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River doctors: Learning from medicine to improve ecosystem management

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ABSTRACT

Effective ecosystem management requires a robust methodology to analyse, remedy and avoid ecosystem damage. Here we propose that the overall conceptual framework and approaches developed over millennia in medical science and practice to diagnose, cure and prevent disease can provide an excellent template. Key principles to adopt include combining well-established assessment methods with new analytical techniques and restricting both diagnosis and treatment to qualified personnel at various levels of specialization, in addition to striving for a better mechanistic understanding of ecosystem structure and functioning, as well as identifying the proximate and ultimate causes of ecosystem impairment. In addition to applying these principles, ecosystem management would much benefit from systematically embracing how medical doctors approach and interview patients, diagnose health condition, select treatments, take follow-up measures, and prevent illness. Here we translate the overall conceptual framework from medicine into environmental terms and illustrate with examples from rivers how the systematic adoption of the individual steps proven and tested in medical practice can improve ecosystem management.

1. Introduction

Human activities are now shaping the earth surface (Vitousek et al., 1997; Foley et al., 2005) to an extent that many contend a new geological epoch has begun, the Anthropocene (Zalasiewicz et al., 2010; Ruddiman et al., 2015). The accelerated transformation of earth is beginning, in turn, to threaten human society itself (Gleick and Palaniappan, 2010; Steffen et al., 2015), prompting calls for adopting sustainability principles and ecosystem stewardship (Chapin et al., 2010). These goals require an effective methodology to manage ecosystems to maintain biodiversity and ensure the continued provision of ecosystem services valued by society (Zhenga et al., 2013; Costanza et al., 2014).

Rapport (1995) pointed out that the similarities between ecosystem integrity and human health and its assessment go beyond an analogy, although this recognition has not gained strong traction. Indeed, apart from controversial discussions about whether ecosystem health is a valid scientific concept (Jax, 2010), there have been few attempts to scrutinize the degree to which principles and practices from medicine can be useful in ecosystem management. The central tenet of this paper is that much can be learned from how patients are diagnosed, treated and subsequent illness prevented, to improve the ways in which ecosystems are assessed and restored, and undesirable conditions avoided in the first place, since the fundamental methodological issues are strikingly similar. Therefore, the conceptual framework of medical health protocols holds tremendous potential to benefit ecosystem management by appropriately translating concepts and practices (e.g. Barton et al., 2015). This tenet is independent of whether one subscribes or objects to the concept of ecosystem health (Rapport et al., 1998; Simberloff, 1998; Karr, 1999; Boulton, 1999; Meyer et al., 2005; Jax, 2005). An important advantage of adopting the medical analogy is that it provides common intuitive ground of concepts and terms, which facilitates interactions among different people and disciplines participating in ecosystem management (scientists, policy makers, stakeholders etc.). Although is clear that one cannot ignore the fundamental difference between humans and ecosystems, which, for instance, neither reproduce nor die, this recognition does not invalidate the usefulness of the parallel.

Conventional medicine is the result of knowledge accumulated at least since the Greek physician Hippocrates over 2500 years ago. Nevertheless, it has only been during the last 150 years that great leaps forward have been made, with medical innovation and improvements

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rapidly accelerating at present. The success of conventional medicine lies in its systematic approach, its capacity to adopt scientific and technological innovations, its use of controlled trials and detailed case-studies as sources of evidence, and also its adherence to a suite of basic principles, along with substantial resourcing for research and patient-centered care. As we illustrate below, these points can be adapted to ecosystem management. Many have already been applied in various contexts, but we argue that substantial further benefits can be gained from systematically embracing the principles of medical practice as a whole.

Here we first identify a series of key medical principles to highlight their potential for ecosystem management. Then we illustrate how specific steps of the medical methodology (i.e. how physicians approach and interview patients, diagnose their condition, select treatments, take follow-up measures, and prevent illness) can be translated into ecosystem management. Finally, we highlight a set of treatment rules that have proven powerful in medical practice. The specific examples relating to ecosystem management that we provide are drawn from rivers to ensure a tangible and coherent account (Table 1), but we expect that the general lessons we derive are similarly applicable to other types of ecosystems.

2. Embracing medical principles

Despite the diversity of medical fields, all physicians follow a series of core principles. Six among these appear to be especially relevant for ecosystem management.

2.1. Understanding structure and function

The first principle is to base practice on a detailed understanding of the anatomy, physiology and functioning of the healthy human body. Similarly, ecosystem management is best based on mechanistic insights into the structure of ecosystems unaffected by anthropogenic pressures (i.e. their constituent elements, including organisms and abiotic factors, their spatial configuration and temporal dynamics) and into the processes that connect the individual elements. The functional dimension of ecosystems has long been ignored in river assessments, although an emerging awareness of its importance (Bunn et al., 1999; Gessner and Chauvet, 2002) increasingly leads to including functional indicators in assessment protocols (Young et al., 2008; Yates et al., 2014). The consequence of adopting these principles is that continuous investment is required to improve understanding of the structure and functioning of unaffected ecosystems that serve as benchmarks to evaluate impacts.

2.2. Identifying causes and mechanisms

A second medical principle rests on the premise that the causes and mechanisms of an illness should be understood before prescribing a cure, so the odds are high that the treatment is effective and does no harm. During much of human history, disorder and disease were erroneously interpreted as a result of agents such as evil spirits and disequilibrium in vital force (Maher, 1999; Ismail et al., 2005). Finding an effective cure on this basis was a matter of luck combined with past experience, and medical advances were slow. Today, the causes of a vast number of illnesses have been identified, including external agents such as infectious diseases or poisons, internal physiological or genetic disorders, dietary deficiencies, or disorders with mixed causes. The underlying mechanisms are often well understood at levels ranging from biochemical reactions to global epidemic outbreaks.

Similarly, changes in ecosystems can be caused by external agents (e.g. pollutants, invasive species), internal factors (e.g. natural changes in species distribution or population genetic structure) or, commonly, mixed causes (multiple stressors). Changes caused by internal factors may not be perceived as impairment, thus limiting the analogy between human bodies and ecosystems. However, since natural processes can lead to undesirable states of ecosystems, for example from a conservation or productivity point of view, the fundamental problems posed to ecosystem management and physicians in practice still remain very similar. Irrespective of the nature of ecosystem change, it is critically important for taking effective management measures to identify the proximate (e.g. excessive nutrient supply) and ultimate (e.g. climate or land-use change) factors causing a particular symptom (e.g. lack of fish or excessive algal growth).

2.3. Defining goals depending on context

Individual medical fields differ in their focus and specific goals. Routine checks involve basic techniques to detect incipient health problems and assess the general health status of a broad population. Sports medicine, in contrast, seeks to maximize physical performance in an elite group of athletes. Plastic surgery focuses on aesthetics, which may or

Table 1
A selection of parallels between medicine and river ecosystem management.

Focus	General purpose	Medicine	River management
Diagnosis	Routine examination	Body temperature, heart rate, physical examination, weight, breathing (asthma, silicosis, pneumonia…)	Water temperature, flow, river habitat survey, conductivity, oxygen deficit (ground water, organic matter…)
	Specific test	Blood examination, electrocardiogram	Detailed water chemistry, oxygen dynamics, hydrology
	Microbiological diagnostics	Microbiological analysis of pathogens	Microbiological analysis of pathogens
	Structural integrity	Radiology, physical examination	Community composition of biotic elements
	Poisoning	Toxicology	Ecotoxicology
	Risk assessment	DNA analyses for tumor screening and tumor susceptibility	Molecular community analyses to detect invasive species
Treatment	Structure restoration	Regenerative surgery	Channel restoration
	Physical elimination of problem	Tumor removal	Dam, levee or pipe removal
	Aesthetics	Plastic surgery	Landscaping
	Improvement of nutrient balance	Diet restriction	Nutrient control
	Remediative medication	Insulin injection	Liming
	Palliative treatment	Dialysis	Flushing flow releases
Prevention	Guidelines	Healthy life-style	Best management practices, sound resource management planning
	Regulation	Health and safety regulation	Environmental regulations
	Protection	Condom, sunscreen	Bio-security measures to prevent spread of invasives, waste water treatment plants
	Enhance resilience	Wound-healing drugs	Enhance river connectivity
	Enhance resistance	Vaccination	Maintenance of genetic diversity
	Education	Health education	Environmental education