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Lake management in 2030—Five future images based on an international Delphi study

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ABSTRACT

The freshwaters of the world are facing enormous pressures and demands. Eutrophication is a widespread problem threatening the biodiversity and usability of waters. Unfortunately, the means to alleviate eutrophication are either difficult to realize, inefficient, or effective only on the short-term. In addition, the use of various means is laden with interests, contradictory values and cultural goals, which further complicate the wicked problem of eutrophication and lake management. To scrutinize the problem, a two-round, international Delphi study was carried out. This paper uncovers lake experts' views on how eutrophic lakes will and should be managed and restored in the future up to 2030. Through cluster analysis, the variety of the views of the experts was condensed into five coherent future images: *Business as Usual, Let's Heal the Lakes, No More Nutrient Discharges, Back to Nature,* and *Dystopia*. The Delphi panel evaluated the *Business as Usual* as the most probable and the *Let's Heal the Lakes* as the most preferred of the future images. In this paper, we discuss the future images, their preconditions and policy requirements. We also discuss the concept of future images as well as methodological characteristics of relatively large Delphi panels.

1. Introduction

Freshwater is a fundamental resource that societies depend on and increasingly exploit (Postel, 2000; Rockström et al., 2009). The continuous flows of nutrients to surface waters have resulted in eutrophication that diminishes the biodiversity and restricts the various uses of freshwaters (Cooke et al., 2005; Smith & Schindler, 2009). It has been considered that the eutrophication induced by excess phosphorus and nitrogen flows is one of the most obvious and prevalent water quality problems that needs to be acted on (Rockström et al., 2009; Schindler, 2012).

External nutrient flows have been successfully diminished at many sites through improved wastewater treatment, but the problems usually continue due to the external nutrient flows from diffuse sources, such as agriculture, forestry, and diffuse dwellings (Cooke et al., 2005). In addition, the nutrients previously settled in sediments of water bottoms tend to be released back in the water column due to various mechanisms (Søndergaard et al., 2003). Lake *management* refers to many kinds of operations that aim to improve, restore, or preserve the lake water quality or to prevent the anticipated problems, while lake *restoration* refers more restrictedly to actions that aim at restoring a certain, often quite subjectively determined, pre-disturbance state Cooke et al., 2005; Higgs, 2003).

The objective for the management and restoration of lakes can be biodiversity restoration, or a more human-centered objective, such as safeguarding the fresh water supply for human communities, improving recreational opportunities or fishing conditions, or

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landscape conservation. The management and restoration actions may be guided by policy targets, such as reaching "good" state of surface waters, as stated in the Directive, 2000*EU's Water Framework Directive (Directive 2000/60/EC)*. Ecosystems that are being restored are resilient to change, and therefore the success of restoration efforts is often difficult to evaluate (Carpenter & Cottingham, 1997; Jeppesen et al., 1991; Suding et al., 2004). Even the most obvious means to combat eutrophication, decreasing the external nutrient loading, does not usually lead to fast improvements in lake water quality (Jeppesen et al., 1991; Marsden, 1989). In addition, the diffuse sources contributing considerably to the total loading are challenging to manage (Schindler, 2006). However, it is generally considered that a precondition for restoring eutrophic lakes in the long term is to reduce the external nutrient loading by decreasing the discharges from the point and diffuse sources and/or to reduce the nutrient flows to lakes (Cooke, 2005; Mattila, 2005).

Several lake restoration methods have been used in order to alleviate eutrophication, but as the lakes constantly evolve, the outcomes of simultaneous management procedures are not easy to confirm (Søndergaard et al., 2007). The Finnish Environment Institute (Väisänen & Lakso, 2005) have found applicable and recommend *artificial oxygenation* (for details, see e.g. Beutel & Horne, 1999), *biomanipulation* (e.g. Jeppesen et al., 2012), *hypolimnetic water withdrawal* (e.g. Nürnberg, 2007), and the *chemical inactivation of phosphorus* (e.g. Lürling et al., 2016) for diminishing the internal nutrient loading from the sediments, and *raising and controlling the water level* (e.g. Coops & Hosper, 2002), *removing macrophytes* (e.g. Cooke et al., 2005), and *dredging* (Cooke et al., 2005) for multifunctional lake management, such as improving the opportunities for boating or swimming. Applicability of the restoration and management methods in each case should be determined by the objectives of the project and an analysis on the characteristics of the lake (morphology, hydrology and physical, chemical and biological parameters) and the catchment area (sources of nutrient loading, and the characteristics of the catchment) (Cooke et al., 2005; Väisänen & Lakso, 2005). However, the outcomes of the restorations seem to have an effect only on the short term (Søndergaard et al., 2007).

Despite the challenges, there is an evident need for improvements in lake water quality. The forcing policy in the EU, the Water Framework Directive (WFD), requires actions in order to reach a good state of all waters, by the year 2027, at the latest (Directive 2000/60/EC). Also outside the EU, there is a need to improve lake water quality, even though forcing policies may vary or not exist. It has been evaluated that climate change will negatively affect the lake water quality in the future, which presents an additional challenge for the restoration practices and policies (Jeppesen et al., 2009; Jeppesen et al., 2017; Whitehead et al., 2009).

Thornton et al. (2013) have shown that the eutrophication of waters is a "wicked problem" (concept from Rittel & Webber, 1973), meaning that there is no easy diagnosis or resolution for the problem and outcomes of the attempts to resolve the problem are not completely understood and usually bring out other problems. It should therefore be considered from various perspectives to discover possible solutions. In addition to the natural scientific knowledge on lake dynamics and ecological responses to different remedying actions, there is a need to study the societal aspects of the topic, because the goals of the restorative actions are based on array of economic, social, cultural, political and moral factors, in addition to ecological ones (Higgs, 2003).

Expectations, hopes, fears and future images of people deeply specialized in lake management should be explored, since these mental constructions direct the actions and decision-making on what measures can and will be taken to alleviate the problems (Rubin & Linturi, 2001). Future images are tools to scrutinize the alternative futures of a topic and to recognize the factors that can be influenced to realize the desired future (Rubin & Linturi, 2001). The future of lake management has been studied in the light of changing climate, but we have found no research on future images and expectations of experts of lake management. Yet, every decision to manage or restore a lake is aimed towards a preferred future or a reaction to a perceived probable future, and thus future images play a central role in lake management, as well.

The purpose of this study is to uncover lake scientists' future images concerning the alternative futures of lake management and restoration up to the year 2030. The Delphi method is commonly used to explore diversified expert insights on the future of a complicated issue, and therefore, we conducted a two-rounded Delphi study and based on a cluster analysis on the responses, alternative, coherent images for the future were created. The images reveal alternatives for future developments and assist in the considerations on the desirable, non-desirable, and plausible futures (Masini, 1993). The target year 2030 was chosen as it is considered that already by then remarkable changes will have to be executed in the European lakes due to the WFD.

2. Research methodology

2.1. Scenarios and images of the future

Scenarios and images of the future are two disparate concepts yet bearing a set of similarities in nature. Scenarios refer to narrative accounts of alternative futures enunciating a set of hypothetical sequence of events, leading from present-day dynamics to future circumstances (Godet, 1994; Jantsch, 1967; Kahn & Wiener, 1967). An image of the future can be defined as a description of the specific state of things at a specific time of the future (Amara, 1981; Bell & Mau, 1971; Kuhmonen, 2017). Unlike the dynamic features of the scenarios, images of the future are rather static, acting as snapshots of the final outcomes arising from a series of changes (Bell & Mau, 1971).

According to Godet (2000), a scenario should be qualified with two basic features: description of a future situation and the course of events that enables one to progress from the original situation to the future situation). That is, the key factor to distinguish scenarios from hypothesis or even images of the future is their development paths from the present to the future states. Two major categories of scenarios can be identified: exploratory/descriptive scenarios and anticipatory/normative scenarios (Godet et al., 2009; Kaiser et al., 1995; van Notten et al., 2003). Exploratory/descriptive scenarios are learning- and direction-oriented, sorting out the enquiries of 'what will happen?' or 'what can happen?', starting from past and present trends to likely futures (Godet et al., 2009;