direction from the releasing to the capture site (Fig. 2).

Among the dusky groupers of the second group, fish were located 50 m (code 154), 36 m (code 161) and 56 m (code 167) from the releasing site few hours after they were at liberty. In the following monthly tracking occasions, from 2 February to 22 May 2002, the fish code 167 was found on average 164±20 m from the releasing site in a depth range of 7-19 m, while the fish code 161 was localised in the range of 995±22 m (9-19 m depth) from the releasing site. This fish disappeared from the tracking on April 2002, while the former was no more localised from the end of June 2002, when the tracking was conducted at a fine scale around the Island perimeter. The fish code 154 disappeared in the week following the release.

Discussion

The results obtained in the present study, although preliminary due to the limited number of individuals and tracking occasions, suggest that homing is already established in juvenile dusky groupers and that prolonged captivity may affect home memory. The outcomes achieved so far evidenced that one juvenile dusky grouper (weight: 679 g, code 5) precisely homed within four days at liberty, after a short-term captivity of about 9 weeks. This behaviour is very similar to that of adult dusky groupers (2-17 kg; adulthood approximated by the lowest limit of the size at first maturity) returned within 3-6 days from the core area of the MPA (releasing place) to their sites of capture, after a short-term captivity (1-7 wks) (Lembo *et al*., 1999a; 1999b). Also the travelled distance (5119 m) is comparable to the longer route estimated for adults (5904 m; unpublished data). In the days after releasing the juvenile dusky grouper showed limited displacements (average: 63±14 m) and a preference for shallower waters (7-14 m), as expected on the basis of the site fidelity behaviour, characterized by small scale movements (9-93 m) at early life stages (113 g) (Lembo *et al*., 2002), and from the nearshore distribution of younger fish (e.g. Lo Bianco, 1909).

Very similar range of restricted daily movements in shallower water was also observed for the other two fish (weight 395 g, code 6; weight 465 g, code 12) located during manual tracking exercises. These juveniles, however, did not show the same precise homing behaviour of the fish code 5. They travelled toward the core area of marine reserve in the days after releasing, but never reached their site of capture, at least during our last monitoring period. Observations were limited by operational conditions due to a number of factors, i.e. the longevity of transmitters, the signal strength compared to the area to be explored during the fish searching, and the ambient noise (e.g. rocky bottom, breaking waves and air bubbles in the water; Stasko and Pincock, 1977). The fate of the fourth fish (weight 343 g, code 11) is unknown but maybe due to its subsequent death in a cave where it would not be possible to receive a signal from the transmitter. (Lembo *et al*., 1999a).

Two of the pre-adults fish that experienced prolonged captivity (codes 161 and 167) never came back to the capture site in the core zone of the MPA, but remained rather close (164±20 m) or bit far (995±22 m) from the releasing site, at least within 2-3 months at liberty. This behaviour is contrasting with the previous observations on the homing of adults occurring in few days (Lembo *et al*., 1999b), thus the captivity could have affected the home memory. Additional tests with a higher number of fish and longer monitoring time are though necessary to confirm this outcome. The fate of these two fish after 2-3 months is unknown like that of the fish code 154, soon disappeared probably as consequence of capture.

The behavioural pattern of dusky groupers, characterised by homing associated with site fidelity, makes this species particularly fragile and susceptible of localised stock depletion. In the Ustica MPA visual census estimates of dusky grouper population (Vacchi *et al*., 1999) reported higher abundance of 21-30 cm size class individuals in the core area of the reserve, while density of smaller fish among the zones was comparable. This result would imply that the shallow rocky shores of all the three zones of the MPA are suitable for the post-settlement phase of early juveniles, having similar potential of recruitment. Conversely diverse fish density among zones might be a consequence of fishery exploitation. Effects of protection on dusky grouper have been also observed in the Cabrera Arcipelago National Park, where fish density, mean and modal sizes resulted higher than in adjacent areas open to the fishery (Reñones *et al*., 1999).

At our current state of knowledge, the homing behaviour and site fidelity of dusky grouper suggest that only the proportion of the population (both juveniles and adults) resident in the core of the MPA at Ustica could be considered protected by the no-take zone. Thus, the effect of reserve on the adjacent areas may only related to the larval dispersal or, eventually, to the occurrence of spawning migrations (not yet proved) around the Island. Re-stocking using individuals in the range size of 0.3-17 kg cannot thus be viewed as an effective management option for stock restoration, unless home memory of re-located individuals is affected by prolonged captivity.

Further investigations are however necessary to confirm the findings of this study as well as to clarify the mechanisms of homing.

Acknowledgements

This research was funded by the Italian Ministry of Agriculture Policy (National Law 41/82) and supported by the MPA of Ustica. We, particularly, wish to thank Gaetano Caminita and Tonino Licciardi from the MPA and the Ustica's fisherman Felice Caminita.

References

Agardy, M.T. 1997. *Marine protected areas and ocean conservation*. San Diego, CA, Academic Press, 244 p.

Apostolaki, P., Milner-Gulland, E.J., McAllister, M.K., Kirkwood, G.P. 2002. Modelling the effects of establishing a marine reserve for mobile fish species. *Can. J. Fish. Aquat. Sci*., 59: 405-415.

Bolden, S. K. 2000. Long-distance movement of a Nassau grouper (*Epinephelus striatus*) to a spawning aggregation in the central Bahamas. *Fish. Bull*., 98: 642-645.

Côté, I.M., Mosqueira, I., Reynolds, J.D. 2001. Effects of marine reserve characteristics on the protection of fish populations: a meta-analysis. *J. Fish Biol*., 59 (Supplement A):178–189.

Holland, K. N., Peterson, J. D., Lowe, C. G. and Wetherbee, B. M. 1993. Movements, distribution and growth rates of the white goatfish *Mulloides flavolineatus* in a fisheries conservation zone. *Bull. Mar. Sci*., 52: 982–992.

Lauck, T., Clark, C. W., Mangel, M., and Munro, G. R. 1998. Implementing the precautionary principle in fisheries management through marine reserves. *Ecol. Appl*., 8 (1): 72–78.

Lembo, G., Fleming, I., Okland, F., Carbonara, P., Spedicato, M.T. 1999a. Homing behaviour and site fidelity of *Epinephelus marginatus* (Lowe, 1834) around the Island of Ustica: preliminary results from a telemetry study. *Biol. Mar. Medit*., 6 (1): 90-99.

Lembo, G., Fleming, I.A., Økland, F., Carbonara, P., Spedicato, M.T. 1999b. Site fidelity of the dusky grouper *Epinephelus marginatus* (Lowe, 1834) studied by acoustic telemetry. *Mar. Life*, 9 (2): 37-43.

Lembo, G., Spedicato, M.T., Økland, F., Carbonara, P., Fleming, I.A., McKinley, R.S., Thorstad, E.B., Sisak, M., Ragonese, S. 2002. A wireless communication system for determining site fidelity of *Epinephelus marginatus* (Lowe, 1834) using coded acoustic transmitters. *Hydrobiologia*, 483 (1-3): 249-257.

Lo Bianco, S. 1909. Notizie biologiche riguardanti specialmente il periodo di maturità sessuale degli animali del Golfo di Napoli. *Mitt. Zool. Stn. Neapel*, 19: 513-61.

Nowlis, J., and Roberts, C. M. 1999. Fisheries benefits and optimal design of marine reserves. *Fish. Bull*., 97: 604–616.

O'Dor, R.K., Aitken, J.P., Babcock, R.C., Bolden, S.K., Seino, S., Zeller, D.C. and Jackson, G.D. 2001. Using radio-acoustic positioning and telemetry (RAPT) to define and assess marine protected areas (MPAs). *In* J. Sibert and J. Nielsen eds. *Electronic tagging and Tracking in Marine Fisheries, Reviews: Methods and Technologies in Fish Biology and Fisheries, Vol. 1*, 147-166 pp. Dordrecht, The Netherlands, Kluwer Academic Press.

Økland, F., Thorstad, E., Lembo, G., Ragonese, S., Spedicato, M.T. 1999. Surgery procedures for implanting telemetry transmitters into the body cavity of *Epinephelus marginatus* (Lowe, 1834). *Biol. Mar. Medit.*, 6 (1): 139-143.

Reñones, O., Goñi, R., Pozo, M., Deudero, S., Moranta, J. 1999. Effects of protection on the demographic structure and abundance of *Epinephelus marginatus* (Lowe, 1834). Evidence from Cabrera Arcipelago National Park (West-central Mediterranean). *Mar. Life*, 9 (2): 45-53.

Rodwell, L., Barbier, E.B., Roberts, C.M., McClanahan, T. 2003. The importance of habitat quality for marine reserve-fishery linkages. *Can. J. Fish. Aquat. Sci.*, 60: 171-181.

Sala, E., Ballesteros, E., Starr, R.M. 2001. Rapid decline of Nassau grouper spawning aggregations in Belize: Fishery management and conservation needs. *J. Amer. Fish. Soc.*, 26 (10): 23-30.

Soh, S., Gunderson D.R., Ito, D.H. 2000. The potential role of marine reserves in the management of shortraker rockfish (*Sebastes borealis*) and rougheye rockfish (*S. aleutianus*) in the Gulf of Alaska. *Fish. Bull.*, 99: 168–179.

Stasko, A. B., & Pincock, D. E. 1977. Review of underwater biotelemetry with emphasis on ultrasonic techniques. *J. Fish Res. Bd. Can.*, 34: 1262-1285.

Starr, R.M., Heine, J.N., Felton, J.M., Cailliet, G.M. 2002. Movements of bocaccio (*Sebastes paucispinis*) and greenspotted (*S. chlorostictus*) rockfishes in a Monterey submarine canyon: implications for the design of marine reserves. *Fish. Bull.*, 100: 324–337.

Vacchi, M., la Mesa, G., Finoia, M.G., Guidetti, P., Bussotti, S. 1999. Protection measures and juveniles of dusky grouper, *Epinephelus marginatus* (Lowe, 1834) (Pisces, Serranidae), in the Marine Reserve of Ustica Island (Italy, Mediterranean Sea). *Mar. Life*, 9 (2): 63-70.

Whaylen, L., Pattengill-Semmens, C.V., Semmens, B.X., Bush, P.G. & Boardman, M.R. 2004. Observations of a Nassau Grouper (*Epinephelus striatus*) Spawning Aggregation Site In Little Cayman, Including Multi-Species Spawning Information. *Envir. Biol. Fish.*, 70: 305-313.

Zeller, D.W. 1998. Spawning aggregations: patterns of movement of the coral grouper *Plectropomus leopardus* (Serranidae) as determined by ultrasonic telemetry. *Mar. Ecol. Prog. Ser.*, 162: 253-263.