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[Article]

Exploring Links between Systematics and Fisheries Management

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Abstract.—We argue that the sustainable management of fisheries resources depends on an understanding of the taxonomy and systematics of fish. Toward this end, it is necessary for fisheries managers to understand and apply the various species concepts that have been developed by taxonomists and evolutionary biologists and to decide, based on a philosophical position, what is necessary and sufficient for a taxon to be recognized as a distinct species. If species are viewed as ontological individuals and as such exist in nature, then it makes sense for managers to develop strategies to sustain and manipulate given populations to achieve management goals. In this series of papers, the authors explore species concepts with respect to fish and demonstrate the value of understanding species concepts, systematics, and taxonomy in addressing modern fisheries management problems.

"What's the use of their having names," the Gnat said, "if they won't answer to them?"
"*No use to them*," said Alice, "but it's useful to the people that name them, I suppose. If not, why do things have names at all?"

Lewis Carroll, *Through the Looking Glass*

Biological diversity, defined as the variability (within species) and variation (among species) of organisms as related to their ecology and habitats (Soule and Wilcox 1980; Norse et al. 1986) is being reduced at an alarming rate. Fish throughout the world are threatened by overfishing, the introduction of exotic species, habitat destruction, and anthropogenically induced environmental stresses.

The management of fisheries resources was defined by Rounsefell and Everhart (1953:ix) as

> the application of scientific knowledge concerning fish populations to the problems of obtaining the maximum production of fishery products, whether stated in tons of factory material or in hours of angling pleasure.

Revisions of this definition have included the concept of sustainability (e.g., Ross 1997), but the concept of maximizing benefits to humans has persisted. In North America, the responsibility for the effective management and conservation of fisheries resources is held by federal, provincial, and state agencies. We believe that without proper species identification, effective management of these important resources is not possible.

Determination of the specific status of local taxonomic units is critical for the development of programs that conserve fish for purposes of food, aquaculture, tourism, disease control, and scientific investigations. Recognition of this fundamental link between systematics, taxonomy, and fisheries management—the provision of names for organisms and determination of the phylogenetic (evolutionary history) relationships among them by systematists and taxonomists—began to fade in the early 20th century because fisheries managers believed that most species had already been described (Fischer 1989). The rapid speciation of fish, however, especially in the tropics, has resulted in a paucity of characters for discriminating among species as well as in additional species to manage. Many species are diagnosed by means of molecular genetic characters or internal anatomical differences; thus, rapid field identification is difficult. The discovery of external characters that can be used to delimit species is critical for determining life history, behavior, distribution, and reproductive biology—all of which are needed to devise effective management strategies. Thus, despite perceptions that the majority of fish species have already been described (and perhaps they have in certain areas, e.g., North America), the need for systematics and taxonomy in support of fisheries management, whether in freshwater or marine systems, persists (Collette and Vecchione 1995).

Moreover, the importance of the appreciation and understanding of systematic and evolutionary biology goes beyond the identification of particular critters. For example, predator–prey and host–parasite combina-

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tions generally coevolve. When nonnative species are introduced into complex systems, the whole system is vulnerable, as shown by the introduction of sea lamprey *Petromyzon marinus* into the North American Great Lakes (Smith and Tibbles 1980) and that of Nile perch *Lates nilotica* in Lake Victoria (Witte et al. 2007, this issue).

The papers in this series stem from presentations by the same authors at a symposium held at the 134th annual meeting of the American Fisheries Society in Madison, Wisconsin, in 2004. The theme of that meeting was Aldo Leopold's legacy for fisheries. Among Leopold's many substantive contributions to fisheries management was his recognition of the interconnectedness of all living things and the nonliving things on which they depend. This series of papers explores the importance of systematics and taxonomy to fisheries management, presenting cases in which the lack of systematic information has caused management strategies to fail (see also Collette and Vecchione 1995) as well as cases in which an understanding of the taxonomy and evolution of target species has enhanced management regimes.

Species Concepts

At the core of systematics and taxonomy is the species concept, which in simplified terms entails a philosophical position regarding what a species is (Wiley 2002) along with a set of criteria (e.g., morphological, molecular, and behavioral) that are both necessary and sufficient for a particular taxon to be recognized as a distinct species. Much of the confusion regarding species is a function of semantic confusion, verbal conventions, logical mistakes, and one's philosophical outlook (Stauffer and McKaye 2001). Some of the uncertainty about species is caused by the different ways biologists use the term. Depending on one's world view, a species can be considered either a category or an ontological individual. If one views species as categories (see Gilmour 1940; Haldane 1956; Ehrlich and Holm 1963), then individual organisms exist as separate entities but classes or categories are constructs of the human mind. One can, however, view species not as categories for taxonomists' convenience but as ontological individuals that exist in nature (see Ghiselin 1997; Stauffer and McKaye 2001). The concept of species as individuals was espoused by Mayr (1949, 1969, 1996), Simpson (1961), Hennig (1966), Ghiselin (1969), Dobzhansky (1970), Grant (1971), and Hull (1976). We submit that the premise that species are individuals is essential to the development of sound fishery management strategies. In short, it simply does not make sense to attempt to manage a construct of the human mind. Conversely, if species are regarded as ontological individuals, then they are spatially and temporally restricted. In other words, species originate through a speciation event, evolve over time, and cease to exist when they become extinct. Viewed in this context, it makes sense for fisheries managers to develop strategies to prevent extinction events, increase harvest levels, and address questions relative to native and exotic species.

Statement of the Problem

The attempt to define species has provoked more arguments than perhaps any other topic in comparative or evolutionary biology (Eldridge 1995). Wilson (1992) referred to the search for a species concept that accurately represents the diversity of life as the quest for the "Holy Grail" of the natural sciences. Darwin (1859:49) recognized the difficulty in delimiting species when he wrote,

> It must be admitted that many forms, considered by highly competent judges as varieties, have so perfectly the character of species that they are ranked by other highly competent judges as good and true species.

Mayden (1999) lists 22 different species concepts. Obviously, the problems in characterizing, delimiting, and understanding species or species concepts, which were also addressed by Nelson and Hart (1999), are not going to be solved in this series of papers. The purpose of these papers is to elucidate the problem as it impacts fisheries management and to illustrate the importance of being aware of the different strategies that will emerge depending on one's view of species.

Wiley (2007, this issue) discusses the importance of understanding how the different species concepts affect the way fisheries managers view the world and develop management strategies. He emphasizes the ways in which one's philosophical view of species may influence the development of management strategies. Toward this end, Courtenay (2007, this issue) states quite clearly that you cannot manage what you do not know. He further notes that many fish systematists have retired in recent years and that fewer students are being trained in fish systematics. Nevertheless, more than 100 new fish species have been described in the journal *Copeia* since 2000, more than 20 of which occur in North American waters, arguably the best understood fish community in the world. Nelson (2006) reported that worldwide more than 300 new fish species have been described *each year* since 1976, with a total of 740 new species descriptions or range extensions in the United States and Canada alone between 1960 and 2004. Witte et al. (2007) traces the catastrophe afflicting Lake Victoria fish fauna following the introduction of the Nile perch and discuss the

differential impacts at the species, trophic group, and community levels. Stauffer et al. (2007, this issue) identify the problems of managing the diverse fish fauna as biological controls for a human disease. Moreover, several of the authors of Stauffer et al. (2007) are practicing taxonomists or systematists who have described species from Lake Malawi and are adherents primarily to the evolutionary species concept. Stauffer et al. (2007) underscore the importance of one's species concept when describing new taxa and give examples that (1) lend support to the notion of species as individuals, (2) provide evidence that fisheries managers ought to care about species concepts, and (3) add support for the contention in the previous paragraph that viewing species as individuals is essential to the development of sound fisheries management strategies.

Fisheries management in the 21st century will become increasingly focused on conserving the biodiversity of fish and the organisms and environments on which they depend. This point is at least implicit in all of the articles in this series and in our view is one of the primary links between systematics and fisheries management. In essence, taxonomists and systematists provide the names, descriptions, and evolutionary relationships of the species that fisheries managers manage and conserve. More than a decade after Collette and Vecchione (1995) reminded us of the necessary links between systematics and fisheries management, our profession still suffers from a lack of integration of these two disciplines. In his Round River essay, Aldo Leopold (1953:190) wrote, "To keep every cog and wheel is the first precaution of intelligent tinkering." We submit that before intelligent management of fisheries can "keep every cog and wheel," managers have to be able to identify the parts, understand the phylogenetic relationships of those parts, and be able to delimit the spatial restrictions of native taxa.

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