

protection is in place, they will come back? In Palau, one aggregation that was possibly fished out was subsequently protected and shows signs of recovery, although too little is known of its natural, pre-fished, state to be able to evaluate the significance of the changes taking place. It is very tempting to focus just on aggregations that still appear to be in good condition but, given the very likely connectivity between reefs and possibly between aggregations, it is also important to consider the need to restore seriously depleted or even extirpated aggregations as part of the bigger picture. Therefore, the monitoring of extirpated sites is useful and important, especially in areas where the populations of aggregating species appear to be depleted and where aggregations were once substantial. It might seem like a futile exercise (the authors have all been through it many times), but the importance in the medium to long term might be great.

VII. F. Concluding Comments

If we really want to set up global long-term monitoring of aggregations, it is going to be necessary to continue the "discovery component" of aggregation work at as fast a rate as possible. At present there are only a handful of sites that could even remotely be considered as adequately quantified to serve as true long-term monitoring sites. We need to be establishing such sites now, and many of the sites needed are not yet even known to scientists or managers. The sites that are known need to be studied and quantified in more, and in sufficient, detail, one of the major reasons we have gone to the trouble of writing this manual.

VIII. References Cited

- Aguilar-Perera, A. 1994. Preliminary observations of the spawning aggregation of Nassau grouper, *Epinephelus striatus*, at Mahahual, Quintana Roo, Mexico. Proc. Gulf and Carib. Fish. Inst. 43: 112-122.
- Appeldoorn, R.S. D.A. Hensley, D.Y. Shapiro, S. Kioroglou and B.G. Sanderson. 1994. Egg dispersal in a Caribbean coral reef fish, *Thalassoma bifasciatum*. II. Dispersal off the reef platform. Bull. Mar. Sci. 54(1): 271-280.
- Beets, J. and A. Friedlander. 1999. Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. Env. Biol. Fish. 55: 91-98.
- Bell, L.J. and P.L. Colin. 1986. Mass spawning of *Caesio teres* (Pisces: Caesionidae) at Enewetak Atoll, Marshall Islands. Envir. Biol. Fishes 15(1): 69-74.
- Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Tech. Rep. NMFS 41:1-15.
- 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.
- Carter, J, G.R. Marrow and V. Pryor. 1994. Aspects of the ecology and reproduction of Nassau grouper, *Epinephelus striatus*, off the coast of Belize, Central America. Proc. Gulf and Carib. Fish. Inst. 43: 65-111.

- Claro, R., and K. C. Lindeman. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. *Gulf and Caribbean Research* 14(2): in press.
- Claro, R., K. C. Lindeman, and L. R. Parenti (eds.). 2001. *Ecology of the marine fishes of Cuba*. Smithsonian Institution Press, Washington, D. C., pp. 253.
- Colin, P. L. 1996. Longevity of some coral reef fish spawning aggregations. *Copeia* 1996(1): 189-192.
- Colin, P. L. 1994. Preliminary investigations of the reproduction of the jewfish, *Epinephelus itajara*. *Proc. 43rd Gulf Carib. Fish. Inst.*: 138-147.
- Colin, P. L. 1992. Reproduction of the Nassau grouper, *Epinephelus striatus*, and its relationship to environmental conditions. *Envir. Biol. Fish.* 34: 357-377.
- Colin, P. L. 1985. Spawning of western Atlantic surgeonfishes. *National Geographic Res. Rpts.* 18 (1977): 243-250.
- Colin, P. L. 1983. Spawning and larval development of the hogfish, *Lachnolaimus maximus* (Pisces: Labridae). *Fishery Bulletin* 80(4): 853-862.
- Colin, P. L. 1982. Aspects of the spawning of western Atlantic reef fishes. NOAA Tech. Mem. NMFS-SEFC 80: 69-80.
- Colin, P. L. 1978. Daily and summer-winter variation in mass spawning of the striped parrotfish, *Scarus croicensis*. *Fishery Bulletin* 76(1): 117-124.
- Colin, P.L. and L.J. Bell 1991. Aspects of the spawning activity of labrid and scarid fishes (Pisces::Labroidei) at Enewetak Atoll, Marshall Islands, with notes on other families. *Env. Biol. Fish.* 32: 229-260.
- Colin, P. L. and I.E. Clavijo. 1988. Spawning activity of fishes producing pelagic eggs on a shelf edge coral reef, southwestern Puerto Rico. *Bull. Mar. Sci.* 43(2): 249-279.
- Colin, P. L. and I.E. Clavijo. 1978. Mass spawning of the spotted goatfish, *Pseudupeneus maculatus* (Pisces: Mullidae). *Bull. Mar. Sci.* 28(4): 780-782.
- Colin, P. L., W.A. Laroche and C.C. Koenig. 1996. Development from egg to juvenile of the red grouper, *Epinephelus morio* (Pisces: Serranidae) in the laboratory: 409-422. in: Arreguin-Sanchez, F., J.L. Munro, M.C. Balgos and D. Pauly (eds.) *Biology, fisheries and culture of tropical groupers and snappers*. ICLARM Conf. Proc. 48, 449 pp.
- Colin, P. L., W.A. Laroche and E.D. Brothers. 1997. Timing of ingress and settlement in the Nassau grouper, *Epinephelus striatus*, (Pisces: Serranidae), with relationship to spawning occurrence. *Bull. Mar. Sci.* 60(3): 656-667.
- Colin, P.L., Douglas Y. Shapiro and D. Weiler. 1987. Aspects of the reproduction of two species of groupers, *Epinephelus guttatus* and *E. striatus* in the West Indies. *Bull. Mar. Sci.* 40(2): 220-230.

- Doherty, P.J. 1987. Light traps: selective but useful devices for quantifying the distributions and abundances of larval fishes. *Bull. Mar. Sci.* 41(2): 423-431.
- Domeier, M.L. and P.L. Colin. 1997. Tropical reef fish spawning aggregations: defined and reviewed. *Bull. Mar. Sci.* 60(3): 698-726.
- Domeier, M, L., P. L. Colin, T. J. Donaldson, W. D. Heyman, J. S. Pet, M. Russell, Y. Sadovy, M. A. Samoilys, A. Smith, B. M. Yeeting and S. Smith. 2002. Transforming coral reef conservation: reef fish spawning aggregations component. Spawning Aggregation Working Group Report, The Nature Conservancy, Hawaii, April 22, 2002. pp. 85 (<http://www.scrfa.org/doc/FSAS.pdf>).
- English, S., C. Wilkinson and V. Baker. 1997. Survey Manual for Tropical Marine Resources, Australian Inst. Mar. Sci., Townsville, 390 pp.
- Garth, F.D. 1991. By the light of the grouper moon. *Scuba Times* 1991: 46-48.
- Gilmore, R.G. and R.S. Jones, 1992. Color variation and associated behavior in the Epinepheline groupers, *Mycteroperca microlepis* (Goode and Bean) and *M. phenax* Jordan & Swain. *Bull. Mar. Sci.* 51: 84-103.
- Graham, T.R. 2001. Advantages of pulse fishing in live product fisheries. Secretariat of the Pacific Community Live Reef Fish Inf. Bull. 9: 5-9.
- Gronell, A. M. and P.L. Colin. 1985. A toroidal vortex for gamete dispersion in a marine fish, *Pygoplites diacanthus* (Pisces:Pomacanthidae). *Animal Behavior* 33(3): 1021-1023.
- Harvey, E.S. and M.R. Shortis. 1996. A system for stereo-video measurement of sub-tidal organisms. *Mar. Tech. Soc. J.* 29(4): 10-22.
- Harvey, E., D. Fletcher and M. Shortis. 2000a. A comparison of the precision and accuracy of estimates of reef-fish lengths determined visually by divers with estimates produced by a stereo-video system. *Fishery Bulletin* 99: 63-71.
- Harvey, E., D. Fletcher and M. Shortis. 2000b. Improving the statistical power of length estimates of reef fish: a comparison of estimates determined visually by divers with estimates produced by a stereo-video system. *Fishery Bulletin* 99:72-80.
- Harvey, E., D. Fletcher and M. Shortis. 2002. Estimation of reef fish length by divers and by stereo-video: a first comparison of the accuracy and precision in the field on living fish under operational conditions. *Fisheries Research* 57(3): 255-265.
- Head, W.D., W.O. Watanabe, S.C. Ellis and E.P. Ellis. 1996. Hormone-induced multiple spawning of captive Nassau grouper broodstock. *Progressive Fish Cult.* 58: 65-69
- Hensley, D.A., R.S. Appeldoorn, D.Y. Shapiro, M. Ray and R.G. Turingan. 1994. Egg dispersal in a Caribbean coral reef fish, *Thalassoma bifasciatum*. I. Dispersal over the reef platform. *Bull. Mar. Sci.* 54(1): 256-270.
- Johannes, R.E. 1981. Words of the Lagoon, Univ. of California Press, 245 pp.

- Johannes, R. E., 1997. Grouper spawning aggregations need protection. Secretariat of the Pacific Community Live Reef Fish Information Bulletin 3: 13-14.
- Johannes, R.E. 1998. The case for data-less marine resource management: examples from tropical nearshore fisheries. Trends Ecol. Evol. 13(6): 243-246.
- Johannes, R.E. and N. Kile. 2001. Protecting grouper spawning aggregations, a potential target of the live reef food fish trade in Ysabel and Wagina Islands. Secretariat of the Pacific Community Live Reef Fish Inf. Bull. 8: 5-9.
- Johannes, R.E. and M.Lam 1999. The live reef fish trade in the Solomon Islands. Secretariat of the Pacific Community Live Reef Fish Inf. Bull. 5: 8-15.
- Johannes, R.E., L. Squire, T. Graham, Y. Sadovy and H. Renguul. 1999. Spawning aggregations of groupers (Serranidae) in Palau. The Nature Conservancy Marine Research Series Publication No. 1, 144 pp.
- Jones, G. P., M. I. Milicich, M. J. Emslie, and C. Lunow 1999. Self-recruitment in a coral reef fish population. Nature (London) 402: 802-804
- Keener, P., G.D. Johnson, B.S. Stender and E.B. Brothers. 1988. Ingress of postlarval gag, *Mycterperca microlepis* (Pisces: Serranidae) through a South Carolina barrier island inlet. Bull. Mar. Sci. 42: 376-396.
- Kiflawi, M., A.I. Mazeroll and D. Goulet. 1998. Does mass spawning enhance fertilization in coral reef fish? A case study of the brown surgeonfish. Mar. Ecol. Prog. Ser. 172: 107-114.
- Koenig, C.C., F.C. Coleman, L.A. Collins, Y. Sadovy and P.L. Colin. 1996. Reproduction in gag, *Mycterperca microlepis* (Pisces: Serranidae) in the eastern Gulf of Mexico and the consequences of fishes spawning aggregations: 307-323 in Arreguin-Sanchez, F., J.L. Munro, M.C. Balgos and D. Pauly (eds.) Biology, fisheries and culture of tropical groupers and snappers. ICLARM Conf. Proc. 48, 449 pp.
- Lobel, P.S. 1992. Sounds produced by spawning fishes. Env. Biol. Fish. 33: 351-358.
- Mapstone, B.D., A. Jones, C.R. Daview, S.J. Slade and A.J. Williams. 2001. The live fish trade on Queensland's Great Barrier Reef: changes to historical fishing practices. Secretariat of the Pacific Community Live Reef Fish Inf. Bull. 9: 10-13
- Marconato, A., D.Y. Shapiro, C.W. Petersen, R.R. Warner and T. Yoshikawa. 1997. Methodological analysis of fertilization rate in the bluehead wrasse *Thalassoma bifasciatum*: pair versus group spawning. Mar. Ecol. Prog. Ser. 161:61-70.
- Myrberg, A.A., W.L. Montgomery and L. Fishelson. 1988. The reproductive behavior of *Acanthurus nigrofuscus* (Forsk.) and other surgeonfishes (Fam. Acanthuridae) off Eilat, Israel (Gulf of Aqaba, Red Sea). Ethology 79: 31-61
- Pet, J. L. Squire, C. Subagyo and A. Mulyadi. 1999. Grouper and Napoleon wrasse spawning aggregation sites Komodo National Park, Monitoring Report 1998-1999. The Nature Conservancy, 43 pp.

- Petersen, C.W. and Warner, R.R. 2002. The ecological context of reproductive behavior. pp. 103-118. In: Sale, P.W. (ed) Coral Reef Fishes, Elsevier Science (USA).
- Petersen, C.W., R.R. Warner, S. Cohen, H.C. Hess and A.T. Sewell. 1992. Variable pelagic fertilization success: implications for mate choice and spatial patterns of mating. *Ecology* 73: 391-401.
- Randall, J. E., and Randall, H. A. 1963. The spawning and early development of the Atlantic parrot fish *Sparisoma rubripinne*, with notes on other scarid and labrid fishes. *Zoologica* (N. Y.) 48: 49-59
- Rhodes, K. 1999. Grouper aggregation protection in proactive Pohnpei. Secretariat of the Pacific Community Live Reef Fish Information Bulletin 6: 14-15.
- Rhodes, K.L. and Y. Sadovy. 2002. Temporal and spatial trends in spawning aggregations of camouflage grouper, *Epinephelus polyphkadion*, in Pohnpei, Micronesia. *Envir. Biol. Fish.* 63: 27-39.
- Rimmer, M.A., R.N. Garrett and M.A. Samoilys. 1994. In vitro fertilization of eggs of coral trout, *Plectropomus leopardus* (Serranidae), collected from an aggregation site on the Great Barrier Reef, Australia. *Bull. Mar. Sci.* 54(1): 356-358.
- Ruitenbeek, H.J. 2001. An economic analysis of the spawning aggregation function in Komodo National Park. Indonesia. Secretariat of the Pacific Community Live Reef Fish Inf. Bull. 9: 13-16.
- Russ, G.R., D.C. Lou and B.P. Ferreira. 1996. Temporal tracking of a strong cohort in the population of a coral reef fish, the coral trout, *Plectropomus leopardus* (Serranidae: Epinephelinae), in the central Great Barrier Reef. *Can. J. Fish. Aquat. Sci.* 53: 2745-2751.
- Sadovy, Y. 1993. The Nassau grouper, endangered or just unlucky? *Reef Encounter* July 1993: 101-2.
- Sadovy, Y. 1996. Reproduction in reef fishery species:15-59 in Polunin, N.V.C. and C.M. Roberts (eds) *Reef Fisheries*, Chapman and Hall, London
- Sadovy, Y and P.L. Colin.1995. Sexual development and sexuality in the Nassau grouper, *Epinephelus striatus* (Bloch) (Pisces: Serranidae). *J. Fish Biol.* 46: 961-976.
- Sadovy, Y. and Eklund, A. 1999. Synopsis of biological data on the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), and the jewfish, *E. itajara* (Lichtenstein, 1822). U. S., Dep. Commer., NOAA Tech. Rep. NMFS 146; FAO Fisheries Synopsis 157, 65 p.
- Sadovy, Y. J. and A. C. J. Vincent. 2002. Ecological Issues and the Trades in Live Reef Fishes. Chapter 18. In: *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem*, Peter F. Sale, ed., Academic Press, San Diego, pp. 391-420.
- Sadovy, Y., Rosario, A., and Roman, A. 1994a. Reproduction in an aggregating grouper, the red hind, *Epinephelus guttatus*. *Env. Biol. Fish.* 41: 269-286.

- Sadovy, Y, P.L. Colin and M. Domeier. 1994b. Aggregation and spawning of the tiger grouper, *Mycteroperca tigris* (Pisces: Serranidae). *Copeia* 1994(2): 511-516.
- Sala, E., E. Ballesteros, R.M. Starr. 2001. Rapid decline of Nassau grouper spawning aggregations in Belize: fishery management and conservation needs. *Fisheries* 26(10): 23-30.
- Samoilys, M. A. 1987. Aspects of the behaviour, movements and population density of the coral trout, *Plectropomus leopardus* (Lacepede) (Pisces: Serranidae) at Heron Island, southern Great Barrier Reef, MSc Thesis, Queensland University, Brisbane, 185 pp. + appendices.
- Samoilys, M.A. 1997a. Underwater visual census surveys. In: Samoilys, M. A., (ed.) Manual for Assessing Fish Stocks on Pacific Coral Reefs. Queensland Department of Primary Industries, Brisbane. Pp. 16-29.
- Samoilys, M.A. 1997b. Periodicity of spawning aggregations of coral trout *Plectropomus leopardus* (Pisces: Serranidae) on the northern Great Barrier Reef. *Mar. Ecol. Prog. Ser.* 160: 149-159.
- Samoilys, M.A. and L.C. Squire. 1994. Preliminary observations of the spawning behavior of coral trout, *Plectropomus leopardus* (Pisces: Serranidae), on the Great Barrier Reef. *Bull. Mar. Sci.* 54(1): 332-342.
- Samoilys, M. A. and G. Carlos. 2000. Determining methods of underwater visual census for estimating the abundance of coral reef fishes. *Env. Biol. Fish.* 57(3): 289-304
- Sancho, G., A.R. Solow and P.S. Lobel. 2000. Environmental influences on the diel timing of spawning in coral reef fishes. *Mar. Ecol. Prog. Ser.* 206: 193-212.
- Shapiro, D.Y. 1981. Size, maturation and the social control of sex reversal in the coral reef fish *Anthias squamipinnis*. *J. Zool., Lond.* 193: 105-128
- Shapiro, D.Y., A. Marconato and T. Yoshikawa. 1994. Sperm economy in a coral reef fish, *Thalassoma bifasciatum*. *Ecology* 75(5): 1334-1344.
- Shapiro, D.Y., Y. Sadovy and M.A. McGehee. 1993. Size, composition, and spatial structure of the annual spawning aggregation of the red hind, *Epinephelus guttatus* (Pisces: Serranidae). *Copeia* 1993(2): 399-406.
- Shenker, J.M., E.D. Maddox, E. Wishinski, A. Pearl, S.R. Thorrold and N. Smith. 1993. Onshore transport of settlement-stage Nassau grouper *Epinephelus striatus* and other fishes in Exuma Sound, Bahamas. *Mar. Ecol. Prog. Ser.* 98: 31-43.
- Sluka, R.D. 2001. Grouper and Napoleon wrasse ecology in Laamu Atoll, Republic of the Maldives: Part 2. Timing, location, and characteristics of spawning aggregations. *Atoll Res. Bull.* No 492: 1-15.
- Smith, C.L. 1972 A spawning aggregation of Nassau grouper, *Epinephelus striatus* (Bloch) *Trans. Amer. Fish. Soc.* 101:257-261.

- St. John, J., G. R. Russ and W. Gladstone. 1990. Accuracy and bias of visual estimates of numbers, size structure and biomass of a coral reef fish. *Mar. Ecol. Prog. Ser.* 64(3): 253-262.
- Swenson, W. A., W. P. Gobin and T. D. Simonson. 1988. Calibrated mask-bar for underwater measurement of fish. *North Amer. J. Fisheries Management* 8:382-385
- Tamaru, C.S., C. Carlstrom-Trick, W.J. Fitzgerald, Jr. and H. Ako. 1996. Induced final maturation and spawning of the marbled grouper *Epinephelus microdon* captured from spawning aggregations in the Republic of Palau, Micronesia. *J. World Aquacult. Soc.* 27(4): 363-372.
- Thresher, R.E. 1984. *Reproduction in Reef Fishes*. T.F.H. Publ., Neptune City, N.J.
- Watson, R. A., G. M., Carlos, and M. A. Samoilys. 1995. Bias introduced by the non-random movement of fish in visual transect surveys. *Ecol. Model.* 77: 205-214
- Vilaro Diaz, D.J. 1884. *Corrida y arribazon de algunos peces cubanos*. Manuel Gomez de la Maza, La Habana, 15 p.
- Zabala, M., A. Garcia-Rubies, P. Louisy and E. Sala. 1997a. Spawning behaviour of the Mediterranean dusky grouper *Epinephelus marginatus* (Lowe, 1834)(Pisces, Serranidae) in the Medes Islands Marine Reserve (NW Mediterranean, Spain). *Sci. Mar.* 61(1): 65-77.
- Zabala, M., P. Louisy, A. Garcia-Rubies and V. Garcia. 1997b. Socio-behavioural context of reproduction in the Mediterranean dusky grouper *Epinephelus marginatus* (Lowe, 1834) (Pisces, Serranidae) in the Medes Islands Marine Reserve (NW Mediterranean, Spain). *Sci. Mar.* 61(1): 79-89.
- Zeller, D.W. 1997. Home range and activity patterns of the coral trout *Plectropomus leopardus* (Serranidae). *Mar. Ecol. Prog. Ser.* 154: 65-77.
- Zeller, D.W. and G.R. Russ. 1997. Marine reserves: patterns of adult movements of the coral trout *Plectropomus leopardus* (Serranidae). *Can. J. Fish. Aquat. Sci.* 55: 917-924.