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Moving beyond the fished or farmed dichotomy

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ABSTRACT

Seafood is widely considered to be either fished or farmed. In contrast to this perception, many types of seafood are produced by enterprises using a combination of techniques traditionally ascribed to either fisheries or aquaculture. Categorizing seafood as either fished or farmed obfuscates the growth potential and environmental impacts of global seafood production. To better capture seafood data, national and international record-keeping organizations should add a new hybrid category for seafood produced using both fisheries and aquaculture methods.

1. Introduction

Demand for seafood is currently at an unprecedented high and is predicted to increase in the future [1]. Apparent annual per capita seafood consumption has risen from 9.9 kg in the early 1960s, when the global population size was around 3 billion, to 17.1 kg in 2008, in a world of almost 7 billion people [2,3]. Seafood is a key component of global food security [4]. In 2007, fish and shellfish contributed at least 15% of the average per capita animal protein consumed by 3 billion people (many in food insecure countries). Additionally, in 2008 the seafood sector provided livelihoods for an estimated 540 million people [2]. Understanding and tracking global seafood production has high social, economic, and environmental importance.

In recent years, the growth in seafood production has generally not come from capture fisheries, whose production has effectively plateaued, but from rapid expansion of aquaculture [2]. Aquaculture provided 46% of global seafood for human consumption (i.e. excluding wild catches used for fishmeal and fish oil production) in 2008, and farmed seafood production is expected to soon exceed food fish production by capture fisheries [2,5]. Farming fish and shellfish is generally an inherently different way to produce seafood than fishing: while fisheries traditionally interact with their target population only at the time of capture, aquaculture, in its "purest" state, controls the entire lifecycle of the organism. Broadly speaking, it is accurate to conceptualize finfish and shellfish fisheries as akin to hunting and gathering and aquaculture as akin to agriculture. Yet global oceans, lakes, rivers, and ponds are populated by seafood operations that often employ methods characteristic of both production systems.

Understanding global seafood production to occupy a spectrum between notions of "pure" fisheries and "pure" aquaculture enables better accounting of the global seafood sector, including its growth potential and impacts on aquatic ecosystems. This

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paper examines the inadequacy of the current seafood production typology – fished or farmed – to meet public policy needs for understanding seafood production. To help better meet these needs, an intermediate category is proposed for describing both fisheries production that uses one or more aquaculture techniques and aquaculture production that uses one or more fisheries techniques.

2. The inadequacy of the fished or farmed dichotomy and a new production category

Fisheries often employ production methods more typically attributed to aquaculture. Likewise, some aquaculture operations rely on techniques generally attributed to fisheries [6,7]. Tables 1 and 2 highlight examples of seafood species produced with a hybrid assortment of production techniques.

Many well-known fisheries use techniques more commonly associated with aquaculture to attain greater control over their harvests (Table 1). For example, to relax natural limits on their target species' population size, fisheries for American lobster (*Homarus americanus*) modify habitats and provide additional food resources. In other examples, fisheries for Pacific salmon (*Oncorhynchus spp.*) in Alaska, New Zealand scallops (*Pecten novaezelandiae*) in New Zealand, and eastern oysters (*Crassostrea virginica*) in the Chesapeake Bay employ hatcheries to stock target populations with juveniles. The oyster and American lobster fisheries also remove sources of natural mortality via predator exclusion or culling.

Table 1
Examples of "fisheries" that use aquaculture techniques.

American lobster	
Aquaculture techniques:	
Feeding	Lobster biomass is significantly augmented through the consumption of bait by small lobsters that repeatedly enter and escape lobster traps until they reach legal catch size [20]. During a fishing season, the volume of bait inputs to the fishery often equals or exceeds the total lobster catch by a factor of two [41].
Hatchery additions	Hatcheries have been used for over 100 years in an effort to bolster lobster populations by rearing and releasing juvenile lobsters into the fishery. The impacts of hatchery additions on lobster populations are unclear [57].
Predator control	Overfishing has extirpated most lobster predators in the Gulf of Maine [21].
Chesapeake Bay Eastern oysters	
Aquaculture techniques:	
Habitat modification	To encourage settlement by juvenile oysters (called "seed") and to improve survivorship, old oyster beds are often dredged, and new beds are constructed [22].
Hatchery additions	Hatchery inputs to the Chesapeake Bay fishery are considerable. To increase survivorship of juvenile oysters, newly settled oyster juveniles are often collected on old oyster shells, which are then transferred to fishermen's leased lands for grow-out before harvest [58,59].
Predator control	Chesapeake Bay oyster harvesters use suction dredges and mops to remove predatory oyster drill snails and sea stars from oyster beds [60].
North American and New Zealand scallops	
Aquaculture techniques:	
Habitat modification	Since the late 1990s, United States and Canadian scallop fisheries management increasingly bears a resemblance to plantation-style forestry, as fishing areas are often closed for one to two years after dredging to allow populations to re-grow [24].
Hatchery additions	New Zealand scallop fisheries managers allocate rights to groups of fishermen to operate in specific areas, similar to granting a lease to an aquaculture facility. In these areas, fishermen are allowed to catch and re-seed larval scallops to bolster the populations and their catches [23].
Pacific salmon	
Aquaculture techniques:	
Hatchery additions	Hatchery-born fish accounted for about 38% of 2000–2002 salmon landings in Alaska, and there are also significant hatchery programs in British Columbia, the United States west coast states, Japan, and Russia [19,61]. Extensive recreational fisheries for Pacific salmon in the Great Lakes are also largely supported by hatchery programs in both the US and Canada [62,63].

Table 2
Examples of "aquaculture" operations that use fisheries techniques.

Bluefin tuna	
Fishery techniques:	
Fishing for stock	Bluefin tuna farms are stocked with juveniles and adults caught by purse-seine fisheries [52,53].
Fishing for feed	Bluefin tuna farms use 10–20 kg of fish as feed for every 1 kg of tuna that they produce [52].
Extensive tropical shrimp	
Fishery techniques:	
Fishing for stock	Extensive shrimp farms are generally stocked with wild-caught juveniles and adults [31].
Fishing for feed	Shrimp farms generally use fish-derived feeds [31].
Eel	
Fishery techniques:	
Fishing for stock	Eel farms in Asia and Europe are stocked with wild-caught juveniles and adults [32,64].
Fishing for feed	Eel farms often use fish-derived feeds [32,64].

Some aquaculture operations, including extensive shrimp farms (primarily giant tiger prawns, *Penaeus monodon*), bluefin tuna ranches (*Thunnus thynnus, T. orientalis,* and *T. maccoyii*), and eel farms (*Anguilla spp.*) use wild-caught animals to stock their operations (e.g., brood stock, juveniles, or adults that are caught and then cultured) (Table 2). Aquaculture of omnivorous and carnivorous fish and shellfish also uses wild inputs for feed. Fishmeal and fish oil from reduction fisheries are used in formulated feeds and whole fish are fed directly to cultured organisms [7].

Despite the frequently blurred lines between fisheries and aquaculture, they are generally managed, studied, and assessed separately. A spectrum, not a duality, more accurately describes modern seafood production; and this spectrum is not accommodated by the current dual seafood production typology (Table 3). Yet, as the fished-farmed typology is the basis for national and global data collection, the degree to which it confounds accurate understanding of the global seafood production sector is unknown.

The fished or farmed typology used to classify seafood production should be amended by adding a new intermediate production category to illuminate the gray area between fisheries and aquaculture. "Hybrid seafood production" would characterize capture fisheries that employ one or more aquaculture production techniques and aquaculture operations that rely on wild inputs.

A higher threshold for what constitutes hybrid production was considered but rejected. For instance, if a particular aquaculture operation employed two or more wild inputs, it would be reclassified as hybrid. However, this definition would exclude aquaculture systems that are "pure" but rely on fishmeal and fish oil for feed. Since the use of wild inputs for feed is an important linkage between fisheries and aquaculture production [8], the hybrid category should accommodate it. The addition of two new production categories, aquaculture-enhanced fisheries and fishery-enhanced aquaculture, was considered. However, discerning whether a particular seafood operation should be classified as one or the other could be problematic. For instance, consider a fishery slowly incorporating techniques more generally attributed to aquaculture: at what point would the manager or scientist distinguish that an aquaculture-enhanced