PASSING THE PANDA STANDARD: a TAD off the mark?

INTRODUCTION

Significant and increasing portions of global industrial aquaculture production for internationally traded species may soon come under the umbrella of voluntary certification schemes [1]. Such schemes operated by organisations including producer groups, retailers, and non-governmental organisations (NGOs), act through product labelling to guarantee that conditions under which farmed aquatic produce is produced conform to various environmental, ethical and health related standards. The presence of an 'eco-label' is intended to act a source of information for consumers, enabling them to assert choices which favour preferred product attributes, thereby facilitating market based-shifts in consumption toward more desirable forms of production.

Production of tilapia[1] has grown rapidly over the last decade. Global output of farmed tilapia doubled between 1997 and 2004 [2] and is anticipated to exceed three million tonnes (live weight equivalent) by 2010, if not sooner [3]. During the same period global trade in tilapia quadrupled in volume and rose 6.5 fold in value as the fish become an internationally traded commodity with major markets in the developed world [2].

Several farm assurance certification schemes for tilapia production have been initiated as a result of these concurrent trends. Prominent amongst these is the Tilapia Aquaculture Dialogue (TAD), a forum established by the World Wide Fund for Nature (WWF). The TAD process is based on development of a set of principles for 'responsible tilapia production' which form the basis for farm certification standards. The 'dialogue' is intended to achieve meaningful and inclusive engagement with a group of stakeholders which includes large-scale tilapia producers, buyers and retailers, environmental NGOs and natural scientists professionally involved in aquaculture research. Principles are designed to provide criteria for identifying sustainable production practices and indicators against which to measure them. These in turn will form the basis of a set of 'better management practices', adherence to which will ultimately earn a retail product the right to display a label denoting the 'responsible' nature in which it was produced [4]. As with other major certification schemes, it is envisaged that, once implemented, compliance assessment and certification of the resulting standards will be conducted by a third party organisation the Aquaculture Stewardship Council (WWF, 2009).

In order to assist aquaculture dialogue stakeholders to develop certification standards, WWF commissioned a review of information on culture methods, possible negative environmental and social impacts and food safety concerns for a number of cultured aquatic species under consideration for certification [5]. Findings relating to tilapia were published in a peer-reviewed paper which provided a reference point for the subsequent development of TAD principles [5]. Because the TAD is an ongoing process that has not yet reached its final conclusion it represents something of a 'moving target'. This paper therefore elects to evaluate the most recent version of the draft standards (which remain under public review and subject to further change) alongside the review (which is a complete document, the central assumptions of which continue, with some notable exceptions, to be reflected in subsequent draft TAD standards). Additional information is drawn from supporting documents published on the TAD website as outcomes of TAD meetings. Taking this approach allows the evolution of the TAD process and, along with the logic that has shaped it, to be traced. Such thorough evaluation is timely and warranted because a close reading of both the review and the draft standards reveals alarming omissions and misconceptions of the issue of sustainability as it relates to tilapia production[1].

CERTIFICATION ISSUES

The original review identified twelve issues for consideration by stakeholders in the certification

[1] Even at this late stage in their development, new proposals, such as the inclusion of fish welfare, are being considered [ ] This article is positioned in expectation that, in line with the ISEAL compliant process being followed by all WWF's aquaculture dialogues [ ], the TAD process is still open to new inputs.

dialogue. These issues, nearly all of which are technical in nature, are listed in Table 1 along with the relative importance that the review's authors' ascribed to each in terms of potential impacts. The issues and principles established in the draft standards are presented in Table 2. A comparison between the categories in the two tables reveals the derivation of the issues in the latter from the former and a high degree of similarity between the two. Since there is some overlap even among the seven issues addressed by TAD, we divide our up analysis into four overarching categories in the discussion which follows. These are; fish health, resource use, water quality and the aquatic environment, and user conflicts and wildlife[2].

Table 1 Relative importance ascribed by the WWF review to the issues addressed [5]

Table 2 Framework for draft standards for responsible tilapia aquaculture developed by TAD (from WWF, 2008)

Fish health

The review [5] notes that tilapia are more resistant to disease than most farmed fish species and that there is little use of antibiotics, drugs and other chemicals for disease control in their culture. It also suggests that certification programmes should discourage the use of antibiotics and drugs and disallow their use as prophylactics. According to the review the spread of disease from farm to wild fish is a possibility, but of low relative importance. The review also indicates that a high incidence of disease on farm can be expected at sites where water quality parameters are outside optimal ranges, and that fish are often susceptible to disease when stocked at high density and subject to stress [5]. The draft standard [ ] reiterates this position, stating that 'there are few recorded cases

[2] A fifth category, 'biological incursion' was originally included in this analysis. The decision was made to remove it to allow for more a detailed exploration of the other issues as the authors endorse the TAD's position on this issue at the time of writing.

of disease directly attributed to tilapia farming'. It also replicates the review's position in advocating the use of use of mortality rates as a key indicator.

Whilst it is true that the hardy characteristics of tilapia are one of the features that make them an attractive culture species, evidence emerging from Asia suggests that disease is becoming a significant and growing problem as production expands and intensifies. Very recent evidence from Thailand suggests that in a number of watersheds a pathogen previously unknown in tilapia, *Microsporidum*, has been responsible for extremely high mortalities in cage raised tilapia and is apparently also fatal to other species of fish [9]. One assessment of tilapia culture in Central Thailand found that disease was the second most common reason, after low farmgate price, for farmers' failure to break even; 30% of pond-based, and 58% of cage-based farms having failed to do so as a result of a disease outbreak [10].

Streptococcus iniae is one of the most economically significant diseases prevalent in farmed tilapia [11]. Antibiotics are only usually effective in treating bacterial outbreak if treatment is applied very early during the course of the disease and in most cases of *Streptococcus* outbreak oral antibiotics are ineffective [12]. Persistent antibiotic application is also likely to result in the emergence of resistant strains [13] and concerns regarding food residues create negative consumer perceptions. Standards could be used to compel farmers to adopt non-therapeutic preventative measures; anti-bacterial vaccines are in rapid development, though without simultaneous improvement in the diagnostic capacity of smaller-scale operations such a standard would simply impose a relatively greater economic burden on this group.

Good management is the best prevention measure for streptococcal disease. This includes maintaining good water quality parameters, removal of dead fish, good diagnostic capacity and maintenance of farm records that monitor disease incidence on a production-unit basis. Stocking rates may also influence the health of tilapia, with high densities linked to high disease transmission rates and mortality [14]. Transmission of *Streptococcus* from Nile tilapia to cyprinids has been observed under laboratory conditions [15], but whether reservoirs of disease in cultured tilapia pose any threat to wild fish of other species is open to question.

As indicated above, tilapia produced in cages (floating enclosures with mesh sides) under intensive conditions may be more susceptible to infectious pathogens than those raised in ponds at lower densities [16]. The review also notes that poor water quality related to high stocking densities may cause frequent or constant stress [5]. These conditions are often linked to outbreaks of streptococcosis [14]. Cages are open to the surrounding environment to facilitate water exchange which provides stocked fish sufficient oxygen and removes metabolites and uneaten feed. The open nature of cages results in extremely poor bio-security, with fish readily exposed to pathogens and pollutants from the surrounding environment. A study from Thailand found that failure to break-even on at least one occasion was far more common among farmers operating cages in rivers and canals than ponds, with poor performance commonly resulting from mortalities related to industrial, agricultural or municipal pollution. Every single cage farmer interviewed for the study had lost money at least once, whilst only half of pond farmers (most of whom had farmed for far longer) ever had. Large fluctuations in market demand/value for cage fish compared to pond fish were found to be an equally important reason for incurring losses however [10]

Resource use

This category addresses the use of land, water, and other natural resources. The review refers to land use in terms of the surface area required for pond production. It notes that pond culture of tilapia is 'land intensive', in comparison to cage based operations which require very little land other than small bank-side staging and storage areas, and suggests that farms should not be built on wetlands or habitat protected by law for conservation purposes, assigning the issue a high level of importance. The current draft standards also reiterate the need to prevent wetland loss [ref].

However, the historical co-development of pond-based tilapia aquaculture with agriculture and urbanisation [15] means that it is unusual for the construction of inland aquaculture ponds to occur on areas of high conservation value such as wetlands, the more common route being conversion of agricultural land or exploitation of 'borrow pits' dug for house or road construction. Land utilized directly for pond-based tilapia production is therefore typically of limited ecological significance. There is also evidence that pond excavation may lead to the creation of a mosaic of terrestrial and aquatic habitats, thus benefiting aquatic biodiversity [20]. More importantly, the land and space resources occupied by aquaculture operations are of far lesser significance than the ecosystem area, or 'ghost hectares' required to supply resources that sustain the activity [18].

The draft TAD standards downplay water use, referring only to a requirement to prevent salinization of groundwater and limit nutrient loadings. This contrasts with the draft Pangasius Aquaculture Dialogue (PAD) standards [ ] for which water use (consumption) features as an important issue. This framing of the water use issue obscures the need to link the quality of intake and output water to any net consumption (or production) of water per unit biomass gained during culture. Feed-associated water use is therefore overlooked. This may be significant since intensive fish production systems reliant on commercial fish feeds produced using primary outputs of terrestrial agricultural production are potentially more water consumptive in this regard than semi-intensive alternatives, as more than 1m^3 of water is required to produce a single kilo of grain [19]. Furthermore the effects of pond construction are misconstrued, since, although subject to losses through evaporation and seepage they tend to be net contributors to overall water budgets since they serve to harvest and store rainwater, as both surface and recharge groundwater that would otherwise be lost as run-off [21].

The only other resource considered by the draft standard is fish meal[3]. Use of fish meal derived from marine fisheries for aquaculture may adversely impact the eco-systems from which it originates [22; 23]. However, as rates of fish meal inclusion in formulated tilapia feeds are relatively low (4-8%), it is theoretically possible to recover greater amounts of fish meal from tilapia processing waste than is used in the feeds on which they are grown. The most recent draft TAD standards develop this concept further, introducing a quantitative measure, the 'Inclusive Feed Fish Equivalency Ratio (IFFER)' in order to 'account for how much fish meal and oil is used and how much is produced via the production process' [24]. Under this standard the IFFER must be ≤0.5 and, if greater than 0, 'the origin of fish meal and oil should be from fish stocks that have an average score > 7.5 with no individual indicator below 6.0' according to data from 'Fishsource' an online tool hosted by the NGO Sustainable Fisheries Partnership. Such an approach is of merit (provided that the offset is a measurement of the actual quantity of fishmeal reclaimed from tilapia carcasses during processing, as opposed to the quantity theoretically possible), in that it effectively stipulates maximum levels of fish meal and oil inclusion in tilapia diets and ensures that they be requisitioned from sustainably managed sources.

There should, however, also be an evaluation of the opportunity cost of using by-products for fishmeal. Flesh/bone separation, mincing and other techniques provide increased opportunities for additional products for human consumption to be made with higher unit-values than fish meal [25]. Furthermore, it is important to acknowledge that although meal derived from farmed fish such as tilapia may be partially substitutable for wild fish in feed, they cannot replace the function of wild fish in the ecosystems from which they were extracted [26]. Fish meal inclusion rates in herbivorous fish feeds are low and its conversion is more efficient than in other livestock production system. However, only a relatively small portion of tilapia and carps are presently

[3] As the remainder of this section makes clear, this represents a major oversight. The emphasis placed on fishmeal, as compared to terrestrial feed ingredients, in particular soy, reflects a focus on the marine environment among most of the NGO members of the TAD Steering Committee (the effective decision making body in the process) and the interests

produced using formulated diets and trends point toward the ongoing intensification of production of these species throughout Asia [27]. The sheer volumes produced, particularly when projected into the future, are such that, notwithstanding lessening demand for fish meal in poultry and pig farming [28], cumulative impacts on demand for fish meal resulting from their intensified production may ultimately be far greater than at present [23].

The standards fail to take into account either the scale or relative efficiency of natural resource consumption associated with intensified tilapia aquaculture. At present the majority of global tilapia production may still occur in ponds under semi-intensive management conditions in which pond water is fertilized to stimulate production of phytoplankton and other micro-organisms. These are utilized by tilapia as natural feeds, usually with additional supplemental feeding[2] [29]. Systems such as these typically utilize local by-products and wastes from other human activities as fertilizers and supplemental feeds, and are thus integrated into the agro-ecosystems in which they are located [30].

A vast array of resources are exploited for this purpose; crop processing provides rice bran and oil cakes; slaughterhouses provide entrails, blood and bone; food manufacturing, breweries and distilleries provide diverse organic residues; and intensive livestock production provides a ready source of manure for pond fertilization [31]. Nutrient utilization is most efficient when tilapia are fed nutritionally complete diets [29], and significantly shorter grow-out times reduce feed energy requirements for stock maintenance as well as increasing labour and capital efficiency. However, broader definitions of efficiency are relevant since, considered *in toto,* integrated systems may be more efficient in terms of nutrient and hydrocarbon utilisation [32]. A significant proportion of total nutrition can also be obtained from natural feed produced *in situ* stimulated by the residual fertilization within pellet-fed ponds.

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and experience of their staff

Intensive aquaculture is heavily reliant on fossil-fuel energy inputs [33] because of the numerous steps involved in production of complete fish feed (production of machines, fertilizers, pesticides and ships to produce feed ingredients, the subsequent manufacturing processes to which they must be subjected and the transportation of these ingredients over long distances) which all require combustion of hydrocarbons [34]. Intensive tilapia culture also possesses a high degree of dependence on external ecosystems, requiring resources from large ecosystem areas outside the farm to produce its feed, to assimilate its nutrient wastes, and to maintain dissolved oxygen [35]. Feed ingredients used in complete feeds (soy meal, fish meal, maize, wheat, linseed etc.) are sourced directly from primary agricultural and fisheries production (i.e. cultivated or captured for the sole purpose of inclusion in fish feed), and are traded internationally as commodities, and transported over many 1000's of miles. Furthermore, production of soy, which comprises approximately 60-70% of the protein in most commercially available formulated tilapia feeds, has been linked to a variety of negative ecological and social impacts, of which perhaps the most troubling is widespread deforestation in the tropics [36]. Using the TAD as a means to endorse soy products certified with respect to their environmental and social credentials could therefore represent an opportunity to mark out tilapia as a highly sustainable 'frontier' product. It would also represent joined up thinking since WWF is in the process of certifying soy producers through a separate initiative but is, at present, a lost opportunity [ ]

Comment [B1]: Need a reference for this

In contrast, the agricultural and agro-industrial by-products used as inputs for integrated systems require less differentiated ecosystem space to produce since they come from areas already appropriated for food production for human consumption. Integrated pond culture which utilizes such nutrients therefore increases the quantity of food produced per unit of total ecosystem area [37]. Furthermore, the nutrients on which integrated tilapia production depends require lower hydrocarbon expenditure to prepare or, because they are generally produced within or close to the agro-ecosystems where tilapia farming occurs, transport to the pond [10]. The ecological footprint associated with production of inputs and assimilation of waste outputs therefore is far larger for intensive cage farming than for intensive/semi-intensive pond farming [35].

Water quality and the aquatic environment

In relation to nutrient enrichment and water pollution the initial review concluded that production of tilapia in ponds where little water exchange occurs allows natural biological processes time to assimilate much of the nutrient originating from application of feed and fertilizers whereas cages, in which these processes cannot occur, have greater pollution potential. Solids (primarily uneaten feed, faeces and their decomposition products) and soluble nutrients are discharged continuously from cages. For semi-intensively managed ponds, wastes are mainly discharged during harvest, and are composed largely of plankton and clay particles which have a lower oxygen demand than cage waste products [5].

Benthic effects result from deposition of organically enriched sediments at much higher rates than would occur under natural conditions. This can cause sediments to become anaerobic, altering the composition of communities of benthic organisms. Although elevated sedimentation may occur at the outflows of land based aquaculture systems, impacts in the vicinity of cages are typically far greater [5]. The same applies to nutrient loading: in terms of weight of nitrogen and phosphorous released to the environment for each kg^{-1} fish produced, open intensive systems exchanging water with the surrounding environment (cages or raceways) are respectively 7-31 and 3-11 times more polluting than static ponds [29]. More than 80% of N and P inputs to semi-intensive pond based fish culture are immobilized in sediments on the pond bottom, whereas no nutrients are sequestered by open intensive culture systems which discharge 73% of N and 86% of P to the external environment [29]. Appropriate harvest and draining methods can reduce the discharge of pollutants from tilapia culture ponds. In addition, whereas pond sediments may also be applied to terrestrial crops as an excellent fertilizer, commercial adoption of technologies for the recovery of wastes from cages used for the on-growing of tilapia have not been developed. However, unlike the review that preceded them, the most recent draft TAD standards make no mention of any difference between cages and ponds. In fact, the TAD Steering Committee (of which several key members are cage-culture based enterprises) now holds that all the major culture systems (cages, ponds, and raceway systems) must be considered equal.

The dialogue opts to address rates of eutrophication increase rather than attempting to determine the carrying capacity of receiving waters since 'addressing an impact rather than an indicator dissuades the debates around the ability for systems to assimilate nutrients' [24, p6]. Therefore, 'rather than requiring an assessment of the phosphorus carrying capacity of the proposed receiving waters, the TAD is proposing to address the actual level of impact itself – the fluctuations of dissolved oxygen in receiving waters'. Producers will also 'be kept to strict limits of chlorophyll a and total phosphorus'. Total farm phosphorus output will be calculated as 'the amount of phosphorus released into the natural environment per mt of fish produced', with 'phosphorus not included in fish at harvest' [24, p15] considered the amount of phosphorus released into the environment. This logic is understandable given the difficulties involved in accurately calculating the carrying capacity of receiving water bodies, but flawed. The draft standards themselves state that 'quantifying the amount of phosphorus in effluents is complicated as a result of various feeding times, different times for drain harvests of ponds, precipitation of phosphorus for particular waters, dissolution of phosphorus for specific waters, specific soil phosphorus absorption conditions and the fact that there is no point-source of effluent from cage operations' [24, p15], and yet by effectively reducing the equation to P in = P out the standard fails to account for important site specific and more generalised qualitative differences in nutrient dynamics, and their related effects, thus painting a far more favourable picture of nutrient emissions from open systems than is warranted. The singular attention to phosphorous is also misplaced since while this element is generally acknowledged to be the primary limiting nutrient in temperate waters, conditions in the Tropics are more complex and nitrogen is known to be more important [25].

There are further inconsistencies. The draft standards take the position that zero nutrient impacts into receiving waters are not possible for commercial systems [ ]. This is incorrect. 'Zero impact' is possible in recirculation systems (RAS), since nutrient wastes can be completely removed from liquid effluent discharge. RAS can also be very conservative in terms of water use, and modern designs prioritise efficient energy use. Investment in RAS for tilapia production is increasing in Europe and North America in response to niche market demand for locally produced food [ ]. Bizarrely, RAS systems unacceptable within the current TAD draft standards, which considers them as a 'trade barrier to small scale farmers and at the present not having enough volume to shift global markets' [ ].

Comment [B2]: Need reference

User conflicts and wildlife

The review commissioned by WWF, [5] reported that although there are few documented instances of tilapia farms depriving local communities of traditional privileges, some evidence of user conflicts exists and is worthy of further exploration by certifiers. The draft TAD standards differ somewhat however, introducing a separate social standard. User conflicts are not mentioned in this standard, and the only 'social' issues incorporated relate to labour regulations and worker rights [ ]. This would appear to favour large vertically integrated enterprises (the dominant voice among the commercial representatives of the Steering Committee), whilst being less well-suited to addressing the more informal labour relations within medium scale and household enterprises more typical in Asia.

The review's observation that piscivorous birds and other predators are sometimes killed by fish farmers to prevent fish predation, and that certification should require non-lethal predator control [5] has been adopted in the draft standard. It is questionable whether this issue deserves the high relative importance ascribed in Table 1. Avian predation is primarily an issue when tilapia are juveniles and can be minimized, without harm to the birds, through the use and correct management of the right type of visible netting over nursery ponds [39]. A more proactive approach might encourage the set-aside of water resources and associated land as dedicated habitat to actively encourage the presence of wildlife compatible with fish culture and mitigate any impacts on wildlife associated with farm construction. The creation of artificial wetlands for this purpose could also serve an additional bio-remediation function by sequestering nutrients discharged from ponds during harvest.

DISCUSSION

Prioritising Sustainability Issues

When the TAD was set up in 2005 its initial focus was to provide certification for the developed world's largest market for tilapia, North America. The majority of fresh tilapia sold in North America originates from Central America, with far larger volumes of frozen imports originating from China and Taiwan [2]. Central America is unusual in that most farms are strongly export oriented, corporately owned, industrial in scale, and intensively managed. This contrasts with Asia where 78% of global tilapia production takes place and the majority is produced less intensively. The operations of most, if not all, the tilapia producers engaged as stakeholders in TAD are located in Central America. The prioritisation of issues arrived at in the initial review (Table 1) and still largely reflected in the draft standard therefore reflects an orientation towards certification of an atypical and, in absolute volume-terms, far less significant production system.

When integrated semi-intensive culture systems are also considered, it is clear that by far the most important sustainability issues revolve around efficiency of resource use [32]. Intensive culture methods demand a high throughput of matter and energy, the hidden costs of which are reflected in a sizeable ecological footprint. This contrasts sharply with integrated culture methods that enhance efficiency of natural resource consumption and, as a result, embody a high degree of sustainability [40; 37]. Standards for tilapia production such as those likely to result from TAD may therefore do little to improve the sustainability of the industry as a whole, though the potential to generate some localised farm level improvements among participating producers exists. The formulation of standards in this manner (i.e. treating the localized ecological impacts of individual farms as the main focus of environmental degradation, and neglecting the important negative externalities associated with the production process) represents a serious failure to grasp the significance of ecological impacts occurring beyond the immediate vicinity of the farm. It is therefore necessary to seriously question the validity of any standards for tilapia which equate responsible production practices solely with highly resource consumptive intensive culture systems.

The Comparative Sustainability of Cage and Pond Based Tilapia Culture

Although significant nutrient losses may occur in ponds through seepage [41] and, periodically, when water is exchanged or drained, cages discharge a far greater proportion of nutrients into receiving waters than do semi-intensively managed ponds [29], and are thus, in general terms, more likely than ponds to promote or add to the eutrophication of surrounding water bodies. This may alter the makeup of ecological communities and their function and, in the most severe cases, result in oxygen depletion that kills fish and other aquatic organisms [42; 43]. Escaped fish should also be considered wastes [18], and although ponds are by no means sufficiently secure to preclude the possibility of fish escaping, the likelihood of escapes is considerably lower than from cages. These factors mean that cage culture is in essence subsidized (the negative externalities associated with the wastes it produces being borne by receiving ecosystems), whereas in intensive/semi-intensive pond culture a large proportion of nutrients are recycled internally or are retained in bottom sediments which remain on-farm and can potentially be applied to terrestrial crops as a fertilizer [44]. This practice remains rare but the increasing real costs of inorganic fertilisation are likely to stimulate greater efficiency through such strategies [ ].

Comment [B3]: Need reference

Extremely high stocking densities in cages place fish under stress, rendering them potentially more vulnerable to the incidence of infectious disease than they might be if stocked in ponds at lower densities [45; 46]. This increases the likelihood that medication will be applied, and more readily released to the wider environment, than if used within ponds. Fish raised in cages are also highly vulnerable to external sources of pollution. In addition to impacting the resilience of smaller producer livelihoods, this has possible implications for food safety and the multi-functionality of water bodies in which cage culture is practiced. Potential for disease transfer from cage fish to wild populations of tilapia or, conceivably, other species is also high because of their openness and high rates of water exchange. Because they are usually located in water bodies with multiple-users, cage based aquaculture also may have greater potential to cause social conflicts than farming in ponds constructed on privately owned land, notwithstanding issues of access, ownership, or tenure that might be relevant in terrestrial farming.

Whilst these factors do not make cage based tilapia culture *de facto* unsustainable, since careful siting can ensure that the assimilative capacity of the receiving water body is not exceeded, they do tend to make it *relatively* unsustainable in comparison to land-based systems. Potential problems associated with cage culture may be compounded by production in waters relatively free of anthropogenic impacts. Several Latin American based export-oriented producers, some of the most influential stakeholders in TAD, specifically emphasize the 'pristine' environments in which their culture systems are located as an attribute in the marketing of their product. Tilapia are naturally adapted to grow in eutrophic conditions and can perform well in water which is somewhat degraded and would be unsuitable for other species [6]. The draft TAD standards specifically state that pristine water will be protected by 'limiting the amount of impact' [ ]. There seems to be little equivalence to this position when compared with the conservation of other highly limited pristine ecosystems (rain forest, coral reefs etc) and the adoption of such by WWF would appear untenable. It is therefore by no means 'responsible' for any certifying body to endorse cage culture of tilapia in relatively intact ecosystems when it can be practised in locations already subject to anthropogenic degradation[4].

Furthermore, in deep stratified lakes and reservoirs (where much of the Latin American cage culture referred to above takes place) there is potential for cage wastes to accumulate in the hypolimnion over long periods, resulting in anoxic conditions which only become apparent when low water levels or changing weather conditions cause sudden mixing throughout the water column. This phenomenon has been documented as resulting in severe mortality among both cage and wild fish [48, 49]. However, Northern consumer understandings of what constitutes clean food production are such that production in ‘pristine’ waters is confused with desirable ‘natural’ attributes, whilst fish production under less aesthetically appealing conditions is likely to be perceived as less acceptable. Certification standards intended to improve the industry’s ecological sustainability should not reinforce this misconception.

Intensive cage-culture has been identified as being the only solution to meeting increasing demand for commodity fish, based on limited land area being available for conversion to ponds [48]. The recent rapid scale-up in freshwater culture of Pangasius catfish culture in Vietnam and of carps, tilapia and catfish in Bangladesh, Myanmar and India suggest that this is far from the case however. It has been suggested that any specific advantages of ponds compared to cages for commodity-scale production of tilapia have declined; in general the relative importance of production compared to costs associated with other parts of market chain diminish in such globally traded products. Thus the importance of culture systems (feed and management) in the overall price to a western

[4] This, of course, excludes any suggestion of culturing in tilapia in waters subject to industrial pollution because of likely off-flavours and potential contamination issues.

consumer for tilapia compared to distribution, marketing costs, import export duties etc, is relatively low [49]. WWF need to consider the likely patterns of tilapia trade into the future however and acknowledge that most consumption will continue to occur in Asia close to production and under these conditions retention of water and nutrient efficient intensive/semi-intensive production is more sustainable.

A review of certification issues in tilapia culture commissioned by WWF in 2004 [50] which preceded the later multi-species review referred to throughout this paper [5], adopts a position that is similar in certain respect to that which we advance here. This first review, which ranks production systems in 'order of environmental friendliness', lists cages as 6^{th} out of a 7 possible culture options [p1], noting that 'certification possibly should be denied to some production systems which have a high potential for causing water pollution, e.g., cages and net pens' [p2], in part because they, 'tend to release much larger amounts of waste in effluent per unit of production than pond culture systems' [p26]. Conversely, the reviewer observes that 'if managed properly, much of the waste from tilapia propagation will be assimilated in ponds' , that, 'ponds managed for semi-intensive production have better quality water than those managed for intensive production' [p26], and that, 'concentrations of potential pollutants increase as production intensity increases' [p18]. The review also prioritises nutrient reuse as a key indicator of good practice, ranking 'raceways and cages integrated into irrigation systems' as the most 'environmentally friendly' culture option, on the basis that 'production systems integrated with irrigation systems, do not cause pollution and should be prime candidates for trial certification' [p1]. Pond-based greenwater culture systems are also potential candidates for certification, given that 'commercial fertilizers can be used in aquaculture without causing adverse environmental impact' and, incorporating guidelines on fertilizer use into certification programs is recommended [p26]. Given that this orientation of values has subsequently shifted so radically toward a position which legitimises, *de facto*, intensive, non-integrated, open tilapia culture systems as prime candidates for certification and pays scant regard to other options, it is reasonable to argue that the TAD has undergone industry capture, becoming fundamentally compromised in the process.

Product Quality

At present, tilapia produced in ecologically sustainable semi-intensive/intensified pond-based culture systems are consumed mainly in Asian domestic markets where cultural preferences and expectations relating to food-fish differ significantly from those in the developed world. Tilapia from these systems are generally harvested at sizes smaller than those preferred in Northern markets, but experience from countries such as Thailand, in which affluent urban consumers increasingly demand bigger fish, demonstrates that large tilapia can be produced in large-scale moderately intensified systems that retain many hallmarks, and benefits, of integrated semi-intensive culture [10].

A more significant objection to semi-intensive tilapia production for Northern markets relates to the sensory quality of fish from fertilised systems. Whereas musty 'off-flavour' in tilapia caused by the absorption of geosmin and 2-methylisoborneol (two metabolites of cyanobacteria that often occur in surface water) may be acceptable to many consumers in Asia, it typically signifies inferior quality product to consumers in export markets [51]. However, raising fish in unfertilised systems using formulated feeds is by no means sufficient to guarantee high sensory quality [52]; off-flavours are related to many aquaculture systems including full recycle systems. In any event, the presence of off-flavour producing chemicals in fish tissue can be reduced to below sensory threshold concentrations by holding live fish in clean water without feed for several days post-harvest and is a well established practice in the US channel catfish industry [51]. Flesh colour is also an issue since fish raised in semi-intensive systems retain white muscle colour less effectively than fish with little or no natural feed in the diet, particularly after prolonged storage. Carbon monoxide, routinely used for humane slaughter of fish, is used successfully in modified atmospheric packaging to overcome this problem however [53].

Furthermore, research indicates that reductions in the natural food produced *in situ* in tilapia diets through the intensification of feeding regimes results in a progressive negative alteration in ratios of omega 3 and omega 6 fatty acids, rendering them less valuable for human consumption in nutritional terms [54]. These factors suggest that drivers for intensification justified in terms of superior product quality may be misplaced, particularly when more holistic values are considered.

CONCLUSION: SETTING MORE SUSTAINABLE STANDARDS

Since market acceptance issues pertaining to product size and quality can be managed to ensure compliance with the demands of Northern consumers, certification standards aimed at ensuring sustainable tilapia production should focus on minimising the management intensity and negative externalities of production systems. It is clear that pond-based culture systems are preferable to cage-culture in terms of sustainability. While cage culture may appear more sustainable if practiced within the carrying capacity of the water body, the risks of uncontrollable contamination, turnover and other factors make this unlikely long term. More semi-intensive culture practices reduce the need for external inputs by stimulating production of natural feed through fertilization. A case has been made for the promotion of semi-intensive culture based on reducing costs. This cannot be achieved in cages, which by virtue of their openness to the surrounding environment are less bio-secure and generally more polluting than static ponds. The commonplace use of livestock manures to fertilize ponds poses minimal risk to human health given appropriate post-harvest product handling [55], but acceptability of such practices to consumers in the developed world would depend on appropriate pre-treatment. Manufactured inorganic fertilizers can also be employed for the same purpose within closed pond systems and, despite lacking the benefits of locally sourced manures in terms of nutrient recycling and low hydrocarbon consumption, reduce the need to apply formulated feeds. Feeding regimes can also be designed to optimize nutrient utilization from combined natural and supplemental feeding [56].

Integrated semi-intensive tilapia culture can recycle locally produced nutrient wastes and by-products from other human activities as feeds. This minimizes the appropriation of ecosystem space and services required to produce feed ingredients, in effect extending the productivity of the areas used in their cultivation. Certification standards should encourage replication of these features as far as is practicable in order to reduce use of feed ingredients cultivated as primary products and discourage the transport of feeds over long distances. Certification should also prioritise the use of processing wastes from fish for human consumption as the source of fish protein in tilapia diets, subject to caveat of what constitutes waste as opposed to failure to fully utilize fish flesh for human consumption.

All these observations point to the inadequacy of certification approaches that focus primarily on the localised impacts of the farm alone. They also imply a need for more rigorous certification which accounts for resource use, negative externalities and other impacts along the entire value chain for the certified product. At present, although there is ample evidence, as presented in this paper, for major differences in relative sustainability between systems of tilapia production at alternative levels of intensity, there has as yet been no definitive comparative study of this nature. Obtaining such data should represent a priority for certifiers, and would be a crucial first step in the creation of a holistic, vertically integrated certification standard for the entire value chain which goes far beyond the more simplistic 'better management practice' guidelines and farm assurance standards currently under formulation.

Any standards introduced to the market should be rational, robust and capable of withstanding close scrutiny from competitors, consumers and other interested parties. This is particularly important where, as here, a new benchmark is being established, since it is likely to become the standard against which subsequent standards, possibly by other certification bodies, will be measured. Given the ratchet effect of standards as they develop, as demonstrated by those for organic aquaculture [57], it is vital that their foundations are sound. The potential scope for miscuing consumers is substantial, and the task of communicating accurate messages about the sustainability of fish resources such that they will be perceived correctly by consumers is notoriously difficult. Once communicated, subsequent modifications, which we contend are necessary here, are all the more difficult to convey. Indeed WWF has recently demonstrated the potentially contentious nature of such issues with its 'Stinky' fish campaign which was initially intended to promote MSC labelled fish products but resulted in widespread dissociation from the aquatic food product sector and ultimately its withdrawal. Source credibility remains key to the effectiveness of messages sent and there is a cost on repeat usage or revision.

This is of particular importance in the case of tilapia. For products such as salmon, production has probably already plateaued and the organisation of production and trade stabilised, limiting the variety of options available for certification and the types of messages produced. For tilapia however, all indications point to large and continuing production increases and an expanding share in Northern markets for aquatic food products well into the future. Thus it is critical that certification efforts conceptualise sustainability issues convincingly and accurately from the outset if they are to allow consumers to exercise informed choices convergent with discouraging destructive practises and fostering positive ones through the market place. Should TAD fail in this regard, only to be subsequently discredited in the light of greater public scrutiny, it would prove damaging, not only to WWF and its other certification projects but, potentially, to the concept of eco-labelling as a whole. Thus, there is clearly a need for WWF to review the TAD from the perspective of broader sustainability, delinking it from the rather narrow perspective of marine ecosystem protection that currently dominates thinking on feed inputs.

Although Asia consumes more than two thirds of the world’s aquatic produce, very few Asian consumers as yet discriminate between products on the basis of their environmental attributes [26]. There has also been limited participation by Asian stakeholders in the TAD process to date. This is in part a function of the greater ease with which larger stakeholders and consumers in the Americas can be engaged. In effect an asymmetric dialogue has resulted, biased towards standards that have less to do with global sustainability and are more reflective of the ability of well resourced vocal stakeholders to secure beneficial endorsements through active participation; and the global North location of the main public constituency from which support for the big marine conservation orientated NGOs involved in TAD derives. This dislocation provides further cause to query the utility and purpose of such standards.

The TAD approach might arguably represent the first necessary step in an evolving process that becomes more geographically inclusive and responsive to the global realities of production and consumption as it develops, were it not to prejudice future opportunities for pond based producers in Asia and elsewhere. At present however, producers who farm tilapia in more sustainable, less intensive systems (and possess weaker market power than the larger intensive export-oriented producers engaged by TAD) are likely to be most adversely affected by a set of certification standards that emphasise the perception of buyers and consumers that fish raised in such a manner are of poor quality. These producers are unlikely to be able to afford subsequent communications challenges to remedy any incorrect perceptions the market has formed. If the stated ultimate goal of WWF's webpage; "to build a future where people live in harmony with nature" [58] is to be achieved with respect to tilapia, then significant redirection is required. Assumptions on which the current TAD process is founded contain sufficient fundamental flaws to clearly fail this challenge.

References and Notes

[1] Primarily *Oreochromis niloticus, O. aureus*, and, to a lesser extent, hybrids of these and various other tilapia species

[2] We define system intensity here according to feeding practice. Tilapia in semi-intensive systems derive a significant portion of nutrition *in situ* from deliberately stimulated (i.e. intentionally fertilised) phytoplankton blooms, with additional supplemental feeding, whereas intensively raised tilapia are very largely dependent on the application of formulated feeds [29]. Semi-intensive systems therefore span a diverse spectrum, in terms of input application, productivity, and scale.

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