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A Systemic-Relational Ethical Framework for Aquatic Ecosystem Health Research and Management in Social–Ecological Systems

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Abstract: This paper argues that if the goal of slowing global ecological degradation, and of sustained improvement in aquatic ecosystem health is to be achieved, then a departure is required from the traditional, discipline-focused approach to aquatic ecosystem health research and management. It argues that a shift needs to be made towards systemic, integrative, and holistic approaches, drawing on diverse disciplines, with values and ethics as fundamental to such approaches. The paper proposes the systemic-relational (SR) ethical framework to aquatic ecosystem health research and management as an essential contribution to addressing the potential intractability of the continuing deterioration of aquatic ecosystem health. The framework recognises the centrality of values in aquatic ecosystem health management, and the role of ethics in negotiating, and constructively balancing, conflicting values to realise healthy ecosystems in social–ecological systems (SES). The implications of the framework in terms of the research-practice interface, decision making, policy formulation, and communication are discussed.

Keywords: aquatic ecosystems; ethics; management; policy; social–ecological systems; values

1. Introduction

The aquatic ecosystems are critical to socio-economic development. Society relies on them for a variety of ecosystem services [1]. However, the continuing deterioration of aquatic ecosystem health globally despite some progress in science and practice with regard to ecosystem health presents a potentially intractable wicked problem. Part of this intractability arises because of insufficient appreciation by both the scientific (e.g., ecologists) and practice (e.g., planners, policy makers, and resource managers) stakeholders of the complexity inherent in the interconnectedness and interdependence between the ecological and social subsystems within any social–ecological system (SES) context. The conceptualisation of the SES recognises that the ecological and social subsystems together form an inseparable, integrated, coupled unitary system, i.e., the SES. We here argue that if the goal of slowing ecological degradation, and of sustained improvement in aquatic ecosystem health, is to be achieved, then a departure is required from the traditional, discipline-focused approach to aquatic ecosystem health research and management. A shift needs to be made towards systemic, integrative, and holistic approaches, drawing on diverse disciplines, with values and ethics as fundamental to such approaches. We take values to be what specific societal groupings or constituencies express or believe at a generalised level to be good or bad, and ethics as a systematic concern with the principles by which conduct, morals, and values are clarified and justified, as we seek to distinguish between right and wrong in our behaviour towards other people and towards nature [2].

In this paper, we propose the systemic-relational (SR) ethical framework to aquatic ecosystem health research and management as an essential contribution to addressing the potential intractability
of the continuing deterioration of aquatic ecosystem health. The paper has six main parts. In Section 1 (introduction), we revisited and analysed the concept of ecosystem health, and placed it within the SES context, arguing that it is an integrative rather than a pure ecological framing. In Section 2, we present the traditional view of ecosystem health, and tools, indicators, and approaches currently used for its assessment. We posit that the traditional biophysical approach only deals with the ecological component of the SES, and therefore not sufficiently integrative, and therefore unlikely to slow the current trajectory of the deterioration of ecosystem health. We then presented (in Section 3) the SR as an integrative framework for aquatic ecosystem health research and management in the SES. An argument is made in Section 4, that value judgement permeates all aspects of the use and protection of aquatic ecosystem in as much as societal and professional value judgements are involved in defining an acceptable ecosystem health condition. The implications of the SR framework are argued in Section 5, in terms of the imperative for integrative assessment tools, the flow of information, ethics of benefits and costs sharing regarding the ecosystem (dis) services flow, the UN sustainable development goals (SDGs), as well as a call for collaborative research and transformative communication. We conclude (in Section 6) by emphasising that policy, managerial, and research efforts need to be redirected to focus on the SES as an integrated whole, to see it as the unit of worth, towards which decision-making, and developmental and preserving action, is directed.

The SR ethically grounded approach recognises that ecological and social-economic components together form an integrated and dynamic complex system and that these two major components are in ongoing complementary and co-supportive interactions, with multiple, cross-scale dynamic feedbacks [2]. The approach recognises the centrality of values in aquatic ecosystem health management, and the role of ethics in negotiating, and constructively balancing conflicting values in order to realise healthy ecosystems. It postulates that within the SES, values relate to and are derived from the SES as a whole, its components as well as the relationships between the components and from the emergent properties of the system [2]. In this paper, we thus propose an SR ethical framework for integrative and holistic aquatic ecosystem health research and management in the SES. Before proceeding to lay out the perspective of the SR framework to aquatic ecosystem health research and management, it is critical to briefly analyse what is meant by aquatic ecosystem health, as well as the approaches and indicators with which it is currently being assessed.

In the 1990s ecologists led the debate on whether or not the concept of ecosystem health, being value-laden, was amenable to scientific analysis [3–5]. Since then, it has gained scientific acceptability and ecologists, policy makers, and resource managers now widely and frequently use the term to describe ecological conditions, using a variety of indicators and endpoints [6,7]. It is not our intention to provide a review of aquatic ecosystem health research as this has been done elsewhere (e.g., [7]), but to provide some analytical consideration of the concept of ecosystem health as a point of departure for our argument.

We agree with [5,8] who distinguishes aquatic ecosystem integrity from health, with the former referring to a state or condition in which the natural processes, structure, dynamics, activities, functions, and all related biophysical attributes of an ecosystem, are maintained with no human or with minimal human influence, and are only influenced by natural evolutionary and biogeographical processes; and the latter (health) referring to a human construct (i.e., value-laden), describing a preferred or an acceptable condition of an ecosystem that has been influenced by humans [5,9]. Thus, the concept of ecosystem health recognises that humans are an integral component of the ecosystem and that the continuing supply (sustainability) of ecosystem services is necessary for sustainable human development [10]. Ecosystem health can therefore be viewed as having two components: the biophysical component (referring to the state of the biological, physical, and chemical conditions of the ecosystem) and the social-economic component, which depends on the supply of vital ecosystem services to meet human social-economic development. The continuing supply of ecosystem services is dependent on the maintenance and functionality of the processes, organisation, structure, and function of the biophysical component of the ecosystem [9]. Thus, a “healthy” aquatic ecosystem
is that which has the capacity to provide social-economic benefits (benefits flowing from ecosystem services) while still being able to sustain its ecological functioning.

Inherent in the concept of ecosystem health, are the notion of human dependence on aquatic ecosystems, as well as the capacity of human activities to alter ecosystem properties, so that sustainability can only be achieved if there is a balance between human uses of ecosystems and their protection. The achievement of this balance must be guided by ethical considerations, taking into account the distribution of costs and benefits between all stakeholders (both present and future generations) and environmental externalities. This would involve selecting and invoking criteria to relate societal values to each other, and to determine the relative value given to human and non-human components of the ecosystem, as well as to shorter and longer term sustainability agendas.

With regard to access to the benefits of aquatic ecosystem services, integrated water resource management (IWRM) ushers in an interest-based, consensus-seeking approach to negotiating access to aquatic ecosystem services. However, the ethical challenge is not only to ensure equal participation by all interested and affected stakeholders e.g., the privileged versus the marginalised, the weak versus the strong, the urban dwellers versus the rural dwellers, the informed versus the uninformed. That is, the challenge is not only a matter of facilitation to bring out the various viewpoints in spite of ‘unequal starting blocks’; it is how to reconcile different principles for taking account of differing viewpoints in taking matters further, such as allowing for those unequal starting blocks, and trade-offs between different value positions. Addressing the underlying power relations, e.g., between the privileged versus the marginalised that shape negotiated access to the benefits of ecosystem services presents a fundamental ethical challenge to resource managers, policy, and decision makers [11]. In this regard, a distinction between practical and ethical challenges needs to be made. With good facilitation skills, managers can ensure that all stakeholders air their views, and all values are documented and accommodated. However, beyond this facilitation process, what is done with the multiple interests for both ecological and social subsystems, perspectives and values and how values are traded off and by what principles and criteria these are done, are fundamental ethical challenges that need to be addressed if benefits accruing from ecosystem services are to be accessed in a manner that is ethically sound.

By access to the decision-making process relating to ecosystem services, we mean the creation of an enabling environment that empowers all stakeholders to have equal voice and influence over decision-making around resource control, use and allocation, as well as the sharing of costs and benefits. A place at the table does not, however, guarantee effective participation in negotiations about a project’s outcome. The danger remains that “participatory approaches may mask different levels of power and influence, exaggerate the level of agreement reached, and expose disadvantaged groups to manipulation and control by more powerful stakeholders” [12]. Stakeholders’ empowerment must be seen as a precondition for effective engagement and participation [13]. Differences in empowerment between stakeholders can be perceived as threats to mutual cooperation, as weaker groups may feel alienated and become resistant to cooperation. In [14], it was noted that although relatively endowed stakeholders in the Sabie Catchment in South Africa for example, seem to cooperate about decision-making around aquatic ecosystem services within their catchments, their appetite for sustained and broad-based cooperation with other stakeholders dwindled over time because of their perception of risks regarding returns on time and effort invested in cooperative deliberations. Thus, risk perception relating to the importance and value of participating in vehicles for natural resource management needs to be addressed as a way of broadening participation in decision-making processes.

A social–ecological system (SES) view of the concept of aquatic ecosystem health has several implications for the research-practice interface. First, the centrality of values regarding multiple claimants to ecosystem services at any given time and place, and the need to identify criteria by which values underpinning such claims can be judged—not only between societal constituencies, but also between societal and ecological constituencies. Second, a clear recognition of the interdependence and mutually constitutive nature of the health of the biophysical and social-economic subsystems
as components of the SES. Third, the inherent and inescapable dependence of humans on aquatic ecosystems through exertion of pressure and consequent ecosystems response, which may supply ecosystem services and disservices [15,16]. Fourth, the ethical implications that the term “acceptable ecosystem health condition” being value-laden, raises, signifying the centrality of collaboration between ecologists and other stakeholders as a prerequisite for addressing the deteriorating ecosystem health, and finally, the imperative for holistic and integrative approaches to addressing the complex, interwoven challenges of the deteriorating aquatic ecosystem health.

We argue that ecologists should take advantage of the full scope of the concept of aquatic ecosystem health to meaningfully engage in research capable of informing practice, particularly with regard to decision making, policy formulation, and resource management—doing so by taking cognisance of the complexity of the SES is where the SR ethical framework for aquatic ecosystem health research and management holds significance. Thus, this paper argues for an SR ethical framework as an enabler of holistic and integrative research and management of aquatic ecosystem health, by taking cognisance of the complexities of the SES within which ecosystems should be viewed and managed.

2. A View of Aquatic Ecosystem Health from the Traditional Ecological Perspective

Traditionally, ecologists have been the primary leaders within the science of ecosystem health, which has had the biophysical component of the SES as its focus. To this end, different approaches and indicators have been developed to assess, evaluate and indicate the health of the biophysical component. The biophysical approach to aquatic ecosystem health research focuses on assessing and indicating the health of ecosystem structure and function [17] without explicit consideration of ecosystem services flow, benefits, and their impact on the social component of the SES. The aquatic ecosystem structure, which relates to the organisation, patterns, abundances, heterogeneity, distribution, and diversity of the biotic and abiotic components of the ecosystem, forms a critical part of the biophysical ecosystem health assessment. Chemical, biological, and physical indicators are the pillars of structural ecosystem health research and management [18,19]. These indicators of ecosystem health are used to assess the departure of the current state of the system from a reference, predevelopment and/or baseline condition. Metals, pesticides, nutrients, dissolved oxygen, pH, temperature, turbidity, and total dissolved solids are examples of physico-chemical indicators of ecosystem health.

The field of biomonitoring/bioassessment is devoted to using biological indicators, from molecular to ecosystem levels, for assessing ecosystem health. It relies on the sound understanding that resident biota (biological indicators) are able to provide an indication of ecosystem health, integrating the effects of chemical, physical, and biological stressors [6]. Commonly used biological indicators include macroinvertebrates, fish, and vegetation [20–22]. Approaches to biomonitoring for assessing ecosystem health include multivariate, multimetric, biotic indices, and the use of multiple biological traits [6]. Apart from physico-chemical analysis and biotic assessment, other aquatic ecosystem structural components often assessed include the habitat heterogeneity and complexity, hydrology and stream morphology, all of which may or may not be integrated to provide a holistic view of aquatic ecosystem health from a biophysical perspective.

Assessing the aquatic ecosystem function is the second component of the traditional approach to ecosystem health research and management [23]. The ecosystem function, which includes material compartments, processes, and fluxes, is critical to maintaining and sustaining aquatic ecosystem health. Processes of the aquatic ecosystem function that are often assessed include nutrient cycling, organic matter processing and decomposition, productivity, biomass turnover, top-down and bottom-up controls, carbon and energy fluxes and pools of materials [24]. As with the structure-based assessment, indicators of the ecosystem function have been developed and the most frequently used in ecosystem health assessments include food web dynamics, leaf litter breakdown rate and decomposition, ecosystem respiration, and an analysis of functional traits and feeding groups [23]. Both the ecosystem structure and function are linked, with the former operating as the organising constraint for the latter [25].
The biophysical approach to assessing aquatic ecosystem health is widely used, and in some jurisdictions, e.g., the United States of America (USA), Europe, Australia, and South Africa, states or their equivalents, are mandated through legislative provisions to monitor the biological, chemical, and physical conditions of aquatic ecosystems, and where necessary to take steps to restore degraded systems to acceptable conditions. The biophysical approach supposes that aquatic ecosystems have an inherent value in their own right, and setting health criteria based on biotic and abiotic components would protect the ecosystem as well as assure the long-term supply of ecosystem services. While this is true to some extent, people may find it difficult to respect such criteria if their aspirations and desired ecosystem services are not considered in setting such criteria, hence the imperative for an integrative approach. Further, the biophysical approach does not go far enough to include the social-economic context inherently embedded in the concept of ecosystem health, because, assurance of ecosystem services supply alone, does not guarantee fair, equitable and just distribution of the benefits and costs arising from such services. Nevertheless, the biophysical approach is widely use for the assessment of ecosystem health in many countries, e.g., [26]. While the approach indicates the health of the structure and function of the ecosystem, which provide the necessary basis for ecosystem services upon which humans depend, we argue that any approach that is not sufficiently integrative of the entire SES is unlikely to slow, halt, and/or reverse the current trajectory of aquatic ecosystem health deterioration. This is particularly true given the overriding influence of humans on ecosystems health in the Anthropocene [27]. Therefore, an integrative approach should integrate the assessments of both the biophysical and social components of the SES, and the ways in which these components interact. Here, we have thus argued for an SR framework for aquatic ecosystem health research and management, integrative of the entire SES.

3. A Systemic-Relational Framework for Managing Aquatic Ecosystem Health

As we have already argued, inherent in the concept of aquatic ecosystem health is the clear recognition of the coupling of social and ecological systems, thus requiring that an SES view is made explicit in the science and practice of aquatic ecosystem health. To do so, a framework that recognises the centrality of values and that develops a systemically interrelated set of environmental ethical principles, which enable working with diverse values is required [2]. The SR framework for ecosystem health management recognises the centrality of values and the overarching importance of ethics in order to achieve healthy systems. Within any given SES context, humans exert pressure on aquatic ecosystems. We argue that the trajectories of such pressure exerted by humans on aquatic ecosystems are largely influenced by societal values (Figure 1). Key drivers of pressure on aquatic ecosystems include escalating human population growth, land use change, economic activities such as agriculture and industry, as well as consumerist lifestyle [28], all of which are partly driven by value systems.

Aquatic ecosystems subjected to pressure often respond, of which a proportion of the response includes the supply of ecosystem services and disservices, components that are respectively beneficial and detrimental to society (Figure 1). For example, a stream system receiving a point source pollution from a wastewater treatment plant may offer the service of waste purification and disposal, but as a part of its broader response may become breeding sites for harmful pathogenic bacteria and disease vectors harmful to society.

Thinking about ecosystem services and disservices is value-laden [29], as various societal constituencies prioritise and rank the relative importance of ecosystem dis (services) in decision-making and policy matters. For example, in some rural African communities [30], certain rivers/parts thereof are considered sacred because they are regarded as places where the ancestors manifest themselves. In such communities, people may act to protect the health of such rivers and to keep them clean because of the high priority accorded to the cultural services provided by the river, yet the same river for a more distant urban dweller may be seen only as a sewage disposal pipe. While the river is valued by both constituencies, the value accorded the river differ in relation to the benefits derived from the ecosystem services. If the ways people relate to and derive value and benefits from
the ecosystems are not made explicit in relation to aquatic ecosystem health research, management, and policy formulation, there is the potential danger of prioritising and ranking certain values over others in relation to the ecosystem services, without rigorous debate and negotiation. Thus, in seeking to address the management of ecosystem health from a holistic SES perspective, the SR framework regards societal values as central to the conception of ecosystem health. It is thus critical to make explicit value systems underpinning claims to ecosystem services in relation to the overarching value of maintaining the overall health of the SES. Debating and reconciling these values in relation to the entire SES is where the SR ethical framework holds significance to aquatic ecosystem health research and management.

**Figure 1.** A systemic-relational framing of a social–ecological system, indicating the centrality of values in relation to the conception of pressure and ecosystem (dis) services. Circles of different sizes are indicative of different interacting constituencies within the social and ecological subsystems.

Human interactions with nature do not only result in the supply of ecosystem services, it may also lead to negative consequences, whether intended or not. Such negative consequences have been termed “ecosystem disservices” [29,31,32]. While there is much debate in the literature regarding
the appropriateness of the concept of ecosystem disservices, and its implications for science and society [31], we have used the concept here to highlight ethical considerations in achieving the health of the SES. We argue that if the ultimate value to be pursued is the overall health and functionality of the SES as postulated by [2], then an explicit attention needs to not be paid not only to the benefits arising from human–environment interactions, but also to the costs arising from such interactions. This is particularly critical because over time, negative effects on any component(s) of the SES, however tangential, may distort the overall systemic functionality of the SES. Further, from a social perspective, people who often bear the most costs of human–environment interactions are the marginalised, tangential groups and the weak, who are hardly visible and are less able to adapt [33]. We thus argue that if the SES functionality is to be sustained, then the benefits and costs arising from ecosystem (dis) services need be to be treated and debated equally in policy and managerial matters, in a manner that all components of the SES, their interactions, and relationships are treated equitably and are accorded equal moral and managerial regard. Such an explicit consideration of ecosystem (dis) services is likely to draw attention of managers and policy makers to the ethical implications of their actions. Our call here has significant implications for the ecosystems research: (i) Distinguishing between disservices arising from inherent ecological processes within ecosystems and those arising because of human transgression of ecological boundaries, (ii) developing the SES indicators for assessing and quantifying ecosystem (dis) services, (iii) developing valuation methods/tools of costs arising from ecosystem (dis) services, (iv) developing communication strategies for ecosystem (dis) services, (v) context-specificity of ecosystem disservices as what might be considered a disservice in one context may not be in another context, and (vi) integrating ecosystem (dis) services and biophysical structure and function within a holistic assessment framework for policy and management.

If the goal of achieving healthy ecosystems is to be realised as captured in the relevant UN SDGs, then the ways in which the components of the SES interact, and the dynamic interactive processes within constituencies in each of the components/subsystem, need to be fully accounted for in research and practice, and treated equitably as far as practically possible in policy and managerial matters. In the SR framework presented in Figure 1, within the social and ecological subsystems, the circular shapes represent different constituencies, e.g., the haves versus the have nots, the urban versus rural dwellers for the social subsystems, and, e.g., taxonomic versus functional richness/diversity, water quality versus quantity for the ecological subsystem. Implicitly, these different constituencies are often treated inequitably in decision-making, represented by different sizes of the circles, where larger circles indicate that it is being accorded a higher value in decision, managerial, and policy matters. The SR framework therefore seeks to highlight the potential danger of such often inadvertent inequitable treatment and thus advocates for equity for all components of the SES as a deliberate managerial strategy.

The SR framework extends equity beyond its conventional use, which is usually associated with social constituencies, e.g., equity between the rich and the poor, gender equity, to include equity between social and ecological constituencies, e.g., equity in water allocation between constituencies of society and those of the aquatic ecosystems. Some progress is already being made in this direction through the implementation of the instream flow requirements [34]. The equity advocated by the SR approach implies due regard for the rights of each of the SES components and their constituencies, without which achieving a healthy aquatic ecosystem within any SES context could be difficult. For example, a social grouping denied access to water services for whatever reason(s), may cause chaos, which may lead to overall SES dysfunctionality. Likewise, continuing pollution of the aquatic ecosystem indicates a lack of due regard to the ecological component of the SES, which may also lead to overall SES dysfunctionality over time.

4. Value Judgement Pervades All Aspects of the Use and Protection of Aquatic Ecosystems in Social–Ecological Systems

As already indicated, human activities exert pressure on aquatic ecosystems, altering their structure, function, and processes. The alteration of ecosystem integrity leads to a particular state of
the aquatic ecosystem health condition and associated ecosystem services (Figure 2). While the natural sciences can provide evidence for the magnitude, frequency, and nature of alteration to ecosystems, it is society that ultimately has to judge what constitutes an acceptable alteration and whether or not the resulting ecosystem health condition is sustainable in perpetuating vital biophysical structure, function, and processes and the supply of associated ecosystem services [35].

Figure 2. Conceptual framework indicating that value-judgements (and thus the need for ethics) pervade all aspects of the use and protection of aquatic ecosystems. Dash arrows are feedback loops, while solid arrows indicate progressive directions.
Biophysical indicators have been developed to determine when an ecosystem health is in ‘good’ or ‘poor’ state from an ecological perspective [18], but in the policy and decision arena, the distinction between “good” and “poor” is the domain of ethics in as much as societal and professional value-judgements are involved. When the health condition is deemed acceptable (value-judgement) based upon the biophysical condition, and the benefits derived from the ecosystem with positive social-economic consequences, no intervention to slow or halt alteration may be needed (Figure 2). However, when the health condition is deemed unacceptable (value-judgement) based upon either the biophysical condition, or diminished ecosystem services supply, interventions such as policy formulation, setting up specific environmental programmes and environmental targets may be initiated.

Depending on the degree of alteration, the extent of ecosystem damage, and the spatial-temporal scales of the damage, the ecosystem may be restored so that it continues to maintain its biophysical processes and also to provide society with benefits. We have argued that an anthropocentric view, with exclusive focus on benefits derived from the ecosystems by humans, or a non-anthropocentric view with the idea of protecting nature for its intrinsic values, are not sufficient to achieve the health of aquatic ecosystems, in as much as they fail to pay attention to the systemic properties and dynamic interactions, relationships, and the emergent properties of the SES. We therefore argued that the SR approach to environmental ethics [2] could better be relied upon in determining when alteration is acceptable or not, and when interventions are necessary to bring the components of the SES, their constituencies, interactions, and properties into balance.

What Then Constitutes an Acceptable Aquatic Ecosystem Health Condition in Social–Ecological Systems?

There is no simple answer to this question, because of the inherent complexity of decisions that are value-laden. In South Africa, for example, a set of biophysical indicators and characteristics are used to assess the degree of deviation of the present state of a site, e.g., of a river from its predevelopment condition, or that condition which would be expected if human impacts/alterations were minimal [36]. Depending on the present state of the site, a recommendation can then be made to restore the health condition to a ‘desired’ future condition. In biophysical terms, the desired future condition is usually expressed between the Ecological Category A–D [36], where A is pristine/natural and D is poor or a largely modified condition. Depending on the recommended desired future condition, several management interventions, including policy formulation/alteration, ecological target setting, designing restoration programmes, and awareness raising, can be triggered.

Values, and ethical contextualisation of these values in relation to aquatic ecosystems, often underpin recommendations for the desired future condition, but this is usually not made explicit in the scientific methods and approaches used in the biophysical assessment processes. For example, in South Africa, in recommending the desired future condition, the present ecological state (PES) and the ecological importance and sensitivity (EIS) are both taken into account [36]. The EIS refers to the importance of the particular aquatic ecosystem in terms of sustaining critical ecological and biodiversity elements and functions, and supplying ecosystem services, as well as the system’s potential to retain its resilience [31]. Aquatic ecosystems considered to be of high EIS are often accorded high protection priority whereas, those with low EIS, low protection priority [37], but in Europe for example, authorities are mandated through the water framework directive (WFD) to restore all waterways to a good ecological condition.

Though not necessarily made explicit, the decision to assign one ecosystem a high protection priority over another, is a reflection of societal value judgements underpinned by various worldviews, as well as the level of risk society is willing to accept in maintaining a prescribed ecosystem health condition. For example, a society with a purely anthropocentric worldview and with a utilitarian and consumerist value system, is likely to have a negotiated threshold of acceptable limit of ecosystem alteration or ecosystem health condition at near one extreme end of the health continuum, provided vital ecosystem services are still supplied, notwithstanding the severe impact human development
could be exerting on the biophysical condition (Figure 3). A practical example is the case of the four dams in the lower Snake River system in the United States of America [38]. The quest for social-economic development without careful consideration of environmental consequences, led to the construction of the four dams on the river—a river vitally important for salmonid annual migration and for the indigenous tribal American population [38]. The construction of the dams, coupled with industrialisation of the catchment, led to pollution and to the obstruction of salmonid migration and to the eventual severe depletion of the salmonid population, until they were designated endangered. This example illustrates some of the implications of upholding a strongly anthropocentric worldview, which we argue as insufficient in upholding the overall health of the SES.

Likewise, a society with a strongly non-anthropocentric ethical position, with a value system of ‘absolute respect’ for nature, may allow for an acceptable limit of alteration to ecosystem integrity near the other end of the health continuum, allowing only minimal development, while ensuring that ecosystems supply only basic human needs (Figure 3). A non-anthropocentric position may drastically undermine claims to human social-economic development. For example, the indigenous tribal Americans within the catchment of the Columbia-Snake River system led a relatively simple life, interwoven with nature—respecting nature, and importantly, the seasonal migration of salmon upriver from the Pacific Ocean [39] and did everything possible to resist western forms of development, which undermine ecological integrity, upon which their lives and those of the salmons depend [40,41]. The SR ethical approach argues for a considered balanced position, recognising the inherent complexity, interconnectedness, and interdependence of social and ecological subsystems. This position, in our view align with the idea of sustainable development, which recognises that social-economic development must not undermine either ecological functioning, or the interactions, relationships, and properties of the SES. From the SR perspective therefore, it is not just about the components, but about the whole SES, and the resultant relationships, emergence, and dynamic interactions. In this regard, the limit/threshold of acceptable pressure on, use, and exploitation of, aquatic ecosystems vis-à-vis acceptable ecosystem health condition, would vary, depending on stakeholders’ ethical standpoints. Thus, what is important is the criteria by which these value judgements are brought to be balanced and reconciled.

![Gradient of ecosystem health](image)

Figure 3. Conceptual relationship between environmental ethical positions/worldview and thresholds of acceptable ecosystem health, showing that the definition of acceptable ecosystem health is influenced by societal value judgement: A (anthropocentric), B (systemic-relational), and C (non-anthropocentric). Ecosystem health continuum adapted from [5].
From the conceptual connection between ethics, values, and aquatic ecosystem health, it is clear that defining an acceptable ecosystem health condition and the threshold of alteration that triggers management actions is not straightforward, since values have both spatial and temporal dimensions [42,43]. For example, differences in attitude and values towards aquatic ecosystems between countries can be stumbling blocks to negotiating political agreements for the integrative management of transboundary river systems, particularly if riparian countries have different and potentially irreconcilable priorities [43].

5. Implications of the SR Ethical Framework for Aquatic Ecosystem Health Research and Management

5.1. A Need for Holistic and Integrative Ecosystem Health Assessment Tools and Approaches

We have tried to argue that the concept of aquatic ecosystem health is sufficiently robust to integrate biophysical and social-economic dimensions of social–ecological systems. Integrative assessment tools, methods, and approaches are therefore needed to indicate the conditions, information flow, and interactive processes between and within the components of the SES Building on the ecosystem service cascade model [44], which depicts the flow of ecosystem services and benefits from the ecological to social subsystem of the SES, we present a conceptual framework for thinking about and developing such integrative tools and approaches, that integrate ethical dimensions of aquatic ecosystem health research and management. The cascade model was developed to illustrate the relationship between the ecosystem services and benefits derived from them and the biophysical processes and structure that support them. Using the cascade and the driver, pressure, state, impact, response (DPSIR) framework as bases, it is possible to develop integrative tools that draw on all elements/components of the cascade to provide an integrative health assessment of the SES [45]. However, as indicated by [44], the cascade does not sufficiently make explicit values and ethical dimensions of the complex SES interactions, feedback, uncertainty, and emergence. We argue that without making explicit such value and ethical issues, achieving the health of the overall SES as envisaged by the SR approach, would be difficult, and almost impossible. This is because values, which are often hidden, play significant roles in the way we behave towards nature and other people, and ethical principles and criteria are thus necessary to interrogate values when they come into conflict [46]. We thus expand the cascade model, indicating the centrality of values and the imperative for ethical principles for sustainable management of aquatic ecosystem health.

As already argued, societal value systems influence the drivers of pressure on aquatic ecosystems, which alter the state/conditions of those systems, producing impacts that can be positive or negative. Society responds, often through measures that enhance the positive impacts and while reducing or minimising the effects of the negative ones. The framework presented in Figure 4 makes explicit the flows of negative and positive consequences of pressure on the aquatic ecosystems. From an ethical perspective, it is critical to pay attention to both dimensions so as to make explicit the flow of benefits and costs to societal constituencies. We take the positive impact of ecosystem response as ecosystem services [47] and the negative ones as ecosystem disservices. Making both positive and negative flows visible enable resource managers and policy makers to think about intended and unintended consequences of their actions, and the ethical implications of having losers and winners within the broader SES. We argue that the concepts of benefits and costs do not only apply to the social components, but to the entire SES. For example, alteration in the state of the aquatic ecosystem may create favourable habitats for certain organisms (beneficiaries of the impact, e.g., the preponderance of non-biting midges population at a sewage outlets in a stream), while eliminating suitable habitats for others (the losers).

While the benefits derived from ecosystem services enhance human well-being, costs on the other hand diminish well-being and ecological integrity (Figure 4). Enhanced and/or diminished well-being may flow into separate societal constituencies (represented by the solid arrows) or the same constituencies (represented by the broken lines between societal constituency and costs/benefit).
In some instances, societal constituencies receiving either benefits/costs or both, interact, whereas in other cases, interaction is minimal, e.g., cases where forests in one region of the world provide a carbon sink that ameliorates global climate change effects, which benefit people in distant places, or extraction of water resources, e.g., hydropower in one region, which benefit people in other regions. Both the enhanced and diminished well-being manifest themselves in different forms of capital, such as economic capital, (e.g., enhanced/diminished income), physical capital (e.g., improved/impaired infrastructure), and social capital (e.g., improved sense of identity and place, or the loss thereof). Within the context of the UN SDGs, our framework, which make explicit the ecosystem (dis) services flow as well as associated benefits and costs, into societal constituencies, can serve as a tool for analysing the implications of policies, and managerial actions—e.g., with regard to those that stand to gain or lose from a particular policy or managerial position.

![Figure 4](image_url)

**Figure 4.** A systemic-relational ethical framework showing the distribution of costs and benefits arising from ecosystem (dis) services into societal constituencies and its impact on well-being, manifested in physical, economic, and social capitals. Values, institutions, management, and governance contexts are the key influencers of drivers of pressures and flows of benefits and costs. Framework developed from the basic idea of the ecosystem service cascade model [43].

On the right side of Figure 4 are values, institutions, management, and governance. Values to a large extent define institutional, management, and governance norms and practices as well as priorities. The directions of flow of benefits and costs accrued from ecosystem services and disservices with regard to different societal constituencies are largely influenced by the interactions between values, institutional, management and governance norms, practices, and priorities. That is, the nature, magnitude, frequency of pressure exerted on the biophysical component, and the direction of flows of benefits or costs from the biophysical to society are not value-neutral, but are outcomes of value-laden choices and decisions, made primarily by people, which are indicated in the framework in Figure 4 by the broken arrows connecting values, institutions, management, and governance to the rest of the model. The framework thus raises a range of ethical questions: (i) Under what condition(s) is a component of the ecosystem considered a (dis) service, by and for whom; (ii) how are costs and benefits distributed both in terms of spatial (local versus regional versus global) and temporal (present versus future generations) scales; (iii) how does the ecosystem services/disservices flow impact on ecological health, and the systemic-relationality inherent in the SES; (iv) which value of the ecosystem is prioritised and why, and what are the implications for the value trade-off and the potential conflict arising from the value inequity, (v) how does exerted pressure influence the biophysical condition, and given the imperative to balance use and protection, whether such pressure and resulting conditions are acceptable. It is not our intention to argue these issues further here, but to raise them as matters worthy of consideration in decisions around the flow and management of ecosystem (dis) services.
The framework further indicates that pressure exerted on ecosystems is an outcome of the complex interaction between values, institutions, management, and governance. For example, the decision to construct a dam (pressure) in a river could be underpinned by a utilitarian value of food production (through irrigation) or hydropower, for which institutional, management, and governance contexts that are conducive for its implementation (the dam project) may be put in place.

In order to provide for holistic health of the SES, integration of all aspects of the framework, from pressure, altering biophysical condition, to the flow of ecosystem services and disservices, benefits and costs (to the ecological and social components) as well as the interacting effects of values, institutions, management, and governance on the SES, is needed. In developing such integrative tools and approaches for assessing ecosystem health, attention needs to be paid to describing the winners and losers (both ecological and social) in the SES so that the ethical implications can be highlighted and taken forward in policy and managerial matters. Further, in evaluating aquatic ecosystem health from the SR perspective, values need to be clarified and assessed, using a clear set of ethical principles [2,29], to ascertain how values influence the use, evaluation, measurement, and public perception of ecosystem services and the biophysical structures and processes that support them.

Within the SES, if such an integrative approach is to be followed, then multiple indicators need to be integrated. Indicators are used to provide the conditions or change in the state of an environmentally relevant phenomenon in ecology [47]. Thus, following the framework presented in Figure 4, indicators of the ecosystem structure, function, and services/disservices flow would need to be integrated [48] with those indicating benefits/costs, well-being, institutional values, and norms as well as management and governance context. When indicating costs and benefits, it is important to note the overarching influence of the SES context, as what constitutes a benefit in one context may become a cost in another context [49]. It is critical to note that within the SES, most indicators interact in complex and non-linear ways, giving rise to complex matrices of interactions [47]. As argued by [50] such integration should take into account the spatial-temporal dynamics/scales at which each component of the cascade operates, while ensuring that the linkages between the components of the cascade, are fully accounted for. [50] have also argued for integrative approaches, stressing that ecosystem services assessments should integrate changes in drivers, pressure, states, and responses of the biophysical components as ecosystem services are outcomes of pressure exerted on the biophysical component of the SES. Overall, we posit that efforts in aquatic ecosystem health research be channeled toward integrative methods and approaches capable of providing a holistic health view of the ecosystems within any SES context. To be successful in developing such integrative approaches and methods, different disciplines, knowledge systems would be required and collaboration at the research-practice interface would be critical. Interestingly, realising the complexities inherent in managing natural resources, the field of transdisciplinarity (TD) and translational ecology (TE) have evolved to draw attention to the imperative for collaborative research.

5.2. Transdisciplinarity and Translational Ecology

Transdisciplinarity emerged in the academic literature in response to calls to do science with and for society in addressing inherently complex, potentially intractable, and wicked problems [51]. Lange et al. define TD as a “reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge” [52]. It recognises the imperative for cooperative and collaborative research, while drawing from multiple knowledge systems in addressing complex societal problems such as the deteriorating aquatic ecosystems health. Transdisciplinarity explicitly calls for knowledge co-production, recognising the centrality of the wider society in producing knowledge that can effect change. In the context of an SR ethical approach to aquatic ecosystem health research and management, it implies regarding all knowledge forms and systems as equally important, while giving careful consideration to critical values of fairness, equity, and sustainability in building the TD team and undertaking adaptive cross-cutting activities aimed
at addressing the deteriorating ecosystem health. We argue that drawing on TD research principles and working across disciplines, would enable ecologists and other researchers interested in aquatic ecosystem health research to move towards developing integrative approaches and methods for holistic assessment of ecosystem health, and taking forward complex ethical issues into policy and practice. Indeed, our call for TD is not the first with regard to ecosystem health research. Earlier, [4] had made a similar call.

Translational ecology (TE) has emerged in recognition of the need for ecologists to connect end-users of their research earlier on in the process, bridging research, and action (practice) [53]. TE explicitly calls on ecologists to engage with other disciplines, particularly the social sciences, and to show long term commitment and cooperation in undertaking integrative research. TE is intentional with regard to seeking to collaborate with other disciplines, and in acknowledging shared responsibility for delivering research products that can inform and facilitate effective decision making in complex contexts with regard to natural resource management and conservation. TE has thus emerged in ecology as an approach for ecologists to conduct socially relevant research that is sufficiently integrative and collaborative to transform societal problems and bring about solutions in complex SES. TD and TE have a number of features in common such as emphasis on societally relevant research, co-production/development of knowledge, cooperative/collaborative research and decision-making and societally-relevant research outcomes. We believe that the combination of TD and TE would enable sufficiently integrative research outcomes that can shape our understanding of how best to move towards achieving healthy ecosystems in SES contexts, and this is particularly true if ecologists are to play a leading role in research that contributes to the realisation of the UN sustainable development goals.

5.3. Transformative Communication

If the public is to relate to aquatic ecosystems in a more humane, responsible, and respectful way, then there needs to be an effective and transformative communication of the value of ‘healthy’ ecosystems to society. By transformative we imply communication that effect behavioural change, and social and mutual learning in ways that contribute to sustaining the SES health.

The continuing degradation of aquatic ecosystem conditions, despite investment in research, policy, and management institutions globally, could be attributed at least partly to the perceived ‘disconnect’ between the human and the ecological subsystems. Communication about the inherent linkages between societal and ecological systems needs to be strengthened in the public and policy domains. It needs to be clear to society that human well-being is explicitly linked to ecological health. Thus, the rationale for protecting ecosystem health becomes systemic, and needs to be underpinned by a systemic-relational ethic that views both the ecological and social systems as coupled.

Furthermore, in communicating the value of protecting aquatic ecosystem health, emphasis also needs to be placed on equity between different social constituencies at the catchment and sub-catchment levels. The variety of aquatic ecosystem services, their benefits to different social consistencies (e.g., poor/wealthy, rural/urban dwellers, etc.), and a shared understanding of the multiple value systems that influence how different constituencies value ecosystem services, needs to be stressed in public and policy domains [54]. Equally important is the appreciation and awareness of the distribution of costs and benefits associated with access to aquatic ecosystem services. Often, access to the benefits of aquatic ecosystems by one constituency could lead to costs/burden carried by another, and therefore communication should address equitable distribution of costs and benefits, and explicitly identify the sets of principles for reconciling and balancing values if and when they come into conflict. This way, communication then makes clear to society decisions regarding access to aquatic ecosystem services and unintended consequences of disservices that may follow. From an academic perspective, it also implies that the traditional mode of disseminating research information through journals is not sufficient, as such mediums can be regarded as exclusive and elitist. If communication is to effect transformative behaviour and attitudes in ways that contribute to sustaining SES health, then it has to achieve social and mutual learning, and empowerment of all interested and affected parties.
6. Conclusions

Ecosystem health—while it is a human construct—needs to be seen within the context of the SES. The SES may be understood as consisting of two major components, i.e., the biophysical and the social-economic. The management of the interrelationship between components of the SES needs to be done in an integrated, holistic manner, which is sustaining to both components and their relationships.

We must take care not to equate values and ethics; ethics, in an important sense, is a meta-values exercise. Ethics is about criteria for the ways in which one relates values—which are not necessarily compatible in all contexts—to each other. Nor must not we equate ethics, or a specific set of environmental ethics, with a list of values. Different environmental ethical approaches, with emphases on different central principles—whether they are anthropocentric, or non-anthropocentric, or relational would relate values to each other in potentially different ways, but here we have presented our argument based on the recently developed SR approach to environmental ethics.

We have argued that ecosystem health needs to be conceptualised and managed in terms of an approach to the ecosystem as an integrated unit, in which the health of the biophysical and the social-economical aspects are mutually sustaining and interdependent. In our understanding, this calls for a systemic-relationally oriented environmental ethics, in which we move towards locating the central value in the overall SES itself, as a set of components in interrelationship, rather than in any specific component, such as the anthropocentric or the non-anthropocentric component. This implies taking the potentially difficult step—certainly from a policy and administrative perspective—of decentralising the human component, which has hitherto been prioritised; instead we need to redirect our focus to the SES as an integrated whole, to see it as the unit of worth, towards which decision-making, and developmental, and preserving action, is directed.

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References

1. MEA. Ecosystems and Human Well-Being: Current State and Trends; Scholes, R., Hassan, R., Ash, N., Eds.; Island Press: Washington, DC, USA, 2005; Volume 1, ISBN 1559632275.

2. de Wet, C.; Odume, O.N. Developing a systemic-relational approach to environmental ethics in water resource management. Environ. Sci. Policy 2019, 93, 139–145. [CrossRef]

3. Scrimgeour, G.J.; Wicklum, D. Aquatic Ecosystem Health and Integrity: Problems and Potential Solutions. J. N. Am. Benthol. Soc. 1996, 15, 254–261. [CrossRef]

4. Rapport, D. Assessing ecosystem health. Trends Ecol. Evol. 1998, 13, 397–402. [CrossRef]

5. Karr, J.R. Defining and measuring river health. Freshw. Biol. 1999, 41, 221–234. [CrossRef]

6. Bonada, N.; Prat, N.; Resh, V.H.; Statzner, B. Developments in Aquatic Insect Biomonitoring: A Comparative Analysis of Recent Approaches. Annu. Rev. Entomol. 2006, 51, 495–523. [CrossRef] [PubMed]

7. O’Brien, A.; Townsend, K.; Hale, R.; Sharley, D.; Pettigrove, V. How is ecosystem health defined and measured? A critical review of freshwater and estuarine studies. Ecol. Indic. 2016, 69, 722–729. [CrossRef]

8. Karr, J. A review of “Engineering within Ecological Constraints” Peter C. Schulze (Ed.), 1996 Washington, DC, National Academy Press ISBN 0309051983 §24.95. Eur. J. Eng. Educ. 1996, 21, 450.

9. Peng, J.; Wang, Y.; Wu, J.; Zhang, Y. Evaluation for regional ecosystem health: Methodology and research progress. Acta Ecol. Sin. 2007, 27, 4877–4885. [CrossRef]

10. Vugteveen, P.; Leuven, R.S.E.W.; Hujibrgs, M.A.J.; Lenders, H.J.R. Redefinition and Elaboration of River Ecosystem Health: Perspective for River Management. Hydrobiologia 2006, 565, 289–308. [CrossRef]

11. Berbés-Blázquez, M.; González, J.A.; Pascual, U. Towards an ecosystem services approach that addresses social power relations. Curr. Opin. Environ. Sustain. 2016, 19, 134–143. [CrossRef]

12. World Bank. Stakeholder Involvement in Options Assessment: Promoting Dialogue in Meeting Water and Energy Needs—A Sourcebook; World Bank: Washington, DC, USA, 2003.
13. Rogers, L.; Luton, P. Strategic Adaptive Management as a Framework for Implementing Integrated Water Resources ...; Water Research Commission: Pretoria, South Africa, 2010; Volume 1.

14. Mirumachi, N.; Van Wyk, E. Cooperation at different scales: Challenges for local and international water resource governance in South Africa. Geogr. J. 2010, 176, 25–38. [CrossRef]

15. Schauhuber, T. A need for equal consideration of ecosystem disservices and services when valuing nature; countering arguments against disservices. Ecosyst. Serv. 2017, 26, 95–97. [CrossRef]

16. Wangai, P.W.; Burkhard, B.; Kruse, M.; Müller, F. Contributing to the cultural ecosystem services and human well being debate: A case study application on indicators and linkages. Landsc. Online 2017, 50, 1–27. [CrossRef]

17. Hook, S.E.; Gallagher, E.P.; Batley, G.E. The role of biomarkers in the assessment of aquatic ecosystem health. Intgr. Environ. Assess. Manag. 2014, 10, 327–341.

18. Resh, V.H. Which group is best? Attributes of different biological assemblages used in freshwater biomonitoring programs. Environ. Monit. Assess. 2008, 138, 131–138. [CrossRef] [PubMed]

19. Pan African Chemistry Network. Africa’s Water Quality—A Chemical Science Perspective; The Royal Society of Chemistry: London, UK, 2010.

20. Fierro, P.; Arismendi, I.; Hughes, R.M.; Valdivinos, C.; Jara-Flores, A. A benthic macroinvertebrate multimetric index for Chilean Mediterranean streams. Ecol. Indic. 2018, 91, 13–23. [CrossRef]

21. Gieswein, A.; Hering, D.; Lorens, A.W. Development and validation of a macroinvertebrate-based biomonitoring tool to assess fine sediment impact in small mountain streams. Sci. Total Environ. 2019, 652, 1290–1301. [CrossRef]

22. Jorgensen, S.E.; Costanza, R.; Xu, F.L. Handbook of Ecological Indicators for Assessment of Ecosystem Health, 2005; CRC Press: Boca Raton, FL, USA, 2005.

23. Mckie, B.G.; Malmqvist, B. Assessing ecosystem functioning in streams affected by forest management: Increased leaf decomposition occurs without changes to the composition of benthic assemblages. Freshw. Biol. 2009, 54, 2086–2100. [CrossRef]

24. Hooper, D.U.; Chapin, F.S.; Ewel, J.J.; Hector, A.; Inchausti, P.; Lavoie, S.; Lawton, J.H.; Lodge, D.M.; Loreau, M.; Naeem, S.; et al. Effects of Biodiversity on Ecosystem Functioning: A Consensus of Current Knowledge. Ecol. Monogr. 2005, 75, 3–35. [CrossRef]

25. Müller, F. Hierarchical approaches to ecosystem theory. Ecol. Modell. 1992, 63, 215–242. [CrossRef]

26. Moog, O.; Schmutz, S.; Schwarzinger, I. Biomonitoring and bioassessment. In Riverine Ecosystem Management—Science for Governing Towards a Sustainable Future; Schmutz, S., Sendzimir, J., Eds.; Springer: Cham, Switzerland, 2018; Volume 8, pp. 371–412.

27. Flitcroft, R.; Cooperman, M.S.; Harrison, I.J.; Juffe-Bignoli, D.; Boon, P.J. Theory and practice to conserve freshwater biodiversity in the Anthropocene. Aquat. Conserv. Mar. Freshw. Ecosyst. 2019, 29, 1013–1021. [CrossRef]

28. Grizzetti, B.; Lanzanova, D.; Lique, C.; Reynaud, A.; Cardoso, A.C. Assessing water ecosystem services for water resource management. Environ. Sci. Policy 2016, 61, 194–203. [CrossRef]

29. Jax, K.; Barton, D.N.; Chan, K.M.A.; de Groot, R.; Doyle, U.; Eser, U.; Görg, C.; Gómez-Baggethun, E.; Griewald, Y.; Haber, W.; et al. Ecosystem services and ethics. Ecol. Econ. 2013, 93, 260–268. [CrossRef]

30. Murove, M.F. African ethics: An Anthology of Comparative and Applied Ethics; University of Kwazulu-Natal Press: Pietermaritzburg, South Africa, 2009; ISBN 1869141741.

31. von Döhren, P.; Haase, D. Ecosystem disservices research: A review of the state of the art with a focus on cities. Ecol. Indic. 2015, 52, 490–497. [CrossRef]

32. Shackleton, C.M.; Ruwanza, S.; Sinasson Sanni, G.K.; Bennett, S.; De Lacy, P.; Modipa, R.; Mtati, N.; Sachikonye, M.; Thondhlana, G. Unpacking Pandora’s Box: Understanding and Categorising Ecosystem Disservices for Environmental Management and Human Wellbeing. Ecosystems 2016, 19, 587–600. [CrossRef]

33. WWF. The Growth of Soy Impacts and Solutions; WWF: Gland, Switzerland, 2014.

34. O’keeffe, J.; Kaushal, N.; Bharati, L.; Smakhtin, V. Assessment of Environmental Flows for the Upper Ganga Basin; WWF: Gland, Switzerland, 2012.

35. Su, M.; Fath, B.D.; Yang, Z. Urban ecosystem health assessment: A review. Sci. Total Environ. 2010, 408, 2425–2434. [CrossRef]

36. Kleynhans, C.J. River Ecodifferentiation: Manual for Ecoclassification (Version 2)—Module A: EcoClassification and EcoStatus Determination; Water Research Commission: Pretoria, South Africa, 2007.
37. Palmer, C.G.; Griffin, N.J.; Scherman, P.-A.; Du Toit, D.; Mandikiana, B.; Pollard, S. A Preliminary Examination of Water Quality Compliance in a Selected Lowveld River: Towards Implementation of the Reserve; Water Research Commission: Pretoria, South Africa, 2013.

38. Rogers, P. Should Salmon Roam Free? Dam Removal on the Lower Snake River; Lenton, R., Muller, M., Eds.; Earthscan: London, UK, 2009.

39. Hart, J. Salmon and Social Ethics. J. Soc. Christ. Ethics 2002, 22, 67–93. [CrossRef]

40. Lichatowich, J. Salmon without Rivers: A History of the Pacific Salmon Crisis; Island Press: Washington, DC, USA, 2000.

41. Gaard, G. Women, Water, Energy. Organ. Environ. 2001, 14, 157–172. [CrossRef]

42. Inglehart, R.; Welzel, C. Intergenerational Value Change. Mod. Cult. Chang. Democr. 2005, 94–114. [CrossRef]

43. Mee, L.D.; Jefferson, R.L.; Laffoley, D.d.; Elliott, M. How good is good? Human values and Europe’s proposed Marine Strategy Directive. Mar. Pollut. Bull. 2008, 56, 187–204. [CrossRef]

44. Potschin-Young, M.; Haines-Young, R.; Görg, C.; Heink, U.; Jax, K.; Schleyer, C. Understanding the role of conceptual frameworks: Reading the ecosystem service cascade. Ecosyst. Serv. 2018, 29, 428–440. [CrossRef] [PubMed]

45. Müller, F.; Burkhard, B. The indicator side of ecosystem services. Ecosyst. Serv. 2012, 1, 26–30. [CrossRef]

46. Groenfeldt, D.; Schmidt, J.J. Ethics and Water Governance. Ecol. Soc. 2013, 18, art14. [CrossRef]

47. Kandziora, M.; Burkhard, B.; Müller, F. Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators—A theoretical matrix exercise. Ecol. Indic. 2013, 28, 54–78. [CrossRef]

48. Haines-Young, R.; Potschin, M. The links between biodiversity, ecosystem services and human well-being. Ecosyst. Ecol. 2010, 110–139. [CrossRef]

49. Martinez-Alier, J. The Environmentalism of the Poor; Edward Elgar Publishing: Cheltenham, UK, 2002; ISBN 9781843765486.

50. Müller, F.; De Groot, R.; Willemen, L. Ecosystem Services at the Landscape Scale: The Need for Integrative Approaches. Landsc. Online 2010, 23, 1–11. [CrossRef]

51. van Breda, J.; Swilling, M. The guiding logics and principles for designing emergent transdisciplinary research processes: Learning experiences and reflections from a transdisciplinary urban case study in Enkanini informal settlement, South Africa. Sustain. Sci. 2018, 14, 823–841. [CrossRef]

52. Lang, D.J.; Wiek, A.; Bergmann, M.; Stauffacher, M.; Martens, P.; Moll, P.; Swilling, M.; Thomas, C.J. Transdisciplinary research in sustainability science: Practice, principles, and challenges. Sustain. Sci. 2012, 7, 25–43. [CrossRef]

53. Enquist, C.A.; Jackson, S.T.; Garfin, G.M.; Davis, F.W.; Gerber, L.R.; Littell, J.A.; Tan, J.L.; Terando, A.J.; Wall, T.U.; Halpern, B.; et al. Foundations of translational ecology. Front. Ecol. Environ. 2017, 15, 541–550. [CrossRef]

54. Van Wyk, E.; Breen, C.M.; Roux, D.J.; Rogers, K.H.; Sherwill, T.; Van Wilgen, B.W. The Ecological Reserve: Towards a common understanding for river management in South Africa. Water SA 2007, 32, 403–409. [CrossRef]