Diversity

Flagship umbrella species needed for the conservation of overlooked aquatic biodiversity

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Introduction

Despite a long-standing debate about the utility of species-centered conservation approaches (Roberge & Angelstam 2004), surrogate species remain popular because they provide useful—or even necessary—shortcuts for successful conservation programs (Caro 2010). Flagship species, a prime example of a surrogate, are primarily intended to promote public awareness and to raise funds for conservation (Veríssimo et al. 2011). In contrast, the protection of umbrella species is expected to benefit a wide range of co-occurring species (Roberge & Angelstam 2004; Caro 2010). Accordingly, the main criteria for selecting flagship species should be based on sociocultural considerations, whereas umbrella species should be chosen principally based on ecological criteria (Caro 2010; Veríssimo et al. 2011) (Table 1). Because these 2 concepts are often confused or mistakenly

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Table 1. Selection criteria for conservation flagship and umbrella species and problems and solutions related to their application to freshwater species.

	Criteria	*Problem*	*Solution*
Flagship species	easy to observe	inconspicuous or cryptic	focus on flagship species specific for each target group (Castello et al. 2009; Ebner et al. 2016);
	anthropomorphic features	anthropomorphic features rare in freshwater species	focus on material and nonmaterial values;
	low taxonomic distance from humans	taxonomically more distant from humans than terrestrial species	public outreach on their conservation needs
	body size	largest freshwater organisms do not reach the dimensions of their terrestrial or marine counterparts	
	publicly perceived extinction threat	low public awareness of the conservation needs of freshwater species	
Umbrella species	large range size	inconspicuous species in a hardly accessible and opaque habitat that makes observing and studying them laborious, time-consuming, and expensive; species often highly mobile with complex spatiotemporal behavior	eDNA and other metabarcoding approaches;
	co-occurring target biodiversity		new and updated biodiversity databases (e.g., Collen et al. 2014; IUCN Red List)
	complex habitat requirements overlap those of sympatric species		

used interchangeably, Caro (2010:248) coined the term *flagship umbrellas* to describe species that explicitly integrate both functions. Li and Pimm (2016) recently demonstrated that the classic flagship species, the giant panda (*Ailuropoda melanoleuca*), can simultaneously act as an umbrella species because its protection benefits many co-occurring endemic mammals, birds, and amphibians. This challenges the often-held views that the umbrella concept has to be abandoned because it is not working efficiently at local scales (Caro 2015); that most flagship species are weak predictors for use in reserve planning (Caro 2010); and that ecosystem- or landscape-based conservation approaches should consequentially be favored over species-based approaches when feasible (Roberge & Angelstam 2004; Caro 2010). Furthermore, there is an increasing demand for a paradigm shift in conservation strategies to specifically target hidden or neglected biodiversity for its intrinsic value and its contribution to ecosystem processes (Dougherty et al. 2016).

We call for an updated conservation framework that covers multiple scales and all organisms, from single-celled organisms to vertebrates. We specifically focus on freshwater ecosystems to elaborate on the essential components of such a unified framework and on the usefulness of the flagship-umbrella approach. Freshwaters are of particular interest here because freshwater species face disproportionate extinction risks (Collen et al. 2014); conservation research and practice are insufficient for freshwater species relative to the anthropogenic threats they face (Supporting Information); inexpensive and noninvasive molecular tools for species detection have been developed and successfully tested in freshwater ecosystems (Hänfling et al. 2016); and the flagship approach has predominantly been deployed in the terrestrial realm, whereas there is little systematic research on the effectiveness of freshwater flagship species. Hence, we addressed the following questions: Which criteria should guide the selection of freshwater flagship umbrella species and what candidate species are discussed in the literature? What are the major obstacles to and what is necessary for successful implementation of the flagship-umbrella approach in freshwater conservation planning and evaluation? We suggest development and testing of conservation programs that take full advantage of the benefits of the flagship-umbrella approach by conceptually integrating them with ecosystem-based approaches to conservation.

Criteria for Selecting Freshwater Flagship Umbrella Species

The most important features of an effective umbrella species are a large range size and complex habitat requirements (Roberge & Angelstam 2004; Caro 2010; Table 1). The effectiveness of the flagship function, in contrast, has to be evaluated on a sociocultural and economic basis (Veríssimo et al. 2011). Because criteria for flagship-species identification were primarily developed with terrestrial species in mind, applying them to freshwater species poses several challenges, such as the greater taxonomic distance of freshwater species to humans and the difficulties of observing these organisms in their natural environment (Table 1). One solution may be to target freshwater species that invoke human emotions because they have been a traditional food resource or are already integrated into established conservation programs (e.g.,

Figure 1. Some freshwater species that have been suggested as flagship species: (a) baiji (Lipotes vexilifer) *(photo by S. Leatherwood); (b) European sturgeon* (Acipenser sturio) *(photo by A. Hartl; (c) Siberian Crane* (Leucogeranus leucogeranus) *(photo by C. Wu); (d) freshwater pearl mussel* (Margaritifera margaritifera) *(photo by J. Berglund); (e) yellow-winged darter* (Sympetrum flaveolum) *(photo by A. Karwath); (f) and Roti Island snake-necked turtle* (Chelodina mccordi) *(photo by M. Kořínek).*

the arapaima [*Arapaima* spp.] in the Brazilian Amazonas [Castello et al. 2009]; and the red-finned blue-eye [*Scaturiginichthys vermeilipinnis*] in the Lake Eyre basin in Australia [Kerezsy 2014]). Ebner et al. (2016) proposed 3 main criteria to select potential flagship freshwater fishes for Australia based on their size, trophic position, and conservation status. Moreover, they defined and discussed different stakeholder perspectives that are important when applying the flagship-species concept (Ebner et al. 2016). However, a focus on large fish will not always be sufficient for successful freshwater conservation programs (Ebner et al. 2016) because, for example, locally restricted and small ecosystems such as ponds or artesian springs do not host large fishes. The small organisms living there, however, might also be suitable flagship species (Kerezsy 2014). Ideally, future attempts to evaluate flagship umbrella species should therefore adopt a multidisciplinary approach to assess a species' potential to attract public attention and funding for conservation programs as well as its potential to protect co-occurring biodiversity in all types of freshwater habitats. Toward this goal, we identified over 60 potential freshwater flagship umbrellas across the globe—multiple species and higher taxa—by scanning the conservation literature for proposed candidates. (See Fig. 1 for examples and Supporting Information for a complete list and methods.)

Selecting and Evaluating Freshwater Umbrella Species

In contrast to the flagship function, umbrella species should be selected based on high co-occurrence between them and other components of biodiversity (Table 1). However, previous work evaluating umbrella species has focused almost exclusively on terrestrial systems (Branton & Richardson 2011). Another general problem when evaluating the suitability of umbrella species is the limitations of current data sets. For instance, Li and Pimm (2016) note that data on species potentially protected by conservation of the giant panda are restricted to a few vertebrate groups. Clearly, more efficient planning and evaluation of conservation efforts requires more comprehensive information about biodiversity distribution, particularly for nonvertebrates. Obtaining this information in aquatic environments is particularly time-consuming, but global data sets of freshwater invertebrate distributions have been compiled recently for freshwater crabs, crayfish, and shrimps, and information for many regions is available for fishes, odonates, and molluscs (Collen et al. 2014; IUCN 2015). These data sets provide a timely opportunity for evaluating the potential use of umbrella species in freshwaters.

Furthermore, recently developed molecular methods are becoming increasingly affordable for biodiversity monitoring. The analysis of environmental DNA (eDNA) combined with high-throughput sequencing (DNA metabarcoding) is an excellent source of information on aquatic species (Creer et al. 2016; Hänfling et al. 2016). The DNA metabarcoding allows identification of multiple species from water samples or from bulk samples containing entire organisms. These cost-efficient tools allow collection of data on aquatic biodiversity and provide comprehensive information on entire communities. Until now, eDNA has not been used widely in conservation assessment or planning, and its interpretation and application still requires methodological development (Creer et al. 2016). Even though biodiversity data obtained through eDNA are not identical to data obtained through classical approaches, results relative to community structure and stress response are similar, and eDNA data are sometimes more accurate than data derived from traditional approaches (Hänfling et al. 2016).

These new tools can be combined with the new data sets on freshwater species distributions of the International Union for Conservation of Nature (Collen et al. 2014; IUCN 2015), which will allow for the development of a more complete, integrated approach to freshwater conservation. Together, such an advanced, evidence-based foundation for reserve planning and biodiversity assessment will improve the suitability of conservation programs, potentially protecting the multiple facets of diversity—from genes to ecosystems—with greater temporal and spatial accuracy.

Unifying Species- and Ecosystem-Based Conservation

The tools for successful implementation of conservation approaches based on single species are now available and should be applied increasingly to enhance freshwater biodiversity conservation. Comprehensive databases on freshwater biodiversity and emerging molecular tools will help with the integration of previously neglected biodiversity into management planning and evaluation. In this way, they will improve the utility of the flagship-umbrella approach and help achieve the ultimate goal of identifying efficient flagship umbrella species for aquatic ecosystems that function, so to speak, as freshwater pandas.

However, successful development and implementation of future approaches to protect biodiversity need the mutual efforts of conservation scientists and practitioners regardless of their main motivation and background (Green et al. 2015), which will consequentially include species-based and ecosystem-based approaches. Khoury et al. (2011) showed for the catchment of the upper Mississippi River that the combined implementation of "fine-filtered" (i.e., species) and "coarse-filtered" (i.e., ecosystem) conservation approaches is not only possible, but it even improves outcome and accuracy in conservation planning. Moreover, there is a growing consensus that only the joint efforts of people inside and outside academic conservation science can guarantee successful and sustainable protection of global biodiversity (Khoury et al. 2011; Green et al. 2015; Ebner et al. 2016). Hence, we believe Dougherty et al.'s (2016) call to boost conservation efforts to encompass hitherto overlooked and neglected biodiversity is timely and justified.

It is true that the conditions for nature conservation have changed remarkably since the 1960s, when the World Wildlife Fund established the panda as the first flagship species decades before the term *biodiversity* became fashionable in the 1990s. Still, we believe the unique potential of many flagship species to engage society cannot be dismissed before such an updated flagship umbrella concept has been implemented and evaluated. Here, we show conceptually how such extended species-centered programs that follow clear guidelines for their sociocultural and ecological functions will likely work in favor of those parts of biodiversity that have been overlooked and neglected. This endeavor can only be successful if conservation scientists focus on the full range of biodiversity—from the smallest to the largest, from the most charismatic to the least appealing—and work together with practitioners and stakeholders to help save the amazing diversity of all forms of life on this planet (Green et al. 2015; Dougherty et al. 2016).

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Supporting Information

Detailed methods and results on the assessment of the conservation research effort towards freshwater species and a list of potential freshwater flagship umbrella species (Appendix S1) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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