ECOSYSTEM-BASED SPATIAL PLANNING AND MANAGEMENT OF MARINE FISHERIES: WHY AND HOW?

Elliott A. Norse

"The obscure we see eventually. The completely obvious, it seems, takes longer,"
Edward R. Murrow, American journalist, 1908–1965

ABSTRACT

In a 2009 paper by Worm et al., fisheries biologists and conservation biologists found common ground in recommending spatial planning to benefit marine fisheries and biodiversity. Frontiers on land and in the ocean have few users relative to resources; as this ratio increases, governance suitable to the frontier no longer works because people's interests collide and biodiversity is lost. Increasing ocean uses and troubled fisheries are reasons to shift to ecosystem-based marine spatial planning and management, which reflect patterns and processes of both fish and people. Protecting places can eliminate fragmentation, spatial and temporal mismatches caused by "siloed" sectoral management, where agencies that regulate different sectors in the same places largely ignore the needs of other sectors. Modern fishery management does not reflect the heterogeneity of fish populations and human uses. By reducing fishing mortality to zero, one spatial tool, marine reserves, restores large female fishes, which produce more eggs, and aids recovery of species in which females become males at larger sizes. Reserves can also maintain fishes' genetic structure. Australia created the "gold standard" for marine spatial planning in Great Barrier Reef Marine Park, a mosaic of ecosystems with differing availability to fishing. Other nations are adopting this approach. Even the best spatial plans will have problems that cross ecosystem boundaries, but advantages accrue to fishermen who stay within designated areas and let fish come to them. Areas can be deliberately configured to improve both biodiversity conservation and fishery yields and to save on fishermen's fuel costs.

In this time of profound ecological, economic, and political change, fisheries are a leading cause of change on the Earth's surface and are themselves buffeted by change. They are affected by shifting fish abundance patterns, habitat loss, aquaculture, globalization of markets, fuel prices, climate change, ocean acidification, catch shares, and an ocean-management paradigm now quickly gaining momentum around the world: ecosystem-based marine spatial planning.

Until recently, fisheries biologists and conservation biologists have been divided about the nature of the problem and solutions to it, but a recent paper (Worm et al., 2009) by leaders in these two groups reached a shared vision: "…new cooperation of fisheries scientists and conservation biologists sharing the best available data, and bridging disciplinary divisions, will help to inform and improve ecosystem management." Here I discuss why these previously divided scientists, citizens, and governments are now examining and adopting ecosystem-based marine spatial planning, and how it can work in general and specifically for fisheries. I hope readers will forgive disproportionate use of U.S. examples, which are most familiar to me.

Bulletin of Marine Science

Governing and Managing Territory Change as User Density Increases

The services that ecosystems provide underlie the survival and wealth of all people, rich and poor, coastal and inland. Resource availability is so important a driver of human affairs that governments have a major stake in the continuing abundance of resources and their widespread spatial distribution. So long as resources abound relative to the human population (the initial situation at frontiers), impacts are hardly a public-policy issue—indeed governments often encourage exploitation—but as increasing population increases impacts and collisions among interests, new measures are needed. Former U.S. Supreme Court Justice Oliver Wendell Holmes summarized this fundamental legal principle as "The right to swing my fist ends where the other man's nose begins." When conflicts reach a threshold, door locks, traffic laws, police, courts, navies, etc, become necessary. As poet Robert Frost said, "Good fences make good neighbors."

On land, variation in intensity of human land use is enormous, from cities and densely populated islands to areas with almost no human habitation or use, but the sea has almost no permanent human habitation: Uses of space are either uninhabited facilities or temporary incursions by people. Some places are intensively used and managed. Disturbance return intervals can be very short in estuaries, coastal waters, and some places farther from shore (e.g., those trawled hundreds of times per year, Watling and Norse, 1998). Nonetheless, farther from land, sea use tends to be extensive (spread over large areas with longer disturbance return intervals), not intensive, typically producing the frontier exploitation pattern described by Berkes et al. (2006), in which fishermen move from place to place, sequentially depleting resources beyond profitability, then moving on.

Moreover, in almost every place on land, individuals, families, tribes, corporations, or governments are the owners and managers, by law or tradition. In the sea, beyond estuaries and nearshore areas, ownership and management authority rest almost exclusively with governments or (for the 64% of the ocean that is high seas beyond national jurisdictions) international governing institutions.

The distinction between frontiers and places that are intensively used and governed is crucial because frontiers have characteristic ecological, economic, sociological, and legal dimensions that differ markedly from those of nonfrontier areas (Norse, 2005a). Frontier use depletes biodiversity, starting with large species and ones at high trophic levels, and is economically wasteful. Users are largely unconstrained by laws. As sea uses expand and intensify, impacts on marine ecosystems and collisions between human interests have increased to the point where frontier exploitation no longer serves the public good.

Fishing now occurs much farther from markets, even in the remotest seas on Earth, and as deep as several kilometers. Ships are much larger and have turned some areas into crowded superhighways with attendant cetacean and ship collisions, spills, trash, epidemics, noise, and crime. The seafloor is increasingly crisscrossed by pipelines, power lines, and optical cables. The sea is already, or soon will be, dotted by intensive space-consuming uses: oil and gas production facilities, liquefied natural gas terminals, wind and wave farms, tidal and current electricity-generating facilities, and aquaculture pens. On the horizon are ocean thermal energy conversion, seafloor mining, and floating or undersea hotels. And because tourism is the world's largest industry (Hall, 2001) and most tourism (and human settlement) is coastal, recreational use in the sea will rise with growing affluence and leisure (to glimpse the future, Google "recreational submarines"). Burgeoning competition for ocean space (see figures in Crowder at al., 2006, and Turnipseed et al., 2009a) indicates a global tipping point, the end of the Wild (Blue) Frontier.

In U.S. waters, marine resources are publicly owned, so managing them as a public trust makes sense (see Osherenko, 2006; Turnipseed et al., 2009a,b), but in federal waters (mostly between 3 and 200 nmi offshore), regulation is fragmented. Fishing is regulated by the National Marine Fisheries Service, oil and gas operations are managed by the Minerals Management Service, wave and tidal power will come under the aegis of the Federal Energy Regulatory Commission, pollutant discharges are the responsibility of the Environmental Protection Agency, dredging is overseen by the Army Corps of Engineers, etc. Oversight of different sectors by different agencies creates gaps and overlaps in authority and spatial and temporal mismatches between governance and ecosystem processes (Juda, 2003; Crowder et al., 2006). Worse still, agencies favor the sectors they regulate while ignoring other interests in the same places, a phenomenon called regulatory capture (Makkai and Braithwaite, 1992; Sanchirico et al., 2010). This sectoral management is not in the public interest.

Management of places on land is fundamentally different. Private property owners or government agencies have more or less comprehensive authority to manage human activities within their boundaries. For example, U.S. National Parks generally prohibit logging; the U.S. Forest Service has no authority to permit logging within National Park boundaries.

In contrast, U.S. National Marine Sanctuaries allow many uses. Sanctuary managers do not generally exercise their authority to manage fishing (Chandler and Gillelan, 2004) although it has the most impact in many sanctuaries. Indeed, in 2006, a powerful U.S. congressman attempted to pass legislation bestowing authority on advisory bodies called regional fishery management councils to govern fisheries even within sanctuaries. The frontier mentality lives.

Now, however, the paradigm is shifting toward managing places. In June, 2009, U.S. President Barack Obama issued a memorandum, http://www.whitehouse.gov/the_press_office/Presidential-Proclamation-National-Oceans-Month-and-Memorandum-regarding-national-policy-for-the-oceans/, directing federal agencies with major ocean impacts or responsibilities to create a framework for ecosystem-based spatial planning in federal waters within 180 d. Among the most important issues to be addressed is fishing.

Problems with Fisheries That Do Not Account for Spatial Heterogeneity

Prevailing marine fisheries management is based on fisheries biology, which derives largely from population biology and does not treat fish populations as components in their ecosystems (Pauly, 2009). It relies more on aggregated catch data, fecundity, and estimates of natural and fishing mortality averaged throughout the ranges of populations than on direct observations of living fishes and the ecological and behavioral factors that generate spatial heterogeneity in fish populations. Moreover, it does not address the spatial heterogeneity of all important threats to fishes (Halpern et al., 2008). Failure to incorporate spatial patterns and processes impairs management of marine ecosystems and fisheries (Wilen, 2004).

Ecosystem effects of fishing, including trophic cascades and loss of habitat-forming species, equal or exceed other human impacts on the sea (Watling and Norse, 1998; Jackson et al., 2001; Dayton et al., 2002; Hutchings and Reynolds, 2004; Kappel, 2005; Halpern et al., 2008). Fisheries perturb ecosystems in ways that affect other fisheries. For example, removal of large sharks releases medium-sized predators from predation; their booming populations caused scallop-fishery collapse (Myers et al., 2007). Top-down control by predators and, consequently, effects on fisheries are widespread (Baum and Worm, 2009). Moreover, fishing is a spatially mosaic process, with intense effects on individual places (equivalent to tesserae, the individual tiles) as well as emergent effects on the broader seascape mosaic. Trawling, longlining, gillnetting, purse seining, and pot fishing are as spatial as fixed weirs, because both "mobile gear" and "fixed gear" are deployed by mobile vessels seeking prime spots to fish.

Population collapses of target species are widespread, from the most charismatic fishes (Fromentin and Powers, 2005) to ones far less studied (Sadovy and Cheung, 2003). Nontarget species are at even greater risk because statistics are less likely to be collected and analyzed. For example, oceanic whitetip sharks [*Carcharhinus longimanus* (Poey, 1861)] declined by 99.7% in the Gulf of Mexico after pelagic longlining for tunas began in the 1950s. This near-extinction of a top carnivore went unnoticed for five decades (Baum and Myers, 2004). Effects of commercial fishing get most attention, but for some places and species, recreational fishing has greater impact (Coleman et al., 2004).

Fisheries themselves are in trouble (see, e.g., Pauly, 1995; Watson and Pauly, 2001; Myers and Worm, 2003; Mora et al., 2009). Orthodox fishery scientists who vehemently disputed such findings (e.g., Hilborn, 2006) now basically agree with them (Worm et al., 2009). The UN Food and Agriculture Organization's *State of World Fisheries and Aquaculture 2008* (FAO, 2009) says that only 20% of the world's fisheries are *not* overexploited or fully exploited (at high risk of being in trouble). Given the obscuring effects of aggregating "stocks" and misreporting from its sources, the FAO's figures are almost certainly underestimates.

If fisheries were well managed, fishes that were abundant and large still would be, and fishermen would have bountiful catches of desired fishes in waters near their homes, but that situation has become vanishingly rare (Dayton et al., 1998; Pauly et al., 1998; Jackson et al., 2001; Crowder, 2005; Roberts, 2007). At the 2009 *International Marine Conservation Congress*, Ruth Helen Thurstan of the University of York showed that biomass of commercially valued U.K. fishes had declined 95% since steam trawlers were introduced (Thurstan, 2009). From 1956 to 2007, the average weight of "trophy fish" at a Key West, Florida, recreational fishing operation declined 88%, from 19.9 kg to 2.3 kg (McClenachan, 2009). Even the most impassioned denial cannot mask the implications of these findings.

Fishermen have always known that size matters, but now biologists better understand how large individuals function differently from smaller conspecifics. A number of epinepheline serranids (groupers) and fishes in some other families are protogynous hermaphrodites; females become males as they grow. In contrast to some wrasses (labrids), parrotfishes (scarids) and anthiinine serranids (Munday et al., 2006), these groupers appear to have no mechanism for adjusting to an absence of males, and their sex ratios are now seriously skewed. Because fishing raises mortality rates, so that fewer individuals ever live long enough to attain large size, such species could be sperm-limited by the scarcity of males (Coleman et al., 1996; Heppell et al., 2006; Hamilton et al., 2007); as a result, population resilience would be reduced far more than spawning biomass reduction alone would predict. Moreover, biologists have long appreciated that in taxa that are not protogynous (the great majority of fishes), larger females produce more eggs per gram (e.g., Trippel et al., 1997; LaPlante and Schultz, 2007). Reduction in sizes of fishes has major implications for spatial planning.

For species in which slot limits cannot work—quite probably a large majority—the only way to maintain size structure in a place is to reduce fishing mortality there to near zero. This goal can be achieved inadvertently during war (Jennings et al., 2001) and in areas closed for reasons of security (Roberts et al., 2001), or purposefully in no-take marine reserves (Baskett et al., 2005; Lester et al., 2009). That is one reason why reserves are useful for fisheries management.

Fishing also alters genetic diversity. Atlantic cod (*Gadus morhua* Linnaeus, 1758) populations were far more genetically structured than fisheries managers realized (Hauser and Carvalho, 2008; Reich and DeAlteris, 2009). Treating them like one panmictic population probably contributed to the 99% reduction reported by Rosenberg et al. (2005). Furthermore, failure to recognize the evolutionary effects of fishing on genetic composition (Conover and Munch, 2002; Law and Stokes, 2005; Árnason et al., 2009) is a recipe for commercial, ecological, or even biological extinction, something neither fisheries managers nor marine conservationists want.

Size structure also affects fishes' impacts on their habitats. For example, larger individuals of three parrotfishes have disproportionately high grazing impact on reefrock (Lokrantz et al., 2009). Red groupers [*Epinephelus morio* (Valenciennes, 1828)] also maintain sediment-free reefrock, and larger individuals do so in different places than smaller ones (Coleman and Williams, 2002). Many corals and sponges, which are important habitat formers, require bare rock for recruitment. Overlooking the importance of fishes in maintaining productive fish habitat has not helped fisheries or biodiversity.

Fishermen "get" that fish populations are spatially structured and focus fishing effort on the largest concentrations of the right-sized (usually largest) fishes, but the leading management tool, stock assessment, treats fish populations as spatially unstructured. Successful fishery management must address spatial heterogeneity because fishes live in ecosystems, which are places. Fisheries are therefore overdue for what Kuhn (1970) called a paradigm shift, a fundamentally different way of envisioning and addressing the situation, a shift to place-based management.

This paradigm shift is essential not only to fisheries scientists, fishermen, and consumers but to all humankind, because everyone (even land-locked people and those who do not eat fish) depends on marine ecosystem services. Because oceans constitute 99% of the volume of the biosphere permanently inhabited by multicellular life, fisheries have a major effect on the habitability, economics, and geopolitics of our world. Given this importance, the paucity of attention that institutions have devoted to restoring fisheries is remarkable. Fisheries are only one major threat to oceans, however (Norse, 1993; Marine Conservation Biology Institute, 1998; Millennium Ecosystem Assessment, 2005). All who care about fisheries must also deal with habitat alteration, marine pollution, alien species, and atmospheric change. Doing so requires highly effective governance. Unfortunately, inadequate governing institutions drive all these proximate threats to the oceans.

Managing Interacting Sectors Independently in the Same Place Cannot Work

In 2003, the Pew Oceans Commission, a group of scientists, conservationists, fishermen, and policy experts, issued its final report about U.S. ocean governance, saying,

> Reflecting the understanding and values of this earlier era, we have continued to approach our oceans with a frontier mentality. The result is a hodgepodge of ocean laws and programs that do not provide unified, clearly stated goals and measurable objectives. Authority over marine resources is fragmented geographically and institutionally. Principles of ecosystem health and integrity, sustainability, and precaution have been lost in the fray.

Starting in 2004, a group of fisheries biologists, marine ecologists, anthropologists, economists, political scientists, and lawyers meeting at the National Center for Ecological Analysis and Synthesis in Santa Barbara, California, asked why humankind seems unable to stop the oceans' decline. They concluded that proximate threats (e.g., overfishing, habitat destruction, climate change) are symptoms; underlying causes are the gaps and overlaps in sectoral governance (Crowder at al., 2006) or what Norse (1993) called "fragmented decision making" (now commonly called "stovepiping" or "siloing"). This kind of governance *cannot* maintain what users and conservationists care about.

Having worked on both forest (Norse, 1990) and marine (Norse, 1993) conservation, I have contemplated differences between terrestrial and marine systems (see, e.g., Norse, 2005b; Norse and Crowder, 2005). The most important one impeding marine conservation is that, in the sea, different authorities generally govern different sectors in each place, whereas on land, one authority generally governs all sectors in each place. A consequence of this siloing is that marine conservation lags terrestrial conservation by decades (Barr and Lindholm, 2000; Sloan, 2002), but change is inevitable (Norse, 2008) and (in the United States) imminent.

This phase of governance—stuck in a bygone time when oceans seemed opaque and healthy, fish were abundant, and scientific understanding was scarce—is not helpful. In many places, jurisdictional lines on maps were drawn long before meaningful information was available about geological, oceanographic, biological, and human use patterns and processes. In the United States, different jurisdictions and management agencies have distinctive legal mandates, goals, and cultures. Some sectors are regulated by more than one agency. For biodiversity, no agency has primary responsibility, and some have very limited responsibility. Agencies therefore have little incentive to address anything outside their mandates. As Rosenberg and Sandifer (2009), put it, "Under sector-by-sector management, trade-offs within a sector may be considered, but those among sectors are largely ignored and often remain unaccounted for." This situation was hardly problematic when ample distance remained between swinging fists and noses, but in the face of today's increasing demands, a system of ocean governance less likely to give us healthy oceans and sustainable economies would be difficult to design. Without strong interagency coordination, sectoral management *cannot* work.

Ecosystem-Based Marine Spatial Planning: A Paradigm That *Can* Work

The growing problems in U.S. waters led two blue-ribbon national commissions (Pew Oceans Commission, 2003; U.S. Commission on Ocean Policy, 2004) to call for governance that reflects the sea's patterns and processes. Such approaches often include the words "ecosystem" explicitly or implicitly, as in the ecosystem approach to management, ecosystem-based fisheries management, ecosystem-based management (EBM), ecosystem-based spatial planning, or ocean zoning.

After the commissions' reports, the Communication Partnership for Science and the Sea (COMPASS) released a statement (McLeod et al., 2005) by 221 scientists saying that the goal of EBM is "to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need" and that EBM: (1) protects ecosystem composition, structure, and functioning; (2) is place-based, focusing on specific ecosystems; (3) addresses connections among air, land, and sea; and (4) integrates ecological, social, economic, and institutional perspectives.

EBM can work because it reflects the heterogeneity of the sea's biophysical and human processes (Crowder and Norse, 2008). Patterns of primary production and seafloor structures have dramatic effects on where fishes feed and spawn; cultural traditions and proximity to harbors have dramatic effects on where people fish. On land realtors say that three things affect the value of real estate: location, location, and location. Except that "places" in the pelagic realm move (Hyrenbach et al., 2000; Norse et al., 2005), the sea is no different. Conservationists do not want to position marine reserves randomly, fishermen know where fishing is most rewarding, wind farm and net-pen operators have specific location criteria, and oil companies willingly pay huge amounts to drill in some places but not in others because, as Napoleon said, "Geography is destiny."

Nevertheless, securing and defending the largest possible space is not necessarily the wisest strategy because, as damselfishes, economists, and soldiers recognize, defending places is costly. The most cost-effective strategy is defending just enough.

Fortunately, the best site for a wind farm might not be the best for a wave farm, a marine reserve, recreational fishing, or bottom trawling. Differing needs reduce competition for space, making it economically desirable to defend only those places that offer return on investment exceeding a certain threshold. Interests need not fight in Congress or court when they can both get most of what they want. Moreover, although some pairs of activities—spearfishing and underwater fish-watching, bottom trawling and pot fishing, or wind farming and parasailing—cannot occur in the same place at the same time, other are spatiotemporally compatible. Recreational fishermen in the Gulf of Mexico know that oil and gas production platforms are among the best places to fish; anglers, in turn, do not impede offshore oil and gas production, so these activities require no separation.

The science and art of separating incompatible interests now and in the future is marine spatial planning (MSP). (I do not say incompatible uses, because conservation is not a use, Norse, 2009). In some places, such planning is done without consideration of biodiversity goals—the goals are almost purely economic—but in the United States, the public's strong interest in maintaining biodiversity means that it will be ecosystem-based.

The United States is already allocating space in state and federal waters but is doing so in an ad hoc, uncoordinated way (Sanchirico et al., 2010), as if each agency wore blinders. Ocean governance could learn from aviation governance, where everyone recognizes that all planes have blind spots, making collisions inevitable without highly effective air-traffic controls.

Similarly, when ocean activities have the same spatial requirements and are incompatible, an overarching decision-making body with strong input from the public is needed to reduce conflicts by separating them. If, for example, the Federal Energy Regulatory Commission favors licensing a wave farm over the interests of fishermen, a government entity with a broader, overarching mandate—one charged with considering the diverse interests of the public as a whole—is needed to find places to accommodate both uses. To level the playing field and accommodate society's diverse interests, comprehensive ecosystem-based marine spatial planning can minimize regulatory uncertainty, unnecessary costs, and biodiversity loss that siloed sectoral management has produced. And the process is not ad hoc; it does so by design.

Comprehensive means two different things: (1) the entire area within a jurisdiction is managed spatially, and (2) essentially all legitimate activities in the region are included. If an activity does not have public support, no room need be made for it, but an intelligent spatial planning system should give legitimate interests fair opportunity to make their distinctive needs known and heard whether they are focused on conservation or particular uses, are longstanding or new.

In the United States, much of the discussion about spatial planning concerns regional ocean governance (see, e.g., Norse, 2003). In any region with similar ecology, economics, culture, and politics, people will probably have more similar opinions about which activities are or are not acceptable than they share with other regions. I suspect that any spatial planning system the USA adopts will have national standards but will be implemented at a regional level.

Changing our system of ocean governance will be resisted, in some cases by people who have prospered under the current system, but resistance will probably come more often from people who fear change, even those unhappy with the status quo. As John Locke (1690) noted, "New opinions are always suspected, and usually opposed, without any reason but because they are not already common."

Fortunately, ecosystem-based spatial planning is not new, so Americans and others need not reinvent it. As cochair of the Federal Committee on Ecological Reserves in 1980, I learned that terrestrial scientists, such as University of Washington forest ecologist Jerry Franklin, were promoting special area designations for conservation, research, and extractive use. In 1992 I visited the visionaries at the Great Barrier Reef Marine Park Authority, who are charged with managing a spatial mosaic of both fully protected places and places supporting a broad range of fishing and other uses. That park is now the canonical example of comprehensive ecosystem-based marine spatial planning (Day, 2002; Olsson et al., 2008), although, as in many marine areas around the world, maintaining its integrity is a constant struggle. My colleagues at UNESCO's Intergovernmental Oceanographic Commission (Ehler and Douvere, 2009) and at the United Nations Environment Programme (O. Vestergaard, pers. comm.) report that more than a dozen nations from Vietnam to Norway are applying such planning in parts or all of their EEZs. I urge people in nations rich and poor, small and large, to absorb the lessons in Ehler and Douvere (2009) to save the precious time and cost of "reinventing the wheel."

A world in which human beings always understood their interests and those of others and made decisions to benefit both would be wonderful, but marine spatial planning is not about being "nice." It is about diverse groups deciding that it is in their self-interest and about governments' interest in finding a workable balance between citizens' present and future needs. The confluence of interest between conservation and economic interests is why nations are adopting comprehensive ecosystem-based marine spatial planning.

Bioregionalization and the Eternal Problem of Boundary-Crossing

Ecosystems are nested like matryoshka dolls, on scales from the globe as a whole and ocean basins through regional seas, gulfs, and bays down to individual reefs, seagrass beds, and even the mounds made by individual polychaetes. Jurisdictional lines drawn by governments almost never reflect meaningful biophysical or human-use phenomena—rather, they transect ecosystem boundaries. Creating a comprehensive spatial plan to facilitate ecosystem-based management, however, requires planning on a scale that works for management: If it is too big, we miss crucial details; if too small, we have an unwieldy number of decision-making groups.

The science of marine biogeography is devoted to understanding larger-scale spatial patterns of living things and can help to inform this process. As is often the case, Australia led the way with the Integrated Marine and Coastal Regionalization of Australia (IMCRA), a comprehensive ecosystem classification system that can be used for marine protected areas or broader spatial planning (Commonwealth of Australia, 2006). It uses data on distributions of bottom-dwelling fishes and physical features to delineate benthic regions and information on offshore water masses and circulation regimes to delineate pelagic regions. Other nations might feel compelled to reinvent bioregionalization, but the Australian system seems a reasonable compromise between ecological validity and utility for management. A similar approach could save precious time for governments wanting results relatively quickly. No matter what criteria and scales are chosen, any bioregionalization will inevitably oversimplify and imperfectly reflect someone's reality, but almost any intelligent delineation of ecosystems boundaries will produce better planning than the current system.

Beyond jurisdictional and bioregional information, human-use maps are essential for spatial planning. Since 2007, the U.S. Marine Protected Areas Science Center and Marine Conservation Biology Institute have worked with knowledgeable officials and users to construct a California Ocean Uses Atlas. The atlas is needed because some spatial information—such as locations of oil and gas platforms or commercial fishing—is readily available, although not always at the resolution needed by ocean and coastal managers, but spatial information on other uses, including recreational fishing, tribal cultural uses, motorboating, sailing, SCUBA diving, shipping, and military uses, was not previously available. The results will allow officials to superimpose information about a broad range of uses upon bioregions and jurisdictions to gain a clear view of opportunities and conflicts in ocean planning areas.

Having usable maps provides a substantive basis for public input and government decision-making, but a problem that bedevils place-based management in the sea, as on land, is processes that transcend lines on maps. Rivers carrying nutrient pulses into the sea, advancing temperature fronts, hurricanes following their sinuous trajectories, fish migratory corridors, alien species expanding their ranges, vessels plying shipping lanes, and military operations responding to crises pay little heed to such boundaries.

No spatial scheme, on land or in the sea, is perfect, but, as Voltaire (1765) observed, "The perfect is the enemy of the good." At the International Marine Conservation Congress, a leading thinker and practitioner of marine spatial planning, Jon Day of the Great Barrier Reef Marine Park Authority, reminded us that zoning can accomplish many of our ecological and economic objectives, but other tools are needed to address processes that cross even the most thoughtfully constructed zone boundaries.

Spatial Fisheries Management

In the United States, only a handful of people (Norse, 1993; Bohnsack, 1996; Ogden, 2001; Brax, 2002) examined ocean zoning until the last few years. Now the fisheries biologists and conservation biologists of Worm et al. (2009) recommend a governance regime change:

> Recovering…[vulnerable or collapsed] species while maintaining global catches may be possible through improved gear technology and a much more widespread use of ocean zoning into areas that are managed for fisheries benefits and others managed for species and habitat conservation.

Zoning offers benefits for both recreational and commercial fisheries (Eagle et al., 2008). What would happen if fisheries biologists and conservation biologists combined their best understanding with that of sociologists, economists, political scientists, and fishermen to devise a new spatial fishing paradigm?

Conservation advocates and fishermen both want more fish and better fishing. Zoning will bring fishermen increased certainty about access to fishing grounds and reduced competition among commercial gear groups, between commercial and recreational fishermen, and between fishermen and other ocean interests. And as Eagle et al. (2008) note, "Zoning can help strengthen politically weak groups and provide ownership-related incentives to all groups."

Methods for comparing gear impacts on by-catch and habitat have been developed in the United States (Chuenpagdee et al., 2003) and Canada (Fuller et al., 2008) that allow zoning to separate incompatible gear types. The problems that fishermen face are largely solvable if they become thoughtful, constructive participants in spatial planning processes. Not only do they have a large stake in the outcome; they often know better than anyone the local spatial patterns of what they care about most: large numbers of the right fish.

However challenging might be the allocation of space suitable to weirs, aquaculture net pens, optical cables, wind farms, or liquefied natural gas facilities, these are relatively easy to think about because they (mostly) do not move. Thinking more discerningly about what makes mobility important to fishing, however, helps us to envision ways to improve fisheries, a primary goal in many comprehensive ecosystem-based marine spatial planning processes. Fishermen use their mobility to locate fish, and then to catch them, and to go to and from places where fish are. Except for people who live aboard boats or who can fish from their hotel windows (as the Beatles did when visiting Seattle), getting to and from fishing grounds is integral to fishing, but locating and pursuing fish are not integral; some ways of fishing do not require these.

Oceanographers know that gathering observations can either be Lagrangian (drifting while gathering data) or Eulerian (stationary, gathering data as water moves past). Ecologists know that some predators pursue prey and others wait for prey to come to them. Anthropologists know that some Native American peoples hunted bison over vast prairies but that others lived in permanent settlements where they either farmed or waited for huge, predictable pulses of salmon to return to them.

Both pursuing and sitting-and-waiting are economically viable strategies, but most modern fishermen seem to have adopted the Lagrangian-pursuit predator–bison hunter strategy. Rethinking this strategy would be useful for three reasons: First, unlimited mobility encourages sequential overfishing: finding the best patches, fishing them until they are no longer profitable, then moving on (Berkes et al., 2006). In contrast, fishermen who work intensively within a defined area they know well where outsiders do not fish, with neighbors they know who both watch and watch out for one another, are much more likely to fish sustainably. To provide good economic returns and safety, the sizes, geometries, neighboring zones, and positions of their fishing grounds would have to depend on the population sizes, mobility, and predictability of their target species. That dependence would pose some new challenges, but no fishery can be sustainable without curtailing roving banditry. Second, profitability has declined because reduced fish abundance near home ports compels fishermen go farther to find and catch target fishes. Traveling farther is less safe and brings higher fuel and labor costs (steaming around in search of concentrations of fish is not a profit-making activity). Moreover, traveling farther requires larger boats, raising capital costs, and also increases costs because longer trips require higher processing (e.g., ice or freezing) costs. Third, exempting fishing is not good policy. If fishermen want sound spatial planning for oil and gas operations, liquefied natural gas terminals, wind farms, aquaculture, and marine reserves, they must be full participants in the planning process. Nobody looks out for fishermen's interests as well as fishermen. Their interests will not be taken seriously if they want everyone else to play by rules they do not accept themselves.

Movements of fish concern fisheries as well. Different species have diverse spatial patterns, from tunas that span entire ocean basins to species that spend their life cycles in the same places. Knowing fish movements is one criterion that distinguishes highliners from other fishermen. No less important (if far less understood) are movements of larvae, which critically affect recruitment patterns.

Many studies around the world show that biomass, density, size, and richness often increase substantially within no-take marine reserves that have good compliance (Lester et al., 2009), but this research is not necessarily compelling to fishermen, who often say they are unconvinced that marine reserves "work," meaning that they export fish and improve fishing outside the reserve. Fishermen's behavior suggests otherwise, however: they "fish the line" (Roberts et al., 2001; Kellner et al., 2007), aggregating near reserves' boundaries to intercept fish (often big ones) that spill into surrounding waters. Fishermen understandably want to benefit from this export.

Although nobody disputes the value of marine reserves for biodiversity, the disagreements between fisheries biologists (e.g., Hilborn et al., 2004) and conservation biologists (e.g., Roberts et al., 2005) about their value for fisheries seem destined to disappear, thanks to Worm et al. (2009).

Instead of reflexively opposing marine reserves, fisherman could use them to improve fishing. In 1999, when the National Research Council's Committee on Evaluation, Design, and Monitoring of Marine Reserves and Protected Areas in the United States met in Seattle, Washington, fisheries biologist Carl Walters of University of British Columbia suggested a fascinating idea: why not reverse the usual thinking on marine reserves and fisheries? Instead of protecting a modest portion of ocean, why not protect nearly all of it in ways that maximize benefits to fisheries? Recently, Ban and Vincent (2009) suggested that we start by presuming all the ocean should be protected except for the most economically productive areas, which would be open to fishing. This practice would dramatically increase biodiversity benefits while minimizing costs to fisheries, because small decreases in fishery yield could free up large areas for protection.

How could we implement these ideas? One way is purposefully manipulating geometry of fishing areas. Reserves could be designed to minimize or to maximize spillover. The fish carrying capacity of an ecosystem is a function of its area, whereas export of fish is a function of its perimeter. To minimize spillover (for example, to rebuild self-recruiting populations within the reserve), minimize perimeter. All things (currents, habitat quality, and total area) being equal, circles have the least perimeter per unit area, although squares are low-perimeter alternatives that are much easier to enforce. Spillover from reserves would be maximized if fishing areas were made narrow and elongate and thus had high ratios of perimeter to area. Indeed, narrow, elongate fishing zones next to such reserves might also be ideal for minimizing the area of seafloor disturbed by bottom trawling, while filling draggers' nets with spillover fish. This approach would require conservationists and fishermen to agree that some zones would be deliberately sacrificed so that others could be protected from all kinds or particular kinds of fishing. Moreover, spatial planning could be combined with another innovative tool, catch shares (Babbitt and Greenwood, 2008; Costello et al., 2008), to form "territorial use rights in fisheries" (often called TURFs) (Hilborn et al., 2005), which confer usage privileges of delimited places on individuals, companies, or communities. In coastal waters of Chile, Japan, and Maine, communities share territories in which fishermen follow carefully prescribed rules and exclude outsiders (Castilla and Defeo, 2001; Acheson, 2005).

Because distance from docks is an important economic and safety consideration for commercial and recreational fishermen, it could be a selection criterion so that—all else (including success in meeting conservation objectives) being equal—fishermen have the shortest possible runs to their fishing grounds. Minimizing travel distances would be welcomed by ocean wildlife-watchers and offshore aquaculturists as well as fishermen, so trade-offs will be necessary. Ocean users who do not depend strongly on biodiversity or fish productivity might also want to be closer to ports. Fortunately, new decision-support tools (e.g., MarZone; see http://www.uq.edu.au/marxan/?page=78499&pid=77690) are available that can generate zoning alternatives to give all key stakeholders as much as possible of what they need.

As a lifelong recreational fisherman, consumer of commercially caught fish, and conservation professional for 31 yrs, I recognize that different individuals and sectors have different objectives. Creating an alternative to the "winner take all" mentality—the mindset in what game theorists call a zero-sum game, which produces a win-lose outcome—will not be easy. After all, humans are primates. In this time of profound change, however, plus-sum games with win-win outcomes are not only essential; they are possible. Rather than being the intransigent victims of change, we can find ways to deal with change…even when it compels people with different objectives to work together to protect, recover, and maintain what we care about in the oceans.

Acknowledgments

I dedicate this paper to the memory of R. A. Myers, a master at extracting key signals from data and a skeptical scientist who asked obvious questions that others should have asked. Despite enduring intimidation from people in power, RAM never lost his enthusiasm or sense of humor. Someday I hope to get past the sadness of knowing that he did not live to see the essential changes he was so instrumental in catalyzing.

I am deeply grateful to F. C. Coleman for inviting me to speak at this outstanding scientific meeting and for being so patient and to A. B. Thistle for her light and deft editorial touch. I owe my ideas on marine spatial planning to many people, most notably G. Kelleher, R. Kenchington, J. Day, L. Crowder, G. Osherenko, O. Young, C. Ehler, F. Douvere, A. Rosenberg, J. Wilson and other participants in our NCEAS working group, Ecosystem-based Management for the Oceans: The Role of Zoning. I am indebted to C. Wahle of NOAA's MPA Center; S. Heppell of Oregon State University; R. Warner of the University of California, Santa Barbara; MCBI's K. Holmes, F. Tsao, J. Ardron, and L. Morgan, who provided keen insights and materials; and MCBI's B. Chandler, K. Cerveny, and E. Douce, who are shaping the political climate for marine spatial planning.

I am profoundly indebted to those whose vision, trust and generosity have fueled the evolution in my thinking, especially Arcadia, the David and Lucile Packard Foundation, the Gordon and Betty Moore Foundation, M. Bloome, B. Hammett, J. and T. Stanley, the Curtis and Edith Munson Foundation, the Marisla Foundation, the Moore Family Foundation, the Tiffany & Co. Foundation, and the Winslow Foundation.

Finally, I thank my loving wife Irene, who endures too many hours, days, and weeks of ocean widowhood to indulge my unceasing need to write, speak, and collaborate to make the world a better place.

Literature Cited

Acheson, J. M. 2005. Developing rules to manage fisheries: a cross-cultural perspective. Pages 351–361 *in* E. A. Norse and L. B. Crowder, eds. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press, Washington, D.C.

Árnason, E., U. Benitez Hernandez, and K. Kristinsson. 2009. Intense habitat-specific fisheries-induced selection at the molecular Pan I locus predicts imminent collapse of a major cod fishery. PLoS One 4: 1–14.

Babbitt, B. and J. Greenwood. 2008. Oceans of abundance: an action agenda for America's vital fishing future. Marine Conservation Biology Institute, Environmental Defense Fund and World Wildlife Fund. Available from: http://www.edf.org/documents/8795_OceansOfAbundance.pdf.

Ban, N. C. and A. C. J. Vincent. 2009. Beyond marine reserves: exploring the approach of selecting areas where fishing is permitted, rather than prohibited. PLoS ONE 47: e6258.

Barr, B. W. and J. Lindholm. 2000. Conservation of the sea using lessons from the land. George Wright Forum 17: 77–85.

Baskett, M. L., S. A. Levin, S. D. Gaines, and J. Dushoff. 2005. Marine reserve design and the evolution of size at maturation in harvested fish. Ecol. Appl. 15: 882–901.

Baum, J. K. and R. A. Myers. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecol. Lett. 7: 135–145.

_________ and B. Worm. 2009. Cascading top-down effects of changing oceanic predator abundances. J. Anim. Ecol. 78: 699–714.

Berkes, F., T. P. Hughes, R. S. Steneck, J. A. Wilson, D. R. Belwood, B. Crona, C. Folke, L. H. Gunderson, H. M. Leslie, J. Norberg, et al. 2006. Globalization, roving bandits, and marine resources. Science 311: 1557–1558.

Bohnsack, J. A. 1996. Marine reserves, zoning and the future of fisheries management. Fisheries 21: 14–16.

Brax, J. 2002. Zoning the oceans: using the National Marine Sanctuaries Act and the Antiquities Act to establish marine reserves in America. Ecol. Law Q. 29: 71–129.

Castilla, J. and O. Defeo. 2001. Latin American benthic shellfisheries: emphasis on co-management and experimental practices. Rev. Fish Biol. Fish. 11: 1–30.

Chandler, W. J. and H. Gillelan. 2004. The history and evolution of the National Marine Sanctuaries Act. Environ. Law Reporter News Analysis 34: 10505–10565.

Chuenpagdee, R., L. E. Morgan, S. Maxwell, E. A. Norse, and D. Pauly. 2003. Shifting gears: assessing collateral impacts of fishing methods in U.S. waters. Front. Ecol. Environ. 1: 517–524.

Coleman, F. and S. L. Williams. 2002. Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends Ecol. Evol. 17: 40–44.

_________, C. C. Koenig, and L. A. Collins. 1996. Reproductive styles of shallow-water grouper (Pisces: Serranidae) in the eastern Gulf of Mexico and the consequences of fishing spawning aggregations. Environ. Biol. Fish. 47: 129–141.

_________, W. F. Figueira, J. S. Ueland, and L. B. Crowder. 2004. The impact of United States recreational fisheries on marine fish populations. Science 305: 1958–1960.

Commonwealth of Australia. 2006. A guide to the integrated marine and coastal regionalisation of Australia, version 4.0. Department of the Environment and Heritage, Canberra, Australia. Available from: http://www.environment.gov.au/coasts/mbp/publications/imcra/pubs/imcra4.pdf.

Conover, D. O. and S. B. Munch. 2002. Sustaining fisheries over evolutionary time scales. Science 297: 94–96.

Costello, C., S. D. Gaines, and J. Lynham. 2008. Can catch shares prevent fisheries collapse? Science 321: 1678–1681.

Crowder, L. B. 2005. Back to the future in marine conservation. Pages 19–29 *in* E. A. Norse and L. B. Crowder, eds. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press, Washington, D.C.

___________ and E. Norse. 2008. Essential ecological insights for marine ecosystem-based management and marine spatial planning. Mar. Policy 32: 772–778.

___________, G. Osherenko, O. R. Young, S. Airamé, E. A. Norse, N. Baron, J. C. Day, F. Douvere, C. N. Ehler, B. S. Halpern, et al. 2006. Resolving mismatches in U.S. ocean governance. Science 313: 617–618.

Day, J. C. 2002. Zoning—lessons from the Great Barrier Reef Marine Park. Ocean Coastal Manage. 45: 139–156.

Dayton, P. K., S. Thrush, and F. C. Coleman. 2002. Ecological effects of fishing in marine ecosystems of the United States. Pew Oceans Commission, Arlington, Virginia. 44 p.

___________, M. J. Tegner, P. B. Edwards, and K. L. Riser. 1998. Sliding baselines, ghosts, and reduced expectations in kelp forest communities. Ecol. Appl. 8: 309–322.

Eagle, J., J. N. Sanchirico, B. H. Thompson, and Barton H. 2008. Ocean zoning and spatial access privileges: rewriting the tragedy of the regulated ocean. N.Y. Univ. Environ. Law J. 17: 646–668.

Ehler, C. and F. Douvere. 2009. Marine spatial planning: a step-by-step approach toward ecosystem-based management. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. IOC Manual and Guides No. 53, ICAM Dossier No. 6. UNESCO, Paris. 99 p.

FAO (Food and Agricultural Organization of the United Nations). 2009. State of world fisheries and aquaculture 2008. FAO Fisheries and Aquaculture Department, Rome. 84 p.

Fromentin, J. M. and J. E. Powers. 2005. Atlantic bluefin tuna: population dynamics, ecology, fisheries and management. Fish Fish. 6: 281–306.

Fuller, S. D., C. Picco, J. Ford, C-F. Tsao, L. E. Morgan, D. Hangaard, and R. Chuenpagdee. 2008. How we fish matters: addressing the ecological impacts of Canadian fishing gear. Ecology Action Centre, Living Oceans Society and Marine Conservation Biology Institute, Halifax. 25 p.

Hall, C. M. 2001. Trends in ocean and coastal tourism: the end of the last frontier? Ocean Coastal Manage. 44: 601–618.

Halpern, B. S., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, et al. 2008. A global map of human impact on marine ecosystems. Science 319: 948–952.

Hamilton, S. L., J. E. Caselle, J. D. Standish, D. M. Schroeder, M. S. Love, J. A. Rosales-Casian, and O. Sosa-Nishizaki. 2007. Size-selective harvesting alters life histories of a temperate sex-changing fish. Ecol. Appl. 17: 2268–2280.

Hauser, L. and G. R. Carvalho. 2008. Paradigm shifts in marine fisheries genetics: ugly hypotheses slain by beautiful facts. Fish Fish. 9: 333–362.

Heppell, S. S., S. A. Heppell, F. C. Coleman, and C. C. Koenig. 2006. Models to compare management options for a protogynous fish. Ecol. Appl. 16: 238–249.

Hilborn, R. 2006. Faith-based fisheries. Fisheries 31: 554–555.

_________, J. M. Orensanz, and A. M. Parma. 2005. Institutions, incentives and the future of fisheries. Phil. Trans. R. Soc. Lond. B Bio. Sci. 360: 47–57.

_________, K. Stokes, J.-J. Maguire, T. Smith, L. W. Botsford, M. Mangel, J. Orensanz, A. Parma, J. Rice, J. Bell, et al. 2004. When can marine reserves improve fisheries management? Ocean Coastal Manage. 47: 197–205.

Hutchings, J. A. and J. D. Reynolds. 2004. Marine fish population collapses: consequences for recovery and extinction risk. BioScience 54: 297–309.

Hyrenbach, K. D., K. A. Forney, and P. K. Dayton. 2000. Marine protected areas and ocean basin management. Aquat. Conserv. Mar. Freshw. Ecosyst. 10: 437–458.

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, et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629–638.

Jennings, S., M. J. Kaiser, and J. D. Reynolds. 2001. Marine fisheries ecology. Blackwell Science, Oxford. 417 p.

Juda, L. 2003. Obstacles to ecosystem-based management. Pages 67–71 *in* Global conference on oceans, coasts and islands. UNESCO, Paris.

Kappel, C. V. 2005. Losing pieces of the puzzle: threats to marine, estuarine, and diadromous species. Front. Ecol. Environ. 3: 275–282.

Kellner, J. B., I. Tetreault, S. D. Gaines, and R. M. Nisbet. 2007. Fishing the line near marine reserves in single and multispecies fisheries. Ecol. Appl. 17: 1039–1054.

Kuhn, T. S. 1970. The structure of scientific revolutions. Univ. Chicago Press, Chicago. 212 p.

LaPlante, L. H. and E. T. Schultz. 2007. Annual fecundity of tautog in Long Island Sound: size effects and long-term changes in a harvested population. Trans. Am. Fish. Soc. 136: 1520–1533.

Law, R. and K. Stokes. 2005. Evolutionary impacts of fishing on target populations. Pages 232–246 *in* E. A. Norse and L. B. Crowder, eds. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press, Washington, D.C.

Lester, S. E., B. S. Halpern, K. Grorud-Colvert, J. Lubchenco, B. I. Ruttenberg, S. D. Gaines, S. Airamé, and R. R. Warner. 2009. Biological effects within no-take marine reserves: a global synthesis. Mar. Ecol. Prog. Series. 384: 33–46.

Locke, J. 1690. An essay concerning humane understanding, vol. I. Introductory epistle dedicatory to the Earl of Pembroke. Thomas Basset, London.

Lokrantz, J., M. Nyström, M. Thyresson, and C. Johansson. 2009. The non-linear relationship between body size and function in parrotfishes. Coral Reefs 27: 967–974.

Makkai, T. and J. Braithwaite. 1992. In and out of the revolving door: making sense of regulatory capture. J. Public Policy 12: 61–78.

Marine Conservation Biology Institute. 1998. Troubled waters: a call for action. Signed by 1605 scientists. Available from: http://www.mcbi.org/publications/pub_pdfs/TroubledWaters.pdf.

McClenachan, L. 2009. Documenting loss of large trophy fish from the Florida Keys with historic photographs. Conserv. Biol. 23: 636–643.

McLeod, K. L., J. Lubchenco, S. R. Palumbi, and A. A. Rosenberg. 2005. Scientific consensus statement on marine ecosystem-based management. Signed by 221 academic scientists and policy experts. Available from: http://compassonline.org/pdf_files/EBM_Consensus_Statement_v12.pdf.

Millennium Ecosystem Assessment. 2005. Synthesis report. Island Press, Washington, D.C.

Mora, C., R. A. Myers, M. Coll, S. Libralato, T. J. Pitcher, U. R. Sumaila, D. Zeller, R. Watson, K. J. Gaston, and B. Worm. 2009. Management effectiveness of the world's marine fisheries. PLoS Biol. 7: e1000131.

Munday, P. L., P. M. Buston, and R. R. Warner. 2006. Diversity and flexibility of sex-change strategies in animals. Trends Ecol. Evol. 21: 89–95.

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

_________, J. K. Baum, T. D. Shepherd, S. P. Powers, and C. H. Peterson. 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. Science 315: 1846–1850.

Norse, E. A. 1990. Ancient forests of the Pacific Northwest. Island Press, Washington, D.C. 327 p.

_________, ed. 1993. Global marine biological diversity: a strategy for building conservation into decision making. Island Press, Washington, D.C. 383 p.

_________. 2003. A zoning approach to managing marine ecosystems. Pages 53–57 *in* B. Cicin-Sain, C. N. Ehler, and K. Goldstein, eds. Workshop on improving regional ocean governance in the United States. December 9, 2002. Washington, D.C.

_________. 2005a. Ending the range wars on the last frontier: zoning the sea. Pages 422–443 *in* E. A. Norse and L. B. Crowder, eds. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press, Washington, D.C.

_________. 2005b. Destructive fishing practices and evolution of the marine ecosystem-based management paradigm. Am. Fish. Soc. Symp. 41: 101–114.

_________. 2008. Ocean zoning is inevitable. Mar. Ecosys. Manage. 1: 5.

_________. 2009. Conservation is a policy goal, not a use. Mar. Ecosys. Manage. 3: 1.

_________ and L. B. Crowder. 2005. Why marine conservation biology? Pages 1–18 *in* E. A. Norse and L. B. Crowder, eds. 2005. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press, Washington, D.C.

_________, L. B. Crowder, K. Gjerde, D. Hyrenbach, C. Roberts, C. Safina, and M. E. Soulé. 2005. Place-based ecosystem management in the open ocean. Pages 302–327 *in* E. A. Norse and L. B. Crowder, eds. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press, Washington, D.C.

Ogden, J. C. 2001. Maintaining diversity in the oceans. Environment 43: 28–37.

Olsson, P., C. Folke, and T. P. Hughes. 2008. Navigating the transition to ecosystem-based management of the Great Barrier Reef, Australia. Proc. Natl. Acad. Sci. USA 105: 9489–9494.

Osherenko, G. 2006. New discourses on ocean governance: understanding property rights and the public trust. J. Environ. Law Litigation 21: 317–381.

Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends Ecol. Evol. 10: 430.

________. 2009. EBM opinion: on marine ecosystems, fisheries management, and semantics. Mar. Ecosys. Manage. 2: 5.

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

Pew Oceans Commission. 2003. America's living oceans: charting a course for sea change. Pew Oceans Commission, Arlington, Virginia. 144 p.

Reich, D. A. and J. T. DeAlteris. 2009. A simulation study of the effects of spatially complex population structure for Gulf of Maine Atlantic cod. N. Am. J. Fish. Manage. 29: 116–126.

Roberts, C. 2007. The unnatural history of the sea. Island Press, Washington, D.C. 435 p.

_________, J. P. Hawkins, and F. R. Gell. 2005. The role of marine reserves in achieving sustainable fisheries. Phil. Trans. R. Soc. Lond. B Biol. Sci. 360: 123–132.

_________, J. A. Bohnsack, F. Gell, and R. Goodridge. 2001. Effects of marine reserves on adjacent fisheries. Science 294: 1920–1923.

Rosenberg, A. A. and P. A. Sandifer. 2009. What do managers need? Pages 13–30 *in* K. McLeod and H. Leslie, eds. Ecosystem-based management for the oceans. Island Press, Washington, D.C.

______________, W. J. Bolster, K. E. Alexander, W. B. Leavenworth, A. B. Cooper, and M. G. McKenzie. 2005. The history of ocean resources: modeling cod biomass using historical records. Front. Ecol. Environ. 3: 78–84.

Sadovy, Y. and W. L. Cheung. 2003. Near extinction of a highly fecund fish: the one that nearly got away. Fish Fish. 4: 86–99.

Sanchirico, J. M., J. Eagle, S. Palumbi, and B. H. Thompson, Jr. 2010. Comprehensive planning, dominant-use zones, and user rights: a new era in ocean governance. Bull. Mar. Sci. 86: 273–285.

Sloan, N. A. 2002. History and application of the wilderness concept in marine conservation. Conserv. Biol. 16: 294–305.

Thurstan, R. H. 2009. A 120 year time series of landings and fishing effort data reveals drastic declines in fish abundance in UK and European seas. Presented at Making Marine Science Matter, the 2009 International Marine Conservation Congress, Washington, D.C.

Trippel, E. A., O. S. Kjesbu, and P. Solemdal. 1997. Effects of adult age and size structure on reproductive output in marine fishes. Pages 31–62 *in* R. C. Chambers and E. A. Trippel, eds. Early life history and recruitment in fish populations. Chapman and Hall, London.

Turnipseed, M., L. B. Crowder, R. D. Sagarin, and S. E. Roady. 2009a. Legal bedrock for rebuilding America's ocean ecosystems. Science 324: 183–184.

_____________, S. E. Roady, R. Sagarin, and L. B. Crowder. 2009b. The silver anniversary of the United States' Exclusive Economic Zone: twenty-five years of ocean use and abuse, and the possibility of a blue water public trust doctrine. Ecol. Law Q. 36: 1–70.

U.S. Commission on Ocean Policy. 2004. An ocean blueprint for the 21st century: final report of the U.S. Commission on Ocean Policy to the President and Congress. Washington, D.C. 522 p.

Voltaire. 1765. La bégueule. L'association Voltaire intégral, Oeuvres Complètes de Voltaire, Dictionnaire philosophique, Préface de la cinquième édition.

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

Watson, R. and D. Pauly. 2001. Systematic distortions in world fisheries catch trends. Nature 414: 534–536.

Wilen, J. E. 2004. Spatial management of fisheries. Mar. Resour. Econ. 19: 7–19.

Worm, B., R. Hilborn, J. K. Baum, T. A. Branch, J. S. Collie, C. Costello, M. J. Fogarty, E. A. Fulton, J. A. Hutchings, S. Jennings, et al. 2009. Rebuilding global fisheries. Science 325: 578–585.

Available Online: 11 March, 2010.

Address: *Marine Conservation Biology Institute, 2122 112th Avenue NE, Suite B-300, Bellevue, Washington 98004. E-mail: <elliott@mcbi.org>.*