Maximum Sustainable Yield
A Myth and Its Manifold Effects

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Some scientific concepts are accepted and sustained by policymakers not because they can accurately explain or predict the state of natural resources, but because they can be used to legitimise certain forms of resource control. Taking the concept of maximum sustainable yield as an example, how it was originally developed in the context of scientific forestry, but entered marine fisheries management and became a part of the "accepted wisdom," has been analysed. The consequences this has had, for marine fisheries globally and also in India, and the critiques it has spurred have been explained. The MSY's persistence is unpacked to suggest that debates on resource management need to be attentive to context, in order to understand how science may get enmeshed in efforts to enclose and appropriate resources.

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Science is often believed to be an unbiased and accurate portrayer of reality and, hence, it is not unusual for critical political decisions to invoke scientific knowledge in order to bolster their legitimacy. This is particularly true of complex domains such as environment and development because they affect the natural and social worlds. On the other hand, claims of knowing nature, speaking on its behalf, and advocating certain trajectories of management have repeatedly been shown to be inseparable from social struggles for power and access to resources, that is, ecological knowledge is frequently enmeshed in politics (Goldman et al 2011). In this article, we review one aspect of this politics of knowledge: How a seemingly objective, technical concept, such as "maximum sustainable (or sustained) yield" or MSY, became an essential part of the state's attempt to consolidate territorial control over land- and sea-based resources in the name of sustainable development; or, in other words, how science was used by the state to meet geopolitical ends.

To illustrate our argument, we revisit two well-documented topics: one is the growth of forestry in India and the United States (US), and the other is the growth of marine fisheries in these two countries. We sketch the connections between the two, to show how a concept that dominated one discipline (scientific forestry) can centuries later play an equally pivotal role in shaping the other because it continues to be politically useful rather than scientifically appropriate. We follow this with an overview of how the MSY concept has shaped the trajectory of marine fisheries in India and discuss its implications for future efforts.

What Is MSY?

MSY is a concept that is frequently encountered in any discussion on the management of fisheries. It is derived from the understanding that in a given population of organisms (be they trees, fish, or crops), a certain number of adults get added to the population each year due to reproduction and growth. At the maximum growth rate, only a fraction of these are required to replace dying adults and maintain the population. Hence, the rest are considered to be "surplus" individuals that can be harvested each year, without any long-term decline in the population, especially if these are older individuals that are anyway likely to die off in the near future. In other words, proponents of MSY believe that a steady peak rate of harvest can be calculated for a given species. It follows that such extraction is beneficial for the population because it eliminates competition for resources by removing the excess, older

individuals, and thereby enables the population to maintain its maximum growth rate or productivity for perpetuity (Brandis 1856; Lowood 1990; Chapman 1949 qtd in Finley 2009). In the next section, we describe some of the larger social currents that influenced the development of the MSY concept.

Search for Rationality and Efficiency

Interestingly, MSY found favour with two schools of thought at least a century apart: cameralism and utilitarianism. The first, cameralism, originated in 18th-century Prussia from a larger movement that advocated "rationalism." According to this school, nature was a machine that was governed by a certain logic, because there was an order and coherence to it, so it could be understood through the exercise of reason and described mathematically (Frängsmyr 1990). Cameralism took this view a step further by insisting that forests were an important source of a state's wealth and, therefore, should be managed according to the principles of economic rationality to prevent bankruptcy and social unrest. This made forestry science a fundamentally quantitative discipline (involving the development of specialised mathematical techniques, such as linear surveys, cartography, wood volume tables, and forest budgets) that focused on improving the production of timber to earn revenue for the state. A forest stand was treated as capital, and techniques were developed to measure and calculate the standing capital. The main goal of forest management was to obtain the optimal interest rate on the standing capital, that is, the maximum sustainable yield of timber (Lowood 1990). In a similar vein, forests in France came to be viewed as physical infrastructure that needed to be developed in order to meet the economic objectives of the nation and, since many of its chief foresters were trained in the German schools, its main features were almost the same (Rajan 2006).

The second, utilitarianism, became highly influential in the US, between the 19th and 20th centuries. According to this theory, which was derived from Protestant ethics, the quality of one's life can be judged by the effect of one's actions and people should strive to do whatever would be beneficial for most of society. It advocated hard work in all domains, in order to serve certain practical social goals, and included the view that nature should be used efficiently to serve human needs. During this period, the environmental sciences aimed at managing nature along industrial lines to "improve" its production of resources. Similar to cameralism, the utilitarian interest in forests was mainly in terms of the valuable (timber) trees they contained, and the thrust of management policies framed during this period was to nationalise these resources, centralise decision-making, and incorporate scientific advice, all in order to ensure their best possible utilisation (Demeritt 2001). In the case of fisheries, the search for efficiency again led to MSY because "less fishing is wasteful, for the surplus of fish dies from natural causes without benefit to mankind; more fishing is wasteful because it depletes the population" (Chapman 1949 qtd in Finley 2009).

We would also like to draw attention to the fact that both cameralism and utilitarianism framed their explicit support for state ownership and management of resources as a corrective to the environmental destruction that had been caused earlier by privately owned resource-based industries. Critics of forest policies in both, British India and the US voiced similar opinions. They felt that private industries were driven entirely by self-interest and lacked any long-term vision with respect to how natural resources could be used to support the progress of society as a whole. They believed that the state, in contrast to the former, would be an impartial actor and could make decisions that can lead to the development of a nation or even the empire (Bryant 1994; Demeritt 2001). In the case of fisheries, however, the criticism was aimed at fishing fleets of other countries, rather than at private actors.

Rise of MSY in Forestry

The concept of MSY first took shape in the British government's efforts to manage the forests of India and Burma during the late 19th century. From previous experience, administrators realised that leaving timber extraction to private contractors (or kings and chieftains who then leased timber licences to the former) and free market forces resulted in extensive deforestation and the eventual non-availability of teak trees. This was a grave problem because teakwood was an extremely valuable resource used to maintain fleets of ships as well as the railways. Therefore, in 1855–56, Governor General of India Lord Dalhousie decided that it was time for the state to step in and actively regulate the working of this sector (Bryant 1994).

It was at this juncture that Sir Dietrich Brandis was appointed as the Superintendent of Pegu, a forested Burmese province. Brandis was trained in "scientific forestry," a Franco–German approach that involved calculating the maximum yield of timber that a given stand could supply each year, over decades, without compromising its ability to regenerate (Lowood 1990). He built up a professional Forest Service to implement this approach in Burma and it was able to bring a large area under its control in a relatively short span of time; for instance, from 134 sq miles in 1871 to over 4,000 sq miles in 1886. In the process, scientific forestry addressed fears about the scarcity of teak as well as strengthened British political presence (Bryant 1994). Similarly, when Brandis was appointed inspector-general of forests in India in 1864, he set up the Forest Ranger School (later known as the Imperial Forest Research Institute and College) in Dehradun to enable the colonial administration to undertake centralised research and train staff in scientific forestry (Winters 1975). The sustainable yield concept was promoted by such institutions and became the accepted basis for forest management throughout the British empire (Rajan 2006). The actual techniques often needed modification to suit local ecological and social conditions, but, on the whole, it found favour even in the postcolonial era because it strengthened territorial control and enriched the state coffers (Vandergeest and Peluso 2006a, 2006b).

Scientific forestry spread to the US by the efforts of Gifford Pinchot who studied briefly under Brandis in 1890. The approach, with its emphasis on a technical understanding of nature to extract the maximum possible amount of resources to serve

larger societal requirements, resonated well with the utilitarian drive of 19th-century US, and Pinchot became an ardent proponent of MSY-based forest management. Since he established influential institutions, such as the US Forest Service and Yale's School of Forestry, the concept became the bedrock of American forestry in general (Balogh 2002). In 1944, the Sustained Yield Forest Management Act was passed so that private forests adjacent to government-owned ones could be managed together as a single unit, by an entity composed of both private foresters and Forest Service personnel, following the principles of scientific forestry (Demeritt 2001). By the 20th century, the MSY concept definitively shaped the management of timber resources and it began to percolate to other sectors as well. We suggest that, similar to the case of British India, scientific forestry resulted in the spatial expansion and consolidation of state control. For instance, by the time Pinchot's tenure ended as chief of the Forest Service (a period of 12 years), 200 million acres of timber-laden forest stands belonged to the government (Balogh 2002).

From Land to Sea

With respect to marine fisheries, historically situated studies indicate that MSY gained traction not only from the rise of statistically driven understandings of nature, but, more significantly, from the political conditions of the time (Hollick 1978; Finley 2009; Finley and Oreskes 2013). To begin with, MSY was first proposed in the context of fisheries shortly after World War II, in 1947–48. It was the time when the US was keen to assert its geopolitical power by claiming certain expanses of the seas as its own and expand its fishing industry as a precursor to consolidating military control of these areas. In order to justify the US's bid to control fisheries over what used to be open seas, MSY was presented as a careful, scientific and, above all, an "American" approach to marine fisheries. It made its debut as an integral part of the US High Seas Policy (released in 1949) and was later carried over into international accords such as the Inter-American Tropical Tuna Commission (signed with Costa Rica in 1949) and the North Pacific International Fisheries Treaty (signed with Japan in 1951).

But, by 1953, several coastal countries had contested the US's claim by designating zones up to 200 nautical miles from the shore as their territorial waters, in which foreign fleets were banned from fishing. However, the US attempted to invoke the principle of the "freedom of the seas" in response, because it was concerned that if the movement of its fishing vessels were restricted in these waters, it will also become impossible for its military vessels to traverse such areas. In 1954, the US approached the Food and Agriculture Organization (FAO), an agency of the United Nations (UN), to resolve the dispute. Following this appeal, FAO hosted the pivotal International Technical Conference on the Conservation of the Living Resources of the Sea, also known as the Rome conference in 1955. During this conference, the US once again insisted that its approach to fisheries was based on the best available scientific expertise and, therefore, its fishing fleets should be allowed to fish anywhere, including inside "under-harvested" coastal waters of other countries, whereas it retained the latitude to impose restrictions on the "unscientific" fishing practices of other countries, such as Japan. Overall, the Rome conference served as a forum for the consolidation of the US's geopolitical power over the seas, and MSY-based management was the main tool used to achieve this.[1]

This concept became further entrenched when it was included in the Convention on Fishing and Conservation of the Living Resources of the High Seas, which was derived from the discussions held during the UN's Geneva conference on the Law of the Sea in 1956. Article 2 of the Convention states that

> [a]s employed in this Convention, the expression "conservation of the living resources of the high seas" means the aggregate of the measures rendering possible the optimum sustainable yield from those resources so as to secure a maximum supply of food and other marine products.

However, with respect to developing countries, the discourse on marine fisheries has been markedly different.

Emergence of Fisheries Institutions in India

In the case of marine fisheries in India, the colonial government had taken note of localised variations and declines in fish stocks in the 19th century itself (Day 1878) and several significant attempts were made to control the trajectory of this sector. Here, we summarise the major milestones and institutions, based on the account compiled by Sridhar and Namboothri (2012). The Indian Fisheries Act of 1897 represents the first of these formal attempts. It empowered the provinces to manage and conserve the fisheries within their territorial jurisdiction (Silas 2003) and allowed them to come down on destructive practices such as the use of dynamite and poison. As a part of its quest for "scientific management" of marine resources and efforts to improve the productivity of the sea to augment food supplies, the British administration went on to set up the Bureau of Fisheries in 1907 in Madras Presidency and supported extensive surveys. As early as 1908, there were efforts underway to promote trawling in the Bay of Bengal and several individuals attempted to set up deep-sea fishing companies. However, this was capital intensive and required much assistance from the government in order to make it economically viable. Since the government itself lacked the necessary financial resources, industrialisation of fisheries proceeded very slowly. Besides, the administrators themselves acknowledged the pitfalls of merely increasing supply without corresponding efforts to build up transportation, storage, and sales facilities (Reeves et al 1996).

During the postcolonial period, the basic structure and functioning of the fisheries departments remained the same, although they were now decentralised and came under the respective state governments. But, after World War II, during which fish became a key nutritional supplement for armies across the world (and Japanese imports were banned in many countries), there was a revival of interest in monitoring the state of edible fish stocks and exploiting them in "optimal" ways. This triggered the establishment of the Central Marine Fisheries Research Station, under Madras University, in 1947. Soon

after, this facility was upgraded into the Central Marine Fisheries Research Institute (CMFRI) and brought under the control of the Union Ministry of Agriculture and Farmers' Welfare (Silas 2003). Simultaneously, interest in tapping into fish stocks in distant waters also grew, leading to the establishment of a deep-sea fishing station, which eventually became the Fishery Survey of India (FSI) in 1983. The FSI's primary responsibility was to conduct stock assessments in the Indian Exclusive Economic Zone. Overall, three agencies were given the task of steering the development of marine fisheries: the state fisheries departments, the CMFRI, and the FSI. As Sridhar and Namboothri (2012) observed, the question of why these three different institutions were all assigned fairly similar mandates, especially with reference to surveying and monitoring, remains to be understood. But, the concept of MSY was central to their calculations and planning as is described in the following section.

Attempts at Modernisation

After independence, marine fisheries was commonly viewed as a technologically primitive sector that underutilised resources because it was dominated by small-scale fishers, a large proportion using traditional craft, gear, and techniques. As a result, it was subjected to a "modernisation" drive, which basically meant provision of external input in the form of foreign technology and knowledge transfers. Alongside, state subsidies were offered to enable fishers to convert to mechanised fishing and supply the growing seafood export market (Kurien 1985; Platteau 1989; Bavinck and Johnson 2008). These attempts to scale up and recast fisheries according to models borrowed from developed countries involved adoption of the MSY concept (for example, tuna fisheries) (James and Pillai 1993; Abdussamad et al 2012). Fishing targets for states still continue to be set based on MSY estimates which directly link to fleet size and fisheries expansion interventions (Kurup and Devaraj 2000). In the absence of scientifically approved alternate models for fisheries management, significant effort has been invested towards arriving at finely refined MSY models. However, the capture fisheries in most key maritime states in India, after a sudden upward trend from the early 1970s to the late 1980s, have shown a steady decline in fish catch from the mid-1990s despite increasing capacities (Boopendranath 2007); so much so that many fisheries have become completely economically unviable.

Using the marine trophic index (MTI) as a potential indicator of trends in fisheries, a recent paper examined the health of high-value predator fisheries in India across half a century (1950–2000) and found that most species showed a substantial decline in their MTI across all 13 coastal states, at rates comparable to the rate of global decline (Bhathal and Pauly 2008). Such studies have contributed to the growing recognition that despite these attempts at "rational management," the coastal waters of India have been seriously overfished due to a host of reasons that include overly large fleet sizes, low returns due to lack of appropriate processing facilities, flawed macro-policies and weak regulatory frameworks (Salagrama 2006; Bavinck and Johnson 2008).

Looking back, we need to acknowledge that although the Indian state took over supervision of marine fisheries by laying claim to superior knowledge and management abilities as compared to small-scale fishers, its track record with respect to fisheries development per se has been a mixed one. However, on the other hand, as with the US, these claims continue to help the Indian state assert its presence in seascapes. For instance, official discourse on Indian fisheries often presents a shift to "optimal" or "sustainable" harvesting of deep-sea marine resources along with serious investment in monitoring, control, and surveillance (MCS) systems as a solution to many of the problems faced in nearshore fisheries, including (illegal) incursions by foreign fishers (Meenakumari et al 2014; Menon and Stephen 2017). This can be viewed as an indication that the geographic expansion of fisheries continues to be associated with state claims over seascapes and, hence, it is often accompanied by references to national security. Overall, we suggest that, similar to the case of forestry, the MSY concept facilitated strong state intervention in the early years.

Pitfalls and Persistence of MSY

The MSY concept is based on certain assumptions about the structure and composition of the environment, and here we provide a brief overview of these in both sectors of interest, that is, forestry and marine fisheries, along with well-established critiques of the concept.

In the case of forestry, as James Scott (1998) elaborates in his seminal book, *Seeing Like a State*, the quantitative approach from which MSY was developed involved a reductionist understanding of the natural environment as being made up of discrete, independent units. German forests were simply seen as timber depots or, at best, a cluster of individual trees, and not components of a larger vegetation community or ecosystem. Further, their value was determined purely from the quantum of commercially useful wood they harboured; even the other parts of such trees, such as fruits or foliage, were not considered. Finally, in order to ensure constant, calculable supplies of wood, the focus was on maintaining uniform tree stands at the expense of floristic and faunal species diversity. Consequently, in a century's time, there were reports about how entire expanses of forests had died out because the food webs and nutrient cycles had been destroyed.

Similarly, in the marine realm, fish populations are treated as a collection of individuals, and while competition between individuals is recognised to influence the stock size and composition, other aspects of their biology, such as sexual dimorphism, protandrous or protogynous traits, variable fecundity, etc, are not considered. Further, fish populations are usually treated as spatially static, equilibrial entities in the calculation of MSY, although in reality they are highly mobile and many species show non-linear population trends. One of the most influential critiques of this concept as applied to marine fisheries (Larkin 1977) listed multiple shortcomings of this approach. These include the following: the MSY model considers only single species populations and hence fails in multispecies fisheries; it does not consider recruitment

failures and fluctuations in fish stocks; the motivation for the model is to maximise profits and not ecological sustainability; therefore, it reframes the management of complex ecological systems as simple economic challenges and results in poor management policies. In short, what appeared to be an "optimal" solution in economic terms was often a disastrous one in ecological terms.

Even after Larkin's critique was published, other researchers reported that the use of MSY continued to be common in the framing of management policies. In several instances, they documented how this approach had led to alarming declines in fish populations (Pauly et al 1998; Myers and Worm 2003; Ferretti et al 2008). A notable example is the Northwest Atlantic cod fishery. In Newfoundland, the cod fishery was a multi-million dollar industry that had supported the communities living on the east coast of Canada for more than 500 years. However, the fishery ended in a spectacular collapse with the Canadian government declaring a complete moratorium in 1992, and many were suddenly left unemployed. Despite being one of the best-studied and well-managed fisheries in the world, where many modifications of the MSY-based model were developed and implemented, the fishery is yet to recover after 20 years of closure (Bavington 2010).

Similarly, a highly influential paper (Myers and Worm 2003) reconstructed trends in marine fisheries and demonstrated that high-value, targeted species that are subjected to intensive scientific fisheries management can undergo drastic declines at a global scale despite MSY-based regulations. The authors reported a 90% decline in the stocks of large predatory fish across the world and warned that it could have long-lasting impacts on piscine community assemblages in the wild. Despite such strong rebuttals and clear failings, MSY continues to be a popular concept in fisheries management due to its relative simplicity, making it easy for policymakers to understand and adopt. Rather than jettisoning it altogether, more refined versions have been developed over the years, such as its reinterpretation as a fishing limit that is to be avoided rather than as a target to be achieved (Mace 2001). Such shifts prolong its existence as a "valid" reference point.

In recent decades, increasing scientific evidence on the multiple tangible and intangible ecosystem services that forests can provide, coupled with a deeper understanding of the long-term ecological and economic implications of deforestation, has shifted resource management on land away from an entirely utilitarian perspective, to one of conservation and protection. For instance, in India, the Ministry of Environment, Forest and Climate Change, which directs the forest department, acknowledges that forests also provide important non-timber products, which play a significant role in climate regulation and serve as critical wildlife habitats. Further, in 2006, the Forest Rights Act was passed with the aim of restoring some measure of control over forestlands to local communities with strong historical claims.

Although the record of implementation of this act has been rather poor so far, it is still a step ahead because such paradigm shifts, even if largely confined to the level of discourse and policy, are yet to be seen with respect to seascapes. For example, assertions such as "the fish are dying of old age" are still commonly used as a precursor to discussions on the "untapped potential" of the nation's marine resources. The very fact that the management of marine fisheries in India comes under the purview of the Department of Animal Husbandry, Dairying, and Fisheries under the Ministry of Agriculture and Farmer's Welfare indicates that it is primarily viewed as a commodity that needs to be harvested at its highest economic potential. Policy documents express little concern about the ecological and social fallouts of such a strongly utilitarian approach, even though many detailed accounts have highlighted the damage caused (Subramanian 2009; Kurien and Achari 2011).

It is ironic that MSY was first adopted by states to facilitate the nationalisation of natural resources because private ownership and control were considered "destructive," but in current times it is invoked to justify the reverse measure, that is, to cut back on state regulation, and encourage private ownership and profit-driven management (Meenakumari et al 2014), that too by large industries because of the economies of scale. However, what remains unchanged is that MSY facilitates the appropriation of resources that make up the marine commons, by one or other of these elite actors. For instance, individual transferable quotas, which are calculated based on MSY, are now promoted in many developed countries as a tool to ensure sustainability, whereas, in practical terms, they involve assigning private rights to the fishing commons (Acheson et al 2015). In a similar vein, the World Trade Organization (WTO) routinely insists that the state welfare schemes and subsidies, given by developing countries to their numerous small-scale fishers, need to be withdrawn completely because such assistance results not only in market disruption, but also keeps this population dependent on the government and prevents them from upgrading their practices. According to the WTO, free market policies, on the other hand, can ensure a "triple win," that is, boost trade, environment, and development, all at the same time (Campling and Havice 2013).

Conclusions

We began with an account of how the MSY concept found traction in the fields of forestry and fisheries because it was presented as a rational and simple solution to the pressing problem of how to extract natural resources "for the greater common good" without causing irreparable damage. We have argued that, in the process, it enabled colonial and postcolonial administrations to extend their territorial claims and oust or limit the participation of other actors. Hence, MSY served a dual purpose: one being the management of resources per se, and the other being state control of forests and fisheries. Further, we have illustrated how certain scientific concepts such as MSY—although outmoded—continue to motivate policies pertaining to the conservation and development of natural resources for the legitimacy that they extend to certain political goals, that is, they permit certain actors to expand their influence and control over new areas. More such examples include the

"sponge model" of forest-mediated regulation of floods (Saberwal 1997), conservation corridors (Goldman 2009), the Universal Soil Loss Equation (Forsyth 2011), and Rosgen approach to stream restoration (Lave 2012).

We have pointed out that concepts such as MSY often represent extreme simplifications of one type of ecosystem or location and are applied in toto to another. Therefore, although such efforts are presented as "rational" management of resources, in the long run, they do not result in positive outcomes for either the environment or society (as described in the previous section). They also completely negate the knowledge, experience, and rights of local communities by framing the larger debate on resource management as a binary choice between either the state or large private industries. Given these factors, we suggest that discussions on natural resource management policies would benefit from considering the context in which certain scientific concepts are invoked and accepted by policymakers, in order to arrive at a better understanding of the multiple interests that shape these domains, as well as to assess who wins and who loses.

NOTE

1 It is worth noting that during this period, the FAO had also established itself as a strong supporter of scientific forestry (Vandergeest and Peluso 2006a).

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