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COMMENTARY

Unplanned ecological engineering

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Fisheries can double the production of protein and revenue by abandoning current single-species management. This provocative prediction is the implication of the work in PNAS by Szuwalski et al. (1). Using the East China Sea as a case, they show how an indiscriminate fishery can support unexpectedly large catches by removing predators from the ecosystem. Such ecosystem engineering stands in stark contrast to reigning management paradigms that do not allow fishing down predators to increase the productivity of their prey.

The theoretical support for such a feat of ecosystem engineering is well developed (2, 3). Trusting the Chinese catch statistics, Szuwalski et al. (1) provide empirical evidence that theory may be turned into practice. But their work is more than "just another fisheries paper;" it underscores highly controversial issues about the unavoidable trade-offs in managing fisheries and ecosystems. If we narrowly consider food security, maximizing fisheries catch from the ecosystem is a "no-brainer," but from a conservation point of view, the loss of biodiversity in the East China Sea may seem like Aquacalypse come true (4). Can we really double fisheries' production by turning the oceans into mega-scale mariculture operations? Is it what we want?

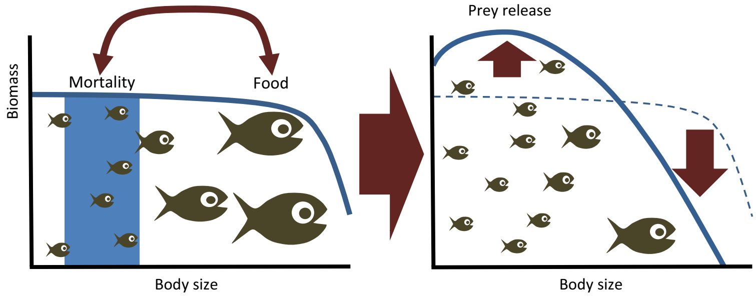

Fig. 1. Illustration of how prey release leads to a large total fisheries catch. As large species are overfished, the predation mortality on their smaller prey (blue patch) is reduced. This reduction in predation mortality releases these highly productive species and allows fishery to catch the released production. Consequently, the catch from the ecosystem is maximized when most large species are fished out of the system.

Is It Really True?

The surprisingly large catches in the East China Sea are reached by the ecological process of prey release. The removal of large predatory species from the ecosystem releases a substantial production from their prey, smaller species that are usually kept in check by predatory fish (Fig. 1). In this manner, the fishery can harvest what would otherwise have been eaten by the predators. This ecosystem cultivation parallels how humans turned from hunter-gathering to agriculture: By removing grazers from crops and isolating grazers from predators, the production of crops and meat for human consumption could be increased to levels beyond what natural ecosystems could support.

It is difficult to perform controlled experiments on natural ecosystems. Consequently, Szuwalski et al. (1) resort to ecosystem models to explore the impacts of fishing. They use a "size spectrum" model that compensates for the lack of detailed information about the feeding relations among all species in the East China Sea, with a reliance on the rule that big fish eat smaller fish (Fig. 1). The model rests on balance between growth and mortality: Growth and reproduction of a larger predator are fueled by the death of its smaller prey. This process is a biologist's version of mass conservation, and it is responsible for the observed prey release.

Models are idealizations of reality, and our understanding of ecosystem processes is far from complete (5, 6). Even though prey release seems logical, not all models support it. For example, a highly influential paper did not see increased catches when all components of an ecosystem were fished (7). By demonstrating correspondence between model simulations and the outcome of the "ecosystem experiment" in the East China Sea, Szuwalski et al. (1) lend credibility to models that replicate prey release. Combining this evidence with observations of trophic cascades, increases in smaller species when predatory fish are overfished (8, 9), makes prey release seem a likely process.

Even though the oceans are severely altered by fishing, they are still wild and uncontrolled ecosystems. Things may therefore not go as planned: Similar to how an organic corn field may be invaded by weeds or insect

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pests, the desirable and highly productive small fish and invertebrates left in the ecosystem may be taken over by undesirable production. The system may, for example, turn into a jelly field (10), and large outbreaks of giant jellyfish and other species have indeed been reported from the East China Sea and Yellow Sea (11). Further, the model version used has a fairly optimistic view of recruitment, the process whereby new offspring are establishing themselves in a fish population. The model can therefore sustain high catch rates, whereas, in reality, the simulated high fishing pressure (up to 95% of the standing stocks are caught every year) makes individual fish populations highly susceptible to crashes. The high catches obtained in the East China Sea and similar heavily exploited systems, such as the South China Sea and the Gulf of Thailand, therefore come at the price of an ecosystem that is not only impoverished in terms of biodiversity but is also increasingly fragile. It is therefore questionable whether the high production can be sustained.

Is It What We Want?

High production is, however, only one aspect of fisheries and ecosystem management. Management faces a trade-off between balancing high yields and food security with high profit and conservation of biodiversity (12). Narrowly focusing on one aspect will compromise the others: You cannot have your fish and eat it too. One extreme is an ecosystem free from fishing. It is a highly diverse ecosystem teeming with diverse life, from small forage fish to large predatory species. However, it does not deliver any catch or economic profit from fisheries. Pleasant as it may seem, a global implementation of this paradigm would require substitutes for the 10% (13) of the world's animal protein production supported by wild-caught fish. The other extreme is the East China Sea and similar heavily exploited ecosystems. Such indiscriminately fished systems are dominated by small and short-lived species such as zooplanktivorous fish, shrimp, and squid. Recognizing this trade-off, Szuwalski et al. (1) suggest that a restoration of the ecosystem toward balancing the opposing objectives of food production and biodiversity comes at a cost: about a 50% reduction in yield and revenue.

Regarding economy, the last aspect in the trade-off, Szuwalski et al. (1) offer only a partial view: They report the value of the catch but not the costs. The prediction that the value of the catch is smaller in a restored ecosystem makes restoration appear economically unattractive for society. Such may not be the case. The high production comes at the cost of an overcapitalized fishery, and the direct costs of extracting the high catches make such a fishery less attractive from an economic perspective (14). Accounting for costs by maximizing profit instead of revenue would lead to lower exploitation rates. Doing so could, at least partially, accommodate conservation of biodiversity (3). Further, the impoverishment of the ecosystem will have economic consequences beyond the fishing industry (e.g., in recreational fisheries or tourism). A comprehensive economic analysis that includes the costs of indiscriminate exploitation will make restoration more economically attractive for society.

Pretty Good Management

Szuwalski at al.'s work (1) reminds us that management needs to develop scenarios that strike a balance between food production, profit maximization, and biodiversity preservation. Emotionally, we want to have our fish and eat it too, and find it difficult to choose. A recently suggested compromise suggests that by foregoing the maximum catch of a fish stock and accepting just a "pretty good yield" (15), a catch close to the maximum, we can expect substantial increases in profitability and conservation. In an ecosystem context, this compromise may translate into an operating space for ecosystem management that allows for a pretty good fulfillment of all three objectives (16).

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