Sustainability **2011**, *3*, 957-964; doi:10.3390/su3070957

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Discussion

Limiting Size of Fish Fillets at the Center of the Plate Improves the Sustainability of Aquaculture Production

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Received: 15 June 2011 / Accepted: 22 June 2011 / Published: 6 July 2011

Abstract: North American dining customers like to have a singular large piece of protein in the center of the plate. When fish is the protein of choice, the portion size from many species is limited by the overall size of the fish. Therefore, for these species, the means to achieve a singular larger portion of "center of the plate" protein is to grow a larger animal. However, fish become less efficient in converting feed to protein as they age. A second option would be to provide two smaller fillets originating from younger, more efficient fish. Here, the sustainability ramifications of these two protein provisioning strategies (single large or two small fillets) are considered for three species of fish produced in aquaculture. Growth data for channel catfish (*Ictalurus punctatus*) produced in ponds, rainbow trout (*Oncorhynchus mykiss*) in raceways, and sablefish (*Anoplopoma fimbria*) in marine net pens, were modeled to assess the total biomass and overall food conversion ratio for the production of small, medium or large fish. The production of small fish added an additional 50% or more biomass per year for trout, catfish, and sablefish compared to the production of large fish. Feed conversion ratios were also improved by nearly 10% for the smaller compared to larger fish of each species. Thus, even though all of these species tend to be considered aquaculture species of low environmental impact (and hence "green" or sustainable options), the product form requested by retailers and served by chefs can further increase the sustainability of these species.

Keywords: channel catfish; efficiency; feed conversion ratio; food production; protein; rainbow trout, sablefish, seafood

1. Introduction

Within the restaurant and food service sectors, the preference in North America tends to be for large portion sizes [1,2]. For the "center of the plate" protein, this means large singular portions. This preference occurs for a variety of reasons, likely indicating value, quality or opulence. Increases in portion size within the "center of the plate" are achieved differently for different proteins. Increases in portion sizes of beef or pork can be achieved by providing a thicker cut or a different larger cut. However, for fish, a different scenario is likely to occur. Many popular species of farmed fish such as tilapia (*Oreochromis* spp.), trout (*Oncorhynchus mykiss*), or catfish (*Ictalurus punctatus*) are too small to merely provide a larger or thicker fillet as could occur with a larger bodied fish such as tuna, *Thunnus* spp.. Thus, increases in fillet size for small bodied fish necessitate the fish to be grown to a larger size. Since larger and older animals tend to convert feed to protein less efficiently than smaller individuals of the same species, there may be sustainability consequences of growing fish to a larger body size. Here we address production efficiencies associated with growing different sized fish, and the implications for the global sustainability of aquaculture.

Global seafood demand is on the rise, and this trend is expected to continue. This is a result of seafood being an efficient protein to produce that is nutritious, and an important dietary component the world over [3,4]. Over the last decade, there has been a growing interest in assuring that seafood is produced in a "sustainable" manner to ensure that our oceans and aquatic resources maintain their full ecosystem functions. One outcome of this sustainability movement has been the creation of standards that certify whether selected species are harvested (wild fisheries) or produced (aquaculture) according to specific social and/or environmental criteria. Currently over 17 [5,6] seafood sustainability certification programs exist for fisheries or farm level aquaculture operations. However, seafood sustainability is not a singular end point, but rather a series of continual improvements through efficiency and innovation that is guided by certification and influenced by the market and societal demands [7,8]. In this "shades of grey" seascape, even proclaimed "sustainable" products can be improved upon at some point. These advances lead to the continual improvements lauded by the industry, academia, and the NGO community.

Aquaculture has been in the spotlight lately because it is growing significantly, and is nearly on par with wild harvest [9]. In North America, aquaculture species hold six of the top ten spots in terms of per capita intake. From a sustainability perspective, aquaculture species are of interest because, as with domestic farmed animals, all aspects of production are controlled. If there are global sustainability impacts from size-based production efficiencies for fish, they should be most easily observed and modified in farmed fish species.

Here we utilize the data for channel catfish reared in ponds [10], rainbow trout in raceways [11], or sablefish (*Anoplopoma fimbria*, [12]) to evaluate the sustainability implications of the decision to source fillets from larger or smaller fish. The metrics assessed include the production (tonnes) per hectare (ha), feed conversion ratio (FCR), and the total use of animals. The results of this analysis are discussed in terms of seafood sustainability and the shortcomings of farm-level certification, along with the ability for restaurants, food service, and other providers of "center of the plate" to impact the sustainability of global aquaculture.

2. Results and Discussion

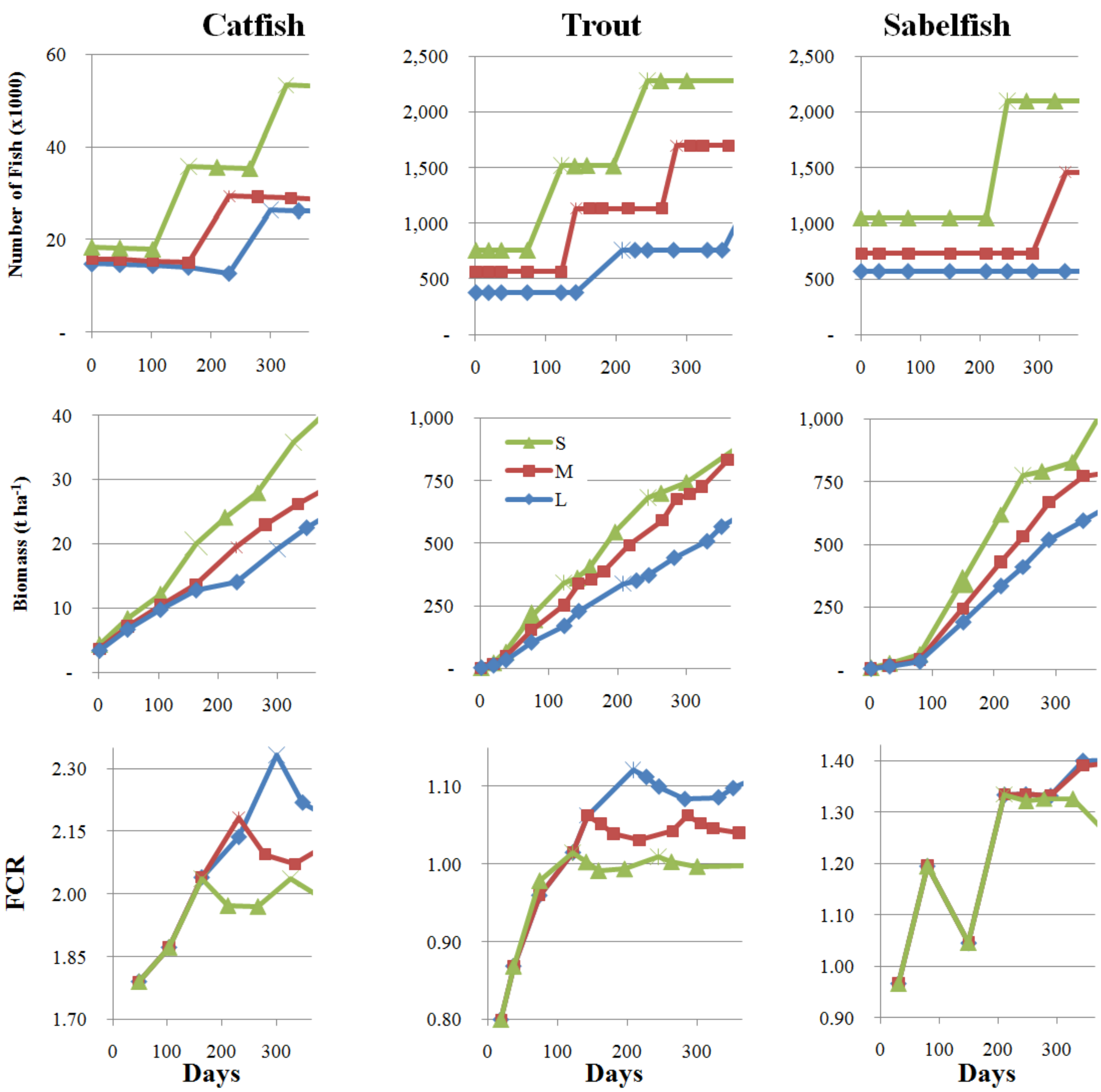
Over the course of one year, producing small fish resulted in 47, 53, and 58% more biomass per hectare for trout, catfish, and sablefish, respectively, compared to when large fish were produced (Figure 1). This result is a combination of higher rates of gain of biomass by the smaller harvested fish, coupled to greater numbers of fish (Figure 1). To reach a similar final biomass, greater numbers of small fish were stocked compared to larger fish. In addition, more total individual fish were utilized for the small size of production since the fish were harvested 96, 137, and 217 days sooner (rainbow trout, catfish, and sablefish, respectively) than the larger individuals of the same species. Because of these differences, one (sablefish) or two (catfish, rainbow trout) crops of small fish could be produced per year period compared to one (catfish, rainbow trout) or no (sablefish) complete crops of large fish (Figure 1). The total use of feed increased by 30, 33, and 43% (catfish, rainbow trout, sablefish, respectively) for the production of small compared to large fish. However, when coupled to the increase in biomass, the cumulative FCR for the production of small catfish, sablefish, or trout decreased by 8, 9, or 10%, respectively, compared to the production of larger individuals (Figure 1). While within species, the FCR increased equally for all size-harvest classes during the first production cycle, the increase was maximized at a lower level for the small fish than for the other size-harvest classes as the new crop of small more efficient fish enter the production cycle, affecting the cumulative FCR value (Figure 1c). For large fish production, the FCR value increased to a larger value prior to harvest than the new crop of small, efficient fish affecting the cumulative FCR value (Figure 1c).

In all cases, the difference between the production of small and large fish were the greatest. The production of medium sized fish was intermediate to that of small or large fish. The exceptions to this were for rainbow trout biomass in which small and medium fish were equivalent, and sablefish FCR, in which medium and large fish were equally high.

The one metric in which the production of small fish was not as efficient as the production of large fish was in the total number of fish used in production. Nearly twice the number of fish was required in the small fish production as compared to the production of large fish (Figure 1). This increase was in part because of the additional fish needed to reach the final density, along with the additional annual harvests that could achieved within small fish production (Figure 1).

According to sustainable seafood guides, catfish and rainbow trout have been identified as being more environmentally friendly species [13]. However, this reanalysis of data demonstrates that not all catfish or rainbow trout production schemes are equally environmentally friendly. This is because specific aspects of sustainability can be most controlled by the farm. Factors such as how effluents and wastes are treated, the sourcing of feed components, and water and energy use are all factors common across the production of a specific farm. While the production of specific size-classes of fish in aquaculture is a farm level decision, the farm is producing a product to meet a specification of the buyer. Thus, while it is important for retailers and chefs to source from farms that have demonstrated sustainable or environmentally friendly production practices (e.g., through certification), these end users can further influence the overall sustainability of the fish offered to the end consumer. The retailers and chefs need to ask for smaller sizes of fish to be produced in order to take advantage of the lower FCRs and greater biomass production per unit area. It is through this purchase specification that fish production in aquaculture can increase to aid in meeting the growing global demand for seafood.

Figure 1. The number of fish (top), the biomass (t ha^{-1}, middle) and the cumulative feed conversion ratio (feed conversion ratio (FCR), bottom) for three species produced in aquaculture. Small fish production is indicated by triangles, medium fish by squares, and large fish by diamonds. X indicates harvests for each production scenario.



3. Experimental Section

First, the harvest density of the large size fish was determined for each species. While the different production methods rely on different metrics and methods for stocking (e.g., raceways on a water flow basis, and cages on a volume basis), for ease of comparison and calculation, results were based on a per hectare basis. The number of small and medium fish required to meet that final density were also determined for each species. A discrete size-specific growth assessment was then conducted for the three size classes of each species of fish. Data for growth were collected from Robinson and Li [10] for catfish while RH provided rainbow trout data and SC provided sablefish data (Table 1). Since a specific species-size class of fish could be harvested in less than 365 days, each production unit (pond/tank/cage) within the model was "restocked" with a new cohort of small fish to mimic continual production. Biomass and cumulative FCR were recorded as values after 365 days of production. For ease of discussion, the results for small and medium sized fish were compared as percentages to the production of the large size class of fish within each species. The catfish data [10] also contained mortality data, and this was incorporated into the model for this species. Since large fish have a greater cumulative mortality, incorporation of this parameter will increase the efficiency of the smaller fish only by the additional mortality large fish experience when growing beyond the size at which small fish were harvested.

Table 1. Harvest density, start weights and growth increments (size and number of days) for production of small (*), medium ($^{\gamma}$), and large (final) catfish in ponds, rainbow trout in raceway, and sablefish in net pens. Note that sablefish production takes longer than one year to the large sized fish.

	Catfish	**Rainbow trout**	**Sablefish**
Harvest Density (t ha^{-1})	15.8	339.0	766.2
Start wt (g)	200	5	7
Wt_1 (g)/d	400/48	31/19	25/31
Wt_2 (g)/d	700/55	88/18	58/49
Wt_3 (g)/d	900/60 *	275/37	339/70
Wt_4 (g)/d	1,200/68 $^{\gamma}$	450/48 *	596/61
Wt_5 (g)/d		605/21 $^{\gamma}$	736/36 *
Wt_6 (g)/d			925/42
Wt_7 (g)/d			1,060/55 $^{\gamma}$
Wt_8 (g)/d			1,207/57
Final wt (g)/d	1,400/69	900/65	1,369/63

4. Conclusions

Global protein demands are increasing. For fish protein, harvests of wild species may be at capacity, whereas aquaculture has the opportunity to meet the growing demand [9]. However, the benefit of aquaculture needs to be maximized by optimizing efficiency and production capacity. Robinson and Li [10] originally demonstrated that the production of small catfish is more efficient than the production of larger sized catfish. Here this idea was expanded to examine how restaurant and food service sourcing of smaller fish could impact the production efficiency of pond, raceway, and net pen based aquaculture. If restaurants and food service were to serve an equal amount of fish, but would require the fillets to come from smaller sized fish, this could increase the production capacity of aquaculture by nearly 60%.

The selection of these three species as menu options is an environmentally friendly decision because all three are largely considered best choices for sustainable seafood. However, even with a strong approval ranking in seafood guides, here we demonstrate that there are ways to make production of these species more environmentally friendly. This supports the idea that sustainable seafood production is a trajectory [7,8] and not a single bar that needs to be passed. Each participant in the supply chain has their role they play in assuring the seafood that reaches the consumer has the lowest impact possible. While requiring an ecolabel is one means to assure this end goal, sourcing specific product forms, such as smaller sized fish, is another means. Since aquaculture operations tend to produce to predetermined specifications, the request for smaller sized fish is an undertaking that can be led by restaurants and food service operations to maximize their impact on the sustainable seafood movement. For maximum effect, this sourcing strategy should be paired with a customer education program describing why the fillet is restricted to the center of the plate, and is not spilling over the edge.

This work points out two ways to increase the sustainability of fish production. Young fish are more resource efficient that older fish, so harvesting younger fish results in more production per unit input (feed, and ultimately fish meal for those species in which this is an issue). However, since the young fish can be produced in a shorter amount of time than older fish, multiple crops can be produced which increases the overall productivity of the space allocated to production. Both of these means will be important to feed the global population, especially given light of its impending growth. Yet, the performance of species in aquaculture is a multifactoral issue both in terms of inputs and outputs. While our arguments point to questions of efficiency, there are additional factors that need to be accounted for. Bauer and Schlott [14] determined that both the cost and risk of producing small fish was less than for larger fish. Yet lower costs of production for smaller individuals are not the case for all species. In shrimp, it was noted that a single long cycle of production resulted in greater profitability for the farmer than two shorter cycles per growing season [15]. While the efficiency of producing small animals is biologically constant across all species, the specific details need to be worked out for each species and production system. Economic considerations are an important point of sustainability, and if the costs of producing small individuals outweighs the benefits, or the producers are not compensated, then this option may not be viable.

The earth has a finite amount of space, and all forms of food production, including fish production in aquaculture will not be able to limitlessly increase. The sourcing decision described within this paper is about how to responsibly increase aquaculture production per unit area available, and how to best select amongst a range of options for a single species. However, for a restaurant or food service, their menu is a mélange of species with each having its own ecological, social, and financial benefits and limitations. The appropriate sourcing of a single species to maximize production per available area is a positive move along the sustainability trajectory. However, retailers that are concerned about the production per unit area can do more than improve on which species are sourced. Another decision to maximize production per unit area would be to ensure that low trophic level species are well represented on the menu [16]. This decision, coupled to the sourcing of appropriate sized products would more rapidly advance the sustainability trajectory.

Acknowledgements

The authors thank E Robinson for his work, and reviewing a draft of this manuscript. The thoughts presented in this paper benefitted from participation in numerous discussions with various participants from the Conservation Alliance for Seafood Solutions with special thanks going to the members of the Sustainable Seafood Initiative at the New England Aquarium.

References

1. Harnack, L.J.; Jeffery, R.W.; Boutelle, K.N. Temporal trends in energy intake in the United States: An ecologic perspective. *Am. J. Clin. Nutr.* **2000**, *71*, 1478-1484.
2. Rolls, B.J. The supersizing of America: Portion size and the obesity epidemic. *Nutr. Today* **2003**, *38*, 42-53.
3. Arts, M.T.; Ackman, R.G.; Holub, B.J. "Essential fatty acids" in aquatic ecosystems: a crucial link between diet and human health and evolution. *Can. J. Fish. Aquat. Sci.* **2001**, *58*, 122-137.
4. Pelletier, N.; Tyedmers, P.; Sonesson, U.; Scholz, A.; Zeigler, F.; Flysjo, A.; Kruse, S.; Cancino, B.; Silverman, H. Not all salmon are create equal: Life cycle assessment (LCA) of global salmon farming systems. *Environ. Sci. Technol.* **2009**, *43*, 8730-8736.
5. Lee, D. Aquaculture Certification. In *Seafood Ecoloabelling: Principles and Practice*; Ward, T.J., Phillips, B.F., Eds.; Blackwell Publishing Ltd: Oxford, UK, 2008; pp. 106-133.
6. World Wildlife Fund (WWF). *Benchmarking Study on International Aquaculture Certification Programmes*; WWF: Zurich, Switzerland and Oslo, Norway, 2007; p. 96.
7. Costa-Pierce, B.A. Sustainable ecological aquaculture systems: The need for a new social contract for aquaculture development. *Mar. Technol. Soc. J.* **2010**, *44*, 88-112.
8. Tlusty, M.F. Environmental improvement of seafood through certification and ecolabelling: theory and analysis. *Fish Fish.* **2011**, doi:10.1111/j.1467-2979.2011.00404.x.
9. Bostock, J.; McAndrew, B.; Richards, R.; Jauncey, K.; Telfer, T.; Lorenzen, K.; Little, D.; Ross, L.; Handisyde, N.; Gatward, I.; Corner, R. Aquaculture: Global status and trends. *Philos. Trans. R. Soc. B* **2010**, *365*, 2897-2912.
10. Robinson, E.H.; Li, M.H. Channel catfish, ictalurus punctatus, size and feed conversion ratio. *J. World Aquacult. Soc*. **2010**, *41*, 829-833.
11. True, B.; Johnson, W.; Chen, S. Reducing phosphorus discharge from flow-through aquaculture I: facility and effluent characterization. *Aquacult. Eng.* **2004**, *32*, 129-144.
12. Cross, S. Growth of sablefish. *Anoplopoma fimbria*. **2011**, unpublished data.
13. Roheim, C. An evaluation of sustainable seafood guides: Implications for environmental groups and the seafood industry. *Mar. Resour. Econ.* **2009**, *24*, 301-310.
14. Bauer, C.; Schlott, G. Fillet yield and fat content in common carp (Cyprinus carpio) produced in three Austrian carp farms with different culture methodologies. *J. Appl. Ichthyol.* **2009**, *25*, 591-594.
15. Krummenauer, D.; Cavalli, R.O.; Ballester, E.L.C.; Wasielesky, W., Jr. Feasibility of pacific white shrimp *Litopenaeus vannamei* culture in southern Brazil: effects of stocking density and a single or a double CROP management strategy in earthen ponds. *Aquacult. Res.* **2010**, *41*, 240-248.

16. Duarte, C.M.; Holmer, M.; Olsen, Y.; Soto, D.; Marba, N.R.; Guiu, J.; Black, K.; Karakassis, I. Will the oceans help feed humanity? *BioScience* **2009**, *59*, 967-976.