Part II

SYMPOSIUM OF THE CALCOFI CONFERENCE, 2000

Lake Arrowhead, California
1 November 2000

ECOSYSTEM-BASED FISHERY MANAGEMENT IN THE NEARSHORE ENVIRONMENT

Ecosystem-based management has been proposed as an improvement over single-species resource management approaches. Yet at this point, we are still grappling with what ecosystem-based management is and how it can be meaningfully applied. We need to understand how ecosystem-level factors interact with fishing to impact stocks (Beamish and Mahnken 1999). In order to be an improvement over single-species management, ecosystem-based management should incorporate ecosystem-level effects on fishing, oceanographic conditions, and multiple interspecific interactions (including positive interactions) to protect against fishery collapse.

Ecosystems are difficult to define, but most definitions include the interactions among the biological and physical components within a definable geographical unit (Lincoln et al. 1998). In addition, ecologists have discussed the possibilities that such interactions manifest emergent properties—an ecosystem correlate often defined by the holistic euphemism: The whole (ecosystem) is greater than the sum of its parts (species). These interactions presumably also contribute to poorly defined concepts such as "ecosystem health," "ecosystem integrity," and "intact" ecosystem (Simberloff 1998). Because many of these concepts have yet to be quantified, they are difficult for resource managers to implement (Larkin 1996). Furthermore, once communities within ecosystems are defined by managers, large-scale shifts in climate (or oceanographic) conditions may rearrange species components (Hunter et al. 1988). Nevertheless, the Sustainable Fisheries Act of 1996 calls for each of the major ecosystems in the United States to be managed using an ecosystem-based approach.

The Ecosystem Principles Advisory Panel convened by the National Marine Fisheries Service has recommended the development of fishery ecosystem plans (FEPs) as a tool to apply ecosystem principles to fisheries conservation, management, and research. These plans are envisioned to coordinate management of existing single-species or species-complex fishery plans, and in the near future managers may be charged with plan development. Implementing FEPs will involve considering species interactions such as those between predators and prey; minimizing the effects of fishing on essential habitat; and considering how bycatch affects the food web and community structure. In order to apply these principles, control rules that must be both practical and enforceable will be drafted, with constituent involvement. One way to apply ecosystem management is through the use of marine protected areas, which are currently the focus of considerable research (Lauck et al. 1998). Ultimately, it is hoped that FEPs will be superior to single-species management approaches.

There is increasing concern that fishing has negative consequences for marine ecosystems (Dayton et al. 1995). Numerous impacts of fishing have been identified, including effects on target and nontarget species, habitat alterations, and changes in the trophic structure of marine communities. Fishing can affect target species by changing age and size structure, sex ratios, and the genetic structure of fished populations (Botsford et al. 1997). Habitat alterations have been attributed to trawling gear (Auster et al. 1996; Engel and Kvitek 1998), and it is estimated that seabed disturbances on the continental shelf each year are 150 times greater than disturbances resulting from clear-cutting in the terrestrial landscape (Watling and Norse 1998). In terrestrial environments we know that logging can affect habitat function by uncoupling nutrient cycling, which leads to a loss of nutrients and productivity (Likens and Bormann 1975). In marine systems, fishing in coral reef communities has been shown to lead to the loss of reef processes such as the accretion of calcium carbonate (Roberts 1995). Fishing removes "engineering" organisms (sensu Jones et al. 1997) that directly or indirectly control the availability of resources to other organisms in the community. The loss of ecosystem engineers to fishing affects habitat function by reducing structural complexity and species diversity (Leichter and Witman 1997). For example, the reduction of oyster beds through mechanical harvest leads to enhanced hypoxic conditions in summer, killing economically important blue crabs (Lenihan and Peterson 1998). Loss of species diversity may alter the structure of communities—potentially rendering these communities, and the fish stocks within them, more vulnerable to perturbations (Roberts 1995). Changes in the structure of trophic webs have been described for heavily fished ecosystems with the near removal of higher-trophic-level predators (Pauly et al. 1998). Are these changes affecting the resilience of marine communities? Do multiple stable states exist in marine systems, some states supporting fished species and other states supporting species with little economic value, such as jellyfish (C. Mills, Friday Harbor Laboratories, Univ. Washington, pers. comm.)?

Overlying the effects of fishing are large-scale oceanographic changes such as the regime shift of 1976–77 (Francis and Hare 1994; Mantua et al. 1997). Oceanographic conditions impact whole systems, such as the California Current, and CalCOFI has made major contributions to our understanding of the ecological consequences of these events. Dramatic reductions in zooplankton (Roemmich and McGowan 1995; McGowan et al. 1998) and other sources of larval fish food affect fishery productivity. Hypotheses that may link ocean conditions to fish abundance are now being proposed, such as the critical size/critical period hypothesis, which suggests that salmon stocks are driven by the growth rates of juveniles in the ocean in summer (Beamish and Mahnken 1999). Surely, multiple species and indeed whole ecosystems are altered during major El Niño events, such as that of 1997–98, which was the focus of the 1999 CalCOFI symposium (Mullin 2000). Recently, oceanographic conditions have been incorporated into fishery management plans because the productivity of many stocks seems to be correlated with temperature, with some stocks more productive during warm regimes and other stocks during cold regimes. For example, the 2001 management guidelines for Pacific sardine incorporate sea-surface temperature (average of preceding three years) into the computation of the allowable catch, which is lower in cold (less productive) years and higher in warm years (Conser et al. 2001).

Species interactions are currently incorporated into ecosystem-based models within food webs. Since the focus of species interactions in food webs is primarily predation, the assumption is that the total yield from a multispecies model, such as virtual population analysis, will necessarily be less (due to predation) than the sum of the maximum yields of the component species models (but see Brander and Mohn 1991). Given these limitations, some researchers have questioned whether multispecies models will yield superior management advice compared with single-species models (Magnusson 1995). Multispecies models should incorporate positive species interactions (sensu Bertness and Leonard 1997). These revisited models may yield practical results on the emergent properties of communities, and novel management options may come to light. For example, the presence of red sea urchins in marine protected areas enhanced the abundance of juvenile abalone compared to fished areas, indicating that sea urchin harvest refugia may enhance the recruitment of abalone (Rogers-Bennett and Pearse 2001). The challenge will be to quantify ecosystem functions and positive species interactions (emergent properties) and incorporate these parameters into ecosystem-based management.

The papers that follow are based on the presentations given at the symposium entitled Ecosystem-Based Fishery Management in the Nearshore Environment. (Several of the presentations were not submitted as papers.) The recommendations of the Ecosystem Principles Advisory Panel are detailed in the first paper of this symposium. The second paper characterizes the biological dynamics of the northern California Current ecosystem (NCCE), the development of a conceptual model of the food web, and an estimation of total removals and how they relate to standing biomass, production, and trophic structure. The authors use Ecopath models to compare the NCCE during a cool regime in the 1960s to the warm regime in the 1990s. The third paper describes the practical application of an ecosystem model for multiple fisheries in a coastal lagoon system and how such models can be used to determine which fishing strategies optimize yields. Finally, a simulated oil spill in the California Current ecosystem is described, and a number of response options, including the use of chemical dispersants, are evaluated. The papers from this symposium were refereed by at least two peer reviewers and edited by Laura Rogers-Bennett and Julie Olfe.

Laura Rogers-Bennett

LITERATURE CITED

Auster, P. J., R. J. Malatesta, R. W. Langton, L. Watling, P. C. Valentine, C. L. S. Donaldson, E. W. Langton, A. N. Shepard, and I. G. Babb. 1996. The impacts of mobile fishing gear on seafloor habitats in the Gulf of Maine (Northwest Atlantic): implications for conservation of fish populations. Rev. Fish. Sci. 4:185–202.

Beamish, R. J., and C. Mahnken. 1999. Taking the next step in fisheries management. Ecosystem approaches for fisheries management. Proceedings of the symposium on Ecosystem Considerations in Fisheries Management Sept. 30–Oct. 3, 1998. Pp. 1–21.

Bertness, M. D., and G. H. Leonard. 1997. The role of positive interactions in communities: lessons from intertidal habitats. Ecology 78:1976–1989.

Botsford, L. W., J. C. Castilla, and C. H. Peterson. 1997. The management of fisheries and marine ecosystems. Science 277:509–515.

Brander, K. M., and R. K. Mohn. 1991. Is the whole always less than the sum of the parts? Multispecies models relevant to management of living resources. ICES Mar. Sci. Symp. 193:117–119.

Conser, R. J., K. T. Hill, P. R. Crone, and D. Bergen. 2001. Stock assessment of Pacific sardine with management recommendations for 2001: executive summary. Pacific States Fishery Management Council, Portland, Ore. 97201.

Dayton, P. K., S. F. Thrush, M. T. Agardy, and R. J. Hofman. 1995. Environmental effects of marine fishing. Aquat. Conserv. Mar. Freshwat. Ecosyst. 5:205–232.

Engel, J., and R. Kvitek. 1998. Effects of otter trawling on a benthic community in Monterey Bay National Marine Sanctuary. Conserv. Biol. 12:1204–1214.

Francis, R. C., and S. R. Hare. 1994. Decadal-scale regime shifts in the large marine ecosystem of the North-east Pacific: a case for historical science. Fish. Oceanogr. 3:279–291.

Hunter, M. L., G. L. Jacobson, and T. Webb. 1988. Paleoecology and the course-filter approach to maintaining biological diversity. Conserv. Biol. 2:375–385.

Jones, C. G., J. H. Lawton, and M. Shachak. 1997. Positive and negative effects of organisms as physical ecosystem engineers. Ecology 78:1946–1957.

Larkin, P. A. 1996. Concepts and issues in marine ecosystem management. Rev. Fish Biol. Fish. 6:139–164.

Lauck, T., C. Clark, M. Mangel, and G. Munro. 1998. Implementing the precautionary principle in fisheries management through marine reserves. Ecol. Appl. 8:S72–S78.

Leichter, J. J., and J. D. Witman. 1997. Water flow over subtidal rock walls: relation to distributions and growth rates of sessile suspension feeders in the Gulf of Maine. J. Exp. Mar. Biol. Ecol. 209:293–307.

Lenihan, H. S., and C. H. Peterson. 1998. How habitat degradation through fishery disturbance enhances the impacts of hypoxia on oyster reefs. Ecol. Appl. 8:128–140.

Likens, G. E., and F. G. Bormann. 1975. An experimental approach to New England landscapes. *In* Coupling of land and water systems, A. D. Hasler, ed. London: Chapman & Hall, pp. 7–30.

Lincoln, R. J., G. A. Boxshall, and P. F. Clark. 1998. A dictionary of ecology, evolution, and systematics. Cambridge, U.K .: Cambridge University Press.

Magnusson, K. G. 1995. An overview of the multispecies VPA—theory and applications. Rev. Fish Biol. Fish. 5:195–212.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific-interdecadal climate oscillation with impacts on salmon production. Bull. Am. Meteorol. Soc. 78:1069–1079.

McGowan, J. A., D. R. Cayan, and L. M. Dorman. 1998. Climate-ocean variability and ecosystem response in the Northeast Pacific. Science 281:210–217.

Mullin, M. 2000. The ecological effects of the 1998 El Niño in the eastern boundary currents. Symposium introduction. Calif. Coop. Oceanic Fish. Invest. Rep. 41:55.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres Jr. 1998. Fishing down marine food webs. Science 279:860–863.

Roberts, C. M. 1995. Effects of fishing on the ecosystem structure of coral reefs. Conserv. Biol. 9:988–995.

Roemmich, D., and J. A. McGowan. 1995. Climate warming and the decline of zooplankton in the California Current. Science 267:1324–1326

Rogers-Bennett, L., and J. Pearse. 2001. Indirect benefits of marine protected areas for juvenile abalone. Conserv. Biol. 15:642–647.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: Is single-species management passe in the landscape era? Biol. Conserv. 83:247–257.

Watling, L., and E. A. Norse. 1998. Disturbance of the seabed by mobile fishing gear: a comparison to forest clearcutting. Conserv. Biol. 12:1180–1197.