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Article

Common Concepts and Theories Between Fisheries Management and other Environmental Issues

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Abstract: This paper explores the application of fisheries management theories to broader environmental issues, including climate change and biodiversity conservation. It underscores the inherent trade-off in fisheries between yield and resource conservation, identifying harvesting as a significant environmental burden. Early recognition of the sustainability concept aimed to address challenges like economic discounts and the tragedy of the commons, contributing to the issue of overfishing. These insights extend beyond fisries to other environmental concerns, particularly climate change. The development of adaptive management, initially tailored to address uncertainties and non-stationarity in fisheries, has found application in diverse environmental issues. Recognizing humans as integral parts of ecosystems highlights the impossibility of achieving zero environmental impact when utilizing natural resources. The paper advocates for passive restoration to prevent overfishing, leveraging nature's resilience. While goals like complete biodiversity restoration are inherent in fisheries, their relevance may not be immediately apparent to other environmentalists. Despite ongoing discussions on the sustainability of ecosystem services, legislation often tends to favor the long-term maximization of fisheries yield. The paper calls for mutual understanding of theories and experiences across various environmental fields, including fisheries, to enhance collaborative efforts in each field.

Keywords: adaptive management; discount rate; the tragedy of the commons; ecosystem services; passive restoration; risk tradeoff; mitigation and adaptation

1. Introduction

Sustainability stands as a fundamental and pervasive concept, extending its influence to encompass a broad spectrum of environmental issues including fisheries. Within the field of fisheries science, the enduring recognition and application of sustainability principles, coupled with the concept of Maximum Sustainable Yield (MSY), seem to be integral to the discipline. Sustainability remains cornerstone for ensuring the long-term profitability of fisheries, yet overfishing remains a persistent challenge beyond centuries [1]. Factors contributing to these challenges include economic discounting and the tragedy of the commons [2], which also contribute to broader environmental problems such as climate change [3,4].

In this article, we put forth bioeconomic ideas that seamlessly integrate responses to environmental shifts within fisheries management. Our approach underscores the contributions of fisheries to the broader ecosystem services [5]. Furthermore, we engage in a discourse on the shared characteristics between fisheries and other environmental issues, encompassing climate change mitigation, biodiversity conservation, and wildlife management. Through these discussions, our objective is to illuminate the versatility of accomplishments in fisheries science, offering insights that extend beyond the realm of fisheries management to address broader environmental challenges.

We present bioeconomic ideas that integrate fisheries management responses to environmental changes, the contribution of fisheries to overall ecosystem services, and climate change mitigation and adaptation measures. Discuss similarities with other environmental issues such as biodiversity conservation and wildlife management [6]. Through these, we will discuss the applicability of achievements in fisheries science not only to fisheries but also to other environmental issues.

2. Analogy to Fisheries Science: Factors Contributing to Biodiversity Loss

2.1. Single Species Population Dynamics

Human utilization of natural resources leads to a decrease in those resources. In contrast, living organisms, capable of self-reproduction, can recover by natural increase. However, this increase is finite and reaches a saturation level determined by the environmental carrying capacity. In the context of population ecology, this relationship is expressed by the following equation:

$$dB/dt = f(B)B - C, \quad (1)$$

where B represents the quantity of resources, t denotes time, $f(B)$ is the per capita natural increase rate, and C is the catch per unit time. For wildlife resources including fisheries and others, a similar formulation is applicable, with C being referred to as the harvest per unit time.

In the logistic equation, $f(B)$ is expressed as

$$f(B)= r\,(1 - B/K), \quad (2)$$

where r and K are the intrinsic rate of natural increase and the carrying capacity, respectively. To generalize more mathematically, r can be defined as $f'(0)$, and K as the maximum value of B satisfying $f(B)$=0.

Major contributors to the decline of wildlife, including fisheries resources, consist of land use change (or habitat loss), overexploitation, climate change, invasive species, and pollution [7]. Habitat loss corresponds to a decrease in K, overexploitation results in excess C, and climate change or pollution primarily reflects a decrease in r, whereas pollution may reduce both r and K. Equation (1) represents a single-species dynamic model and does not consider interspecific interactions. To account for relationships with invasive species, we need to incorporate interspecific interaction into the dynamics model. Alternatively, B, f, and C can be regarded as vectors consisting of abundances of multiple species, and Equation (1) can be considered a community dynamics model [8]. There may also be cases where contamination reduces not only r but also K.

Climate change can have impacts on survival and reproductive rates in a local population, which potentially alters the intrinsic rate (r). Additionally, it is considered to influence the carrying capacity (K) through changes in habitat area. Many studies on the impacts of climate change on biodiversity utilize species distribution models (SDMs) [9,10]. constructing habitat suitability predictions based on current environmental conditions within a species' distribution range [11,12]. These models then project changes in habitat area by incorporating future climate change scenarios, including variations in temperature, precipitation, and land-use changes that may be accompanied with climate change mitigation measures [13]. In other words, when predicting biodiversity loss due to climate change, only two of the five factors contributing to biodiversity loss are considered. In addition, many of these studies implicitly assume a steady-state condition and hypothesize that the increase in extinction risk for a species or population is caused by a decrease in environmental carrying capacity, except some articles [14].

Sustainable resource utilization occurs when C is less than the maximum value of $f(B)B$. As well-known in fisheries science, this maximum value is referred to as Maximum Sustainable Yield (MSY) [2], and the corresponding harvest level, denoted by C_{MSY}, is defined as C_{MSY} = max[$f(B)B$] that realizes this resource abundance is denoted by B_{MSY}. In the case of the logistic Equation (2), C_{MSY} = $rK/4$, and B_{MSY} = $K/2$.

Overexploitation is not irreversible damage, which is referred to by precautionary principle in Rio Declaration [15]. In the case of the logistic Equation (2) or more generally in Equation (1) if $f(B)$>0 for any B < K, the resource can recover if harvest C is stopped before the resource is depleted. Ecological restoration, in this context, does not involve adding resources artificially by making C

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negative in Equation (1) or increasing r or K beyond "natural state". Instead, it generally means reducing C sufficiently or restoring r and K to values close to their "natural states".

Here, we have defined the "natural state" as a condition free from human exploitation or influence, explicitly denoting the state where C=0 and that of $f(B)$ including r or K before human impact. However, as mentioned later, humans have existed since prehistoric times and interacted with other species in ecosystems. It is also conceivable to aim for restoration to a state before the industrial revolution or a more recent state.

2.2. Economic Discounts do not Justify Climate Change Mitigation Measures

In fisheries, it is well known that, given economic discounting, a higher present value can be obtained by overfishing than the present value of a permanent catch of the MSY. The same occurs with other environmental issues, for example, climate change.

To understand the effect of discounting the future values, we consider the following simple situation. Let $M(t)$ be the mitigation cost paid in year t, let $G(t) = G_0 + at - b\int_0^t M(t)dt$ be greenhouse gas (GHG) concentration in year t due to mitigation measures from the starting year (t=0) to year t, and let $D[G(t)]$ be the economic loss in year t due to climate change. The present value Y of total cost until 100 years later is expressed as follows.

$$Y = \int_0^{100} e^{-\delta t}\left(M(t) + D\left[G_0 \int_0^t a - M(\tau)d\tau\right]\right)dt \tag{3}$$

In reality, GHG concentrations may not exhibit a linear increase with slope a in the absence of mitigation measures. The reduction in GHG concentrations due to cumulative mitigation measures may not follow a straightforward proportional constant b. Moreover, the mitigation effect b is possible to vary across different decades.

Considering the likelihood of a concave, nonlinear relationship between GHG concentration and economic loss D, we assume this relationship as $D(G) = c[G(t) - G_0]^2$. We assume that $a = b = 1$ and c = 0.02.

For simplicity, we further assume that the mitigation cost M is constant each year; the M that minimizes the economic loss Y up to 100 years is a monotonically decreasing function of the discount rate per year, denoted by d, and is zero at d >3.2%, i.e., it can be economically rational to adopt no mitigation measures.

Furthermore, if M can be allowed to vary with year t, then mitigation measures are implemented from the first year if d =0, but if d =1%, the total loss would be lowest if the implementation is postponed for the first decade, and if d =3%, the total loss would be lower if the implementation is postponed for the first half century.

Assuming a 4% discount rate, including non-market values, there are concerns about the high costs associated with climate change mitigation measures. Regardless, when factoring in discounts, it becomes undeniable that mitigation costs may surpass the costs incurred from climate change [16].

However, it's worth noting that even in such cases, support for a 4-degree warming scenario may not be justified [17]. There are arguments advocating for the consideration of discount rates separately for market and non-market values, the rate corresponding to the latter is called "social discounting". In this context, it is believed that a 2-degree scenario would reduce the present value of total losses [18].

The value of fisheries yield denotes a provisioning service, and there may be no compelling reason to employ a low discount rate. However, as detailed below, if the presence of aquatic resources embodies values related to other ecosystem services or natural capital, these values may be considered with a low discount rate.

2.3. The Tragedy of the Commons in Climate Mitigation Measures

Next, we consider the case where countries can voluntarily decide on mitigation and adaptation measures, similar with the NDC (Nationally Determined Contribution) of the Paris Agreement.

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Future climate change from mitigation measures will depend on the sum of the efforts of all countries, while adaptation measures will contribute to reducing impacts within their own countries. Thus, the mitigation and adaptation costs for country i are denoted by M_i and A_i, respectively, the total loss V_i due to climate change for country i can be considered a function of the sum of global mitigation costs $\sum M_j$ and its own adaptation cost A_i. For example, it can be expressed as follows.

$$V_i = B_i D_i\left[\textstyle\sum_j M_j, A_i\right] - M_i - A_i \tag{4}$$

where B_i means the economic size of country i and $D_i(\sum M_j, A_i)$ is the economic loss due to climate change of country i, which is a decreasing function of $\sum M_j$ and A_i.

Similar to the tragedy of the commons in fisheries [2], if we consider this as a non-cooperative game, the non-cooperative solution adheres to the following conditions:

$$\frac{\partial V_i}{\partial M_i} = B_i \frac{\partial D_i}{\partial M} - 1 = 0 \text{ if } M_i > 0 \text{ or } B_i \frac{\partial D_i}{\partial M} - 1 < 0 \text{ if } M_i = 0, \tag{5a}$$

$$\frac{\partial V_i}{\partial A_i} = B_i \frac{\partial D_i}{\partial A_i} = 0, \text{if } A_i > 0 \text{ or } B_i \frac{\partial D_i}{\partial A_i} - 1 < 0 \text{ if } A_i = 0 \tag{5b}$$

If $\partial D_i/\partial \sum M_j < 1/B_i$ as per Equation (5b), then M_i is 0 at the non-cooperative solution. This condition is more likely met for smaller countries with smaller B_i. In essence, smaller countries tend to refrain from implementing mitigation measures and instead take advantage of larger countries. Furthermore, as the number of countries increases, the mitigation costs in the non-cooperative solution decrease. This mirrors the logic of the tragedy of the commons and is referred to as the "tragedy of mitigation measures" [8].

If numerous countries collaborate, a more cooperative solution with reduced economic losses for all countries compared to the non-cooperative solution becomes attainable. Mechanisms to curb self-interested actions are essential. While there are various methods to prevent the tragedy of the commons [13], nationally determined contributions (NDCs) serve as a mechanism to encourage countries to contribute voluntarily [19]. As each country establishes its NDC under the Paris Agreement, a diplomatic obligation arises to publicly disclose and adhere to the determined NDC. The effectiveness of NDCs will be assessed beyond 2030.

2.4. Ambiguities in Defining "Full Recovery of Biodiversity" and "Nature-Positive"

The Kunming-Montreal Global Biodiversity Framework (GBF), adopted at the 2022 Meeting of the Conference of the Parties to the Convention on Biological Diversity, outlines the 2050 goal as follows: "By 2050, biodiversity is valued, conserved, restored, and wisely used, maintaining ecosystem services." [20] However, as of March 2022, alternative drafts have been proposed: "Zero [net] loss of nature from 2020, [net] positive by 2030, and full recovery by 2050 – for the benefit of all people and life on Earth" [21], a proposal frequently cited even after the final agreement. The call for complete restoration has been presented by Locke et al. [22]. We assess its implications within the context of resilience and sustainable use of natural resources discussed above.

As of 2010, the Secretariat of the Convention on Biological Diversity recognized that biodiversity was still diminishing at an accelerating rate. The Aichi Biodiversity Target 2010-2020 aimed to decelerate this trend. The GBF seeks to halt biodiversity loss and also to initiate recovery in the near future, which is termed as a "nature-positive" approach [23]. As mentioned earlier, if resource utilization remains below the natural increase, resources can commence recovery, which is referred to as "passive restoration" [24]. However, in resource dynamic model (1), as long as resources are used, the resource abundance will not return to the carrying capacity. Complete restoration is deemed unattainable as long as human activities persist, and there may be no imperative for it. The term "nature-positive" is sometimes employed to signify that biodiversity is progressing towards recovery, while in other instances, it suggests that biodiversity is exceeding its "natural state." The concept of full recovery of biodiversity appears to align with the latter interpretation.

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The adoption of the Convention on Biological Diversity was grounded in the precautionary principle based on the Rio Declaration [25], which asserts that measures should be implemented to prevent irreversible or serious impacts, even lack of full scientific certainty. Conservation efforts were founded on the belief that species extinction is an irreversible event and that the value of biodiversity is irreplaceable [26]. Moreover, the timeframe of 2050 represents too short, within a single generation for long-lived organisms. If complete restoration could be achieved within such a brief period, one might argue that the precautionary measures are unnecessary.

Without clearer definitions of "full recovery of biodiversity" and "nature-positive", there are risks of misinterpretation. It is also plausible to consider the ecosystem, excluding humans, as a natural state and deem it the ideal ultimate goal. However, humans have coexisted with other species since prehistoric times. Conversely, the widespread acceptance in the Convention on Biological Diversity is that humans should not be external to nature [27]. The "coexistence with nature" and "living in harmony with nature" [28,29] are the major goal of the GBF. Recovering or beyond the natural state is unrealistic and unnecessary. There is a necessity to redefine concepts such as the target state for recovery and carrying capacity. If "nature-positive" implies a direction towards biodiversity recovery, then achieving full recovery of biodiversity by 2050, or even in the infinite future, may not be necessary.

Satoyama and satoumi, traditional rural landscapes and seascapes including human activities with nature, are defined as areas where human engagement enhances biodiversity or ecosystem services beyond their natural state [30]. While there are instances of improvement compared to alternative land uses [31], there is a scarcity of examples demonstrating that the enhancement surpasses the natural state. One such instance is the traditional fishing technique known as stone weirs, practiced globally [32], while it represents only a fraction of satoumi activities. Our objective is sustainable utilization rather than a mutual relationship with nature.

2.5. Why Aim for Net Zero Greenhouse Gas Emissions?

Similarly, the justification for pursuing net-zero greenhouse gas (GHG) emissions is not entirely clear [33]. As mentioned earlier, there exists a trade-off between the costs of mitigation and the losses incurred from the impacts of climate change. Simply halting warming may not result in the optimal reduction of total losses. Our objective should be to minimize overall losses [18]. Achieving this may require a complete cessation of warming from a specific point, coupled with a concerted effort to reduce atmospheric GHG concentrations. In such a scenario, the aim is to reverse the upward trend of GHG concentrations, and the concept of net-zero emissions may not align seamlessly with this goal.

In essence, net-zero emissions imply a state where anthropogenic emissions are offset by artificial absorption including afforestation. It does not mean elimination of emissions, excluding artificial absorption. If artificial absorption surpasses artificial emissions, net-negative emissions are possible, and net-zero emissions are just one of the continuous values between net-positive and net-negative.

2.6. Maximum Sustainable Ecosystem Services

The MSY concept could be defined for fisheries management targeting a multi-species community. However, defining Maximum Sustainable Yield (MSY) in a multispecies system is not straightforward. The maximum sustainable ecosystem yield (MSEY) [34] is defined as maximizing the total yield in a steady state [35], it may not ensure the coexistence of multiple species [8]. Furthermore, it has been pointed out that the long-term maximization of overall ecosystem services, rather than maximum sustainable ecosystem yield, should be more desired [5,36]. In addition, if carrying capacity is defined as a steady state in the natural state, the utilization by one species could potentially increase the steady state of another species [37], theoretically contributing to the increase of that species itself. Furthermore, it is highlighted that relying solely on the MSY concept is inadequate for developing fishing practices that consider the ocean's carbon absorption capacity [38].

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Marine resources constitute a form of provisioning services, where the present value of future profits considers economic or social discounts. Considering economic discounts, biological resources with low intrinsic rates of natural increase may induce overexploitation. Even in such cases, it is recommended to avoid overfishing and adhere to Maximum Sustainable Yield (MSY). The MSY concept does not account for discounting, and this term is explicitly mentioned in the text of the UN Convention on the Law of the Sea

However, criticisms abound regarding the MSY concept [39], because the MSY defined from equation (1) is based on a perfect information, steady-state, single-species system. Although extending the MSY concept to uncertain and non-stationary cases is possible, obtaining a scientifically unique management strategy is not based on risk management [13]. Classical MSY is determined solely by biological parameters, while actual management strategies are grounded in social consensus, as mentioned by the ecosystem approach [40].

Value judgments are reflective of societal choices rather than scientific decisions. Aligning with society's selected objectives allows for the analysis of means, evaluation and verification methods, and issues associated with human activities [13].

The value of fish catches constitutes only a portion of ecosystem services. The value we should sustainably maximize is not MSY, but the maximization of ecosystem services. This is called maximum sustainable ecosystem services (MSES) [41]. Regulatory services derived from marine ecosystems hinge on abundance rather than fish catches. As a result, the fishing rate for the MSES would likely be smaller than that for MSY [5]. This disparity is not attributable to precautionary measures for uncertainty.

Beyond regulating services, the value derived from marine ecosystems encompasses cultural services. Industrial fisheries, game fishing, and the tourism industry interact with each other [42]. In addition to natural resources, fishing activities may also have tourism value. Because ecosystem services are defined socioeconomically, MSES, unlike MSY, is a concept that inherently includes socioeconomic aspects. In addition to natural resources, fishing activities may also have tourism value. Because ecosystem services are defined socioeconomically, MSES, unlike MSY, is a concept that inherently includes socioeconomic aspects.

3. Adaptive Management Scheme

3.1. History of Adaptive Management

Adaptive management was invented and developed by ecologist Crawford S. Holling [43] and fisheries scientist Carl J. Walters [44]. An example is the Revised Management Procedure (RMP) agreed by the Scientific Committee of the International Whaling Commission (IWC) [45].

Even in the presence of uncertainty regarding the knowledge and information about the biological population to be managed, it is feasible to regulate the number of animals captured, track changes in the population's status, and adapt policies in response to changes—utilizing a feedback control approach—to attain management objectives. This process often involves reliance on untested assumptions. Moreover, it is distinguished by the inclusion of a procedure for validating these assumptions. [46]

On the whaling issue, opponents and supporters of whaling were at odds, involving scientists, but in 1992 the Scientific Committee agreed to establish a Catch Limit Algorithm based on the RMP [47]. This means that they did not agree on the number of animals to be captured, but rather how to determine the catch limit. Unfortunately, Japan withdrew from the IWC in 2019 without reaching agreement among the member countries in the IWC on implementation schemes, and Japan resumed coastal whaling. Norway and Iceland also continue commercial whaling after a moratorium of commercial whaling. These countries set their own catch quotas based on the RMP.

Subsequently, based on the United Nations Convention on the Law of the Sea, which came into effect in 1994, in the management of fisheries resources for each fish species in each country around the world, in exchange for granting exclusive economic zone rights to coastal states, responsibility

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for the sustainable management of resources was imposed on major fish species. The provisions specify the total allowable catch (TAC) for the fish, and many countries use adaptive management similar with the RMP to set the TAC [48].

In addition to fisheries resources, efforts are not limited to population management but is widely applied, such as the artificial release plan at Glen Canyon Dam in the United States from the 1990s [49] and the Sika Deer Management Plan in Hakkaido, Japan, from 1998 [50], natural resource management, ecosystem management, and follow-up processes to environmental impact assessments [44].

3.2. Defining Adaptive Management

Adaptive management (AM) is often broadly associated with the PDCA cycle (plan, do, check, and adjust for improvement) or "learning by doing," which is called “passive AM”. However, in a more specific context, “active AM” [51] involves predetermining control methods for refining policies using dynamic models, treating management as an experiment. It necessitates establishing a decision-making process (Figure 1) to determine how to validate or reassess unproven assumptions, aligning with the preferences of the involved stakeholders [46].

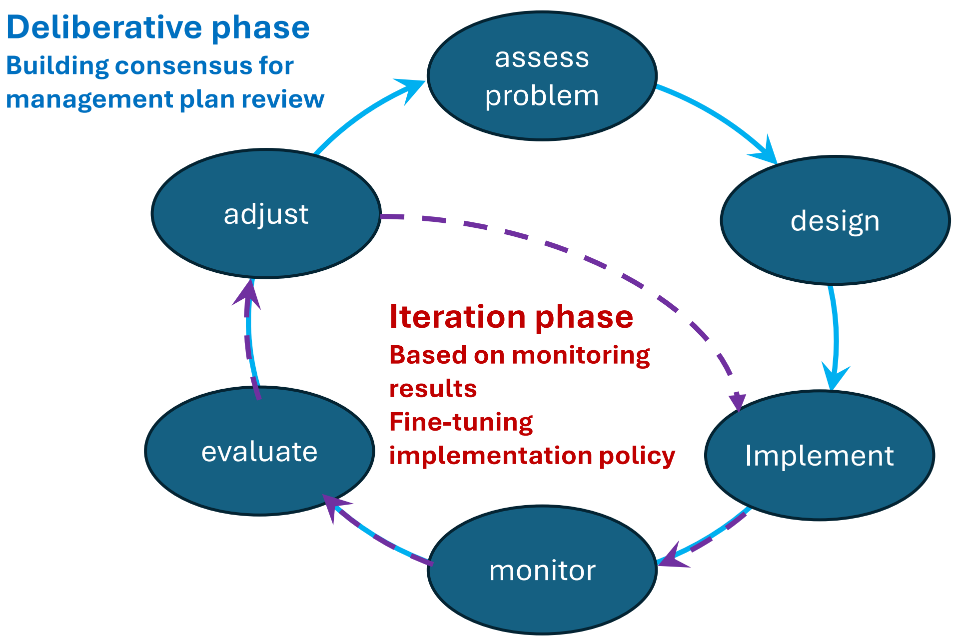

Figure 1. Adaptive management consists of an adaptive learning cycle (deliberative stage, practice) that includes periodic management plan reviews, and a feedback control cycle (iteration phase, broken line) of the plan in response to short-term changes in conditions (modified from Williams and Brown 2014 [46]). In the original article, the iteration phase arrow is depicted as originating from the adjust stage to the monitor stage.

In the iterative phase, the management entity formulates an implementation plan based on advice from scientists, and then consults with stakeholders. At the deliberative phase, we are providing a more thorough opportunity to hear the opinions of interested parties, including public comments.

AM is similar with the precautionary principle and risk management [52] in that it is reflected in policy without waiting for scientific proof. Adaptive management is characterized by the fact that it includes procedures for reviewing the management plan and verifying the assumptions used.

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3.3. Mathematical Models for Adaptive Management

Taking fishery resources as an example, a management dynamics model can be expressed as follows.

$$B(t+1) = B(t)e^{r - kN(t) + x(t)} - F(t)e^{h(t)}N(t), \tag{6}$$

where $B(t)$ and $F(t)$ are the abundance and fishing rate in year t, respectively; $x(t)$ and $h(t)$ are the annual fluctuations in the natural increase rate (process error [44]) and management implementation (operational) error [53] obtained by normal random numbers with mean 0 and variances s_r^2 and s_F^2, respectively; and r and k are positive constants representing the mean value of the intrinsic rate of natural increase and the magnitude of the density effect, respectively.

The catch amount is determined by the latest estimated abundance. In fisheries management, e.g.,

$$F(t) = \max\left[0, F_{lim} \min\left[1, \left(\frac{Be^{\varepsilon(t)} - B_{ban}}{B_{lim} - B_{ban}}\right)\right]\right], \tag{7}$$

where F_{lim}, B_{lim}, and B_{ban} represent the limit of fishing pressure, limit of stock abundance, and the stock level of ban-on-fishing, respectively; $e(t)$ is a normal random number with mean 0 and variance s_B^2 representing the stock amount observation/measurement error [44]; and $Be^{e(t)}$ is the estimated resource abundance in year t.

In this case, if the resource amount $B > B_{lim}$, it is used sustainably at a constant fishing rate; if $B_{ban} < B \leq B_{lim}$, the fishing rate is lowered to try to recover the resource; and if $B \leq B_{ban}$, fishing is banned to conserve resources. Choose a catch limit algorithm characterized by F_{lim}, B_{lim}, and B_{ban}, that improves the following three criteria: (1) maintain a higher minimum stock abundance, (2) increase the average catch, and (3) have small annual fluctuations in catch. Management Strategy Evaluation (MSE) is the process of considering good management rules by examining actual fishery information and procedures for estimating stock abundance [54].

In this way, we will change fishing rates and other measures in response to changes in the status of stock levels, and verify the accuracy of abundance estimates and parameters of resource dynamics models such as r and k. while conducting management [55]. In this case, state-space models that consider population dynamics models and observation errors at the same time, and Bayesian methods that calculate posterior distributions from prior distributions, are suitable. In addition, a method for analyzing causal relationships in adaptive management using Bayesian networks has also been proposed [56].

3.4. Limits and Key Points of Adaptive Management

Feedback control is not always effective. To stabilize the steady state and prevent overshooting, it's crucial to adjust policies based on the more recent state, initiating significant changes initially and gradually reducing them as the target state is approached. When a target species interacts with others, effectiveness is enhanced by not only tracking the managed species but also monitoring the status of species interacting with it [13,57].

Adaptive management does not imply managing without understanding the true characteristics of resource dynamics, such as r and k. Instead, it involves the ongoing process of comprehending the resource dynamics mechanism while actively managing and refining strategies to make them more suitable. This encapsulates the essence and purpose of adaptive management.

4. Discussion

Theories of fisheries resource management, including economic discounting and the tragedy of the commons, are applicable to broad environmental issues such as climate change [58]. While capture fishery differs from agriculture, forestry, and aquaculture by utilizing wildlife resources, it shares the commonality of relying on self-reproducing biological resources. While most of the latter have

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mechanisms to maintain seedlings, capture fishery, in particular, relies on the remainder of the harvest for reproduction. Harvesting constitutes the primary environmental impact of capture fishery, and as long as there is a harvest, the environmental impact cannot be reduced to zero. In this regard, the perspective on nature derived from fishing diverges from that of endeavors striving for zero impact. As explored in this article, fisheries' environmental impact during harvesting may hold unique insights for addressing broader environmental issues such as climate change and biodiversity.

Finally, active adaptive management (AM) is often employed in fisheries management, while passive AM is commonly used in other fields. Active AM, utilizing Bayesian statistics and state-space models, can also find application in diverse fields.

It is noted that the term "adaptive" carries a different connotation in the context of climate change from AM. AM can be employed for climate mitigation measures, managing a single variable like greenhouse gases concentration (GHG), rather than focusing on climate adaptation measures. Additionally, it's worth mentioning that the term "mitigation measures" is used with different meanings in climate change and environmental impact assessment (EIA). In EIA, mitigation measures refer to environmental conservation measures and are akin to adaptation measures in the context of climate change. Despite the varying meanings of terms across different fields, there exist common theories and concepts that can provide mutually beneficial insights.

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