Abstract—This publication of the NOAA Professional Paper NMFS Series is the product of a special symposium on "Emerging Technologies for Reef Fisheries Research and Management" held during the 56th annual Gulf and Caribbean Fisheries Institute meeting in Tortola, British Virgin Islands, November 2003. The purpose of this collection is to highlight the diversity of questions and issues in reef fisheries management that are benefiting from applications of technology. Topics cover a wide variety of questions and issues from the study of individual behavior, distribution and abundance of groups and populations, and associations between habitats and fish and shellfish species.

Emerging technologies for reef fisheries research and management

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Introduction

It is now recognized that fisheries activity around the world has reached and most probably exceeded its maximum sustainable yield (Pauly et al., 2002; Myers and Worm, 2003). This is most certainly the case in coral reef systems where significant human impacts such as overexploitation, harmful fishing practices, and habitat destruction have decimated many reef fish populations (Jackson et al., 2001; Pandolfi et al., 2003). Reef ecosystems support some of the most diverse taxa in the aquatic world (Sale, 2002) and therefore degradation of habitats and extirpation of species through fisheries harvest can have unexpected consequences to the functioning of these ecosystems. Artisanal harvest of reef species also contributes significantly to the local economy of many island communities of the Caribbean, Gulf of Mexico, and tropical western Atlantic, and so has also suffered from the decline in reef ecosystems (Russ, 1991).

While we are gaining a better appreciation for the role coral reef habitats and reef fisheries play in coastal ecosystems and tropical economies, the techniques which fisheries managers have used to collect vital statistics on the status of populations lag behind the need for such data. This is not surprising as many of these species are solitary as adults or elusive as sub-adults and juveniles, using the reef structure as refuge from predation, making them difficult to detect and enumerate. Traditional means of surveying for population estimates or community structure, such as diver-visual surveys, have proven costly and sometimes ineffective in assessing abundance and distribution patterns of many of the most important reef fish populations. In addition, the limitations on dive bottom times and underwater characteristics such as light penetration and visibility place a necessary limit on the range, areal coverage, and depth of the study site that can be surveyed using this traditional method. It is critical that we develop methods that will provide extensive and yet rapid and efficient surveys of both reef habitats as well as the fish species that inhabit them. Ideally, such methods would permit rapid coverage of large spatial extents, produce abundance estimates or species distribution movement maps in real-time or with minimal post-processing, and be non-invasive so they do not interfere with the behavior and thus affect the detection of species of interest.

This collection of papers is a product of a special symposium entitled "Emerging technologies for reef fisheries management" that was held at the 56th annual meeting of the Gulf and Caribbean Fisheries Institute in Tortola, British Virgin Islands, in November 2003. The papers presented in this volume encompass a wide diversity of habitats, species, regions, and techniques and also address issues of reef fisheries ecology including the study of individual behavior, distribution and abundance of groups and populations, and associations between habitats and species. They also cover many aspects of fisheries management such as species conservation,

marine protected area design and implementation, and stock assessment and management. These papers are meant to serve as examples of ways in which technology has been employed and resulted in significant improvements in our understanding of reef fisheries and ecosystem processes. Readers interested in the foundations of a particular technology described in this collection should consult references in each paper. Moreover, this collection does not cover other applications of technologies in coral reef conservation and management, particularly remote sensing techniques that are being used to map coastal habitats and coral cover (Mumby et al., 2004). However, several papers in this series do attempt to link these habitat-based objectives with applications that include linking habitats with species of commercial or ecological interest.

This collection of papers is divided into two broad categories: 1) population assessments and distribution patterns of single species, and 2) organism-habitat relationships. In many cases, the technology serves as a complimentary tool in each project. Several of the authors also identify advantages and limitations of their respective application and suggest how the limitations may be overcome in the future.

Distribution and abundance

Rand et al. used a diver-operated stereo video system to improve measurements of individual Nassau grouper in a spawning aggregation. The application also provided some of the first measures of small-scale, three-dimensional spatial structure within a reef fish spawning aggregation.

Johnston et al. used mobile split-beam hydroacoustic surveys to assess the spatial distribution and abundance of red hind (*Epinephelus guttatus*) spawning aggregations along the continental shelf of Puerto Rico. Their survey covered several hundred kilometers along the shelf-break on Puerto Rico and identified regions that held large red hind aggregations during the February and March spawning season.

Taylor et al. present results from a high-resolution mobile hydroacoustic sampling of a Nassau grouper (*Epinephelus striatus*) aggregation. They used a two-stage geostatistical model to estimate the abundance of fish and compared these estimates with those made using scuba visual census. The geostatistical model provided an objective measure of the spatial extent of the aggregation. Measures such as these can be difficult to obtain using traditional diver visual surveys.

Habitat-organism relationships

Glazer and Delgado used sonic telemetry coupled with Geographic Information Systems (GIS) to determine movement and home ranges for queen conch (*Strombus gigas*) on a back reef in Florida Keys. Overlapping home ranges of several individuals during spawning and non-spawning seasons were used to make objective and informed decisions on establishing boundaries of a marine fishery reserve to protect conch populations around the Florida Keys.

Gleason et al. used recent advances in bottom habitat classification from single-beam hydroacoustics along with diver-assisted surveys for grouper to make inferences about species-habitat associations. They found a significant relationship between the distribution of grouper and sediment type and a newly derived acoustic property of the bottom. Their work will lead to habitat-based population assessments for near-shore grouper species and improve site selection for fish surveys using divers.

Weaver, Naar, and Donahue and Weaver, Hickerson, and Schmahl used high-resolution bathymetric maps produced from multibeam sonar surveys to direct submersible surveys for reef habitat features in the Tortugas South Ecological Reserve and Northwestern Gulf of Mexico, respectively. Unique and rare coral habitats and deep reef species were identified at both sites using these complimentary surveying techniques.

Rivera et al. used side-scan sonar imaging from habitat surveys to identify acoustic targets in the water column; acoustic targets not associated with bottom features are typically considered as noise in habitat surveys, so current software packages do not permit analyses of such data. The authors manually extracted water column signals and linked them to the habitat maps through synoptic geopositioning data. Using this novel technique, they are able to begin to make connections between fish distribution and habitat types in a shallow, near-shore reef environment.

Mason et al. used several complimentary technologies to establish relationships between reef habitat quality and fish growth. A combination of active hydroacoustics, passive acoustics, video, and advanced biochemical techniques provided insights into the functional linkages between reef attributes (e.g., structural complexity and prey availability) and processes that regulate gag grouper (*Mycteroperca microlepis*) performance.

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Literature cited

Jackson, J. B. C., M. X. Kirby, W. H. Berger, K. A. Bjorndal, L. W. Botsford, B. J. Bourque, R. H. Bradbury, R. Cooke, J. Erlandson, J. A. Estes, T. P. Hughes, S. Kidwell, C. B. Lange, H. S. Lenihan, J. M. Pandolfi, C. H. Peterson, R. S. Steneck, M. J. Tegner, and R. R. Warner.
2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293(5530): 629–638.

Mumby, P. J., W. Skirving, A. E. Strong, J. T. Hardy, E. F. LeDrew, E. J. Hochberg, R. P. Stumpf, and L. T. David.
2004. Remote sensing of coral reefs and their physical environment. Mar. Poll. Bull. 48(3–4): 219–228.

Myers, R. A., and B. Worm.
2003. Rapid worldwide depletion of predatory fish communities. Nature 423(6937): 280–283.

Pandolfi, J. M., R. H. Bradbury, E. Sala, T. P. Hughes, K. A. Bjorndal, R. G. Cooke, D. McArdle, L. McClenachan, M. J. H. Newman, G. Paredes, R. R. Warner, and J. B. C. Jackson.
2003. Global trajectories of the long-term decline of coral reef ecosystems. Science 301(5635): 955–958.

Pauly, D., V. Christensen, S. Guenette, T. J. Pitcher, U. R. Sumaila, C. J. Walters, R. Watson & D. Zeller.
2002. Towards sustainability in world fisheries. Nature 418(6898): 689–695.

Russ, G.
1991. Coral reef fisheries: effects and yields. *In* The ecology of fishes on coral reefs (P. F. Sale, ed.), p. 601–635.

Sale, P. F.
2002. Coral reef fishes dynamics and diversity in a complex ecosystem. Academic Press, New York, 500 p.