3) Consumption of *Chara* by "tilapia" in aquaria.

Hughes[5] pointed to nutrient-poor aquarium conditions as a possible factor in the rapid consumption of the non-vascular macrophyte *Chara* by "tilapia". Hughes failed, however, to recognize or at least to mention that these same nutrient-poor conditions, which are characteristic of Lake Apoyo (Waid et al 1999), could also account for the disappearance of Chara beds in the lake. Furthermore, we are surprised that he does not share the same level of alarm regarding the disappearance of Chara beds in Lake Apoyo and the possibility that "tilapia" introductions had something to do with it. More studies are required in Lake Apoyo to determine why *Chara* disappeared. However, Hughes (2002) does not present an alternative hypothesis to explain the critical ecosystem change. *Oreochromis niloticus* remains the primary suspect for causing the complete disappearance of *Chara* from this lake, an event which now threatens several endemic species with extinction. [6]

It is unfortunate that *O. niloticus* does not consume water hyacinth *(Eichhornia crassipes)*; like the "tilapia", this plant is an exotic species, that causes tremendous destruction in tropical aquatic ecosystems with its uncontrolled proliferation. Unlike the water hyacinth, Chara is an important component of several freshwater ecosystems in Nicaragua, providing critcal habitat for some endmic fishes, thus its disappearance from Lake Apoyo is of great concern and additional "tilapia" introductions could be expected to have similarly castastrophic consequences in other aquatic ecosystems such as Lake Xiloa.

Hughes also stated *"The data in no way permit one to deduct that O. niloticus stocked in a natural body of water in Nicaragua will entirely eliminate native plants".*[7] His statement is dangerously misleading, as "tilapia" are well known to eliminate aquatic vegtation in a variety of settings around the world as has been documented in the scientific literature.[8]

"Tilapia" introduction by aquaculturists in Lake Apoyo is presently the only suspect in the alarming disappearance of *Chara spp.* beds. The NICANOR project's

[5] McCrary et al. 2001
[6] McKaye et al. 2002
[7] Hughes 2002
[8] Courtenay & Robbins,1973, Zaret and Paine 1973, Jubb and Skelton 1974, Lamarque 1975, George 1976, Nomura 1976, Philbert and Ruwet 1982, Welcomme 1984, Contreras and Escalante 1984, Fryer 1991, Courtenay and Williams 1992, Kaufman 1992, Courtenay 1993, McKaye et al 1995, McCrary et al. 2001

advisors argued that it was impossible for the caged fingerlings to escape into the lake, and even if they did, the stocks consisted of 100% males that would not reproduce in the lake. Prior to the introduction, McKaye in direct conversations with these consultants and MARENA, explained that "tilapia" would escape and that the fish can change sex. Because of a unique situation in which an UCA-MARENA research team was studying the ecology of Lake Apoyo, we were able to document the dramatic damage caused by the introduction. Often there is no baseline data available to demonstrate conclusively the negative impact of the introduced species. Had these consultants and MARENA heeded warnings by McKaye to take a precautionary approach to the project, the problem might have been avoided.

The documented environmental services and habitat for rare fish species, that *Chara* provides, once again indicates the necessity to take a conservative approach to the introduction of non-indigenous fish species and cultivation of such in natural bodies of water. This is particularly true for species such as "tilapia" that have been shown to consume macrophytes under low nutrient conditions. In additon, given the overwhelming evidence worldwide we strongly recommend prohibiting the further introduction of "tilapia" in all natural waters until a consensus can be reached on how destruction of natural ecosystems by escaped "tilapia" can be prevented or mitigated (Stauffer et al. 1988)[8].

4) Waste created by cage culture of "tilapia" in proposed project in Lake Nicaragua.

Van den Berghe[9] estimated that approximately 30 tons per day of solid fecal waste would be produced by the proposed Lake Nicaragua Ometepe Island project and Hughes[10] postulated a figure of approximately 6 tons per day. However, assuming even the lower estimate, there still remain significant ecological effects such as eutrophication, spread of disease vectors, and parasites into the lake which often accompany large sustained additions of fecal matter into lakes. This level of contamination simply should not be allowed to enter the lake through any source, and the aquaculturists are taking advantage of a legal loophole that strictly regulates the quantities of fecal matter introduced into the lake by slaughterhouses, poultry farms, and other similar activities but does not specifically contemplate aquaculture. The absence of a law specifically dealing with aquaculture waste is an oversight which does not

[8] Stauffer et al. 1988
[9] 2002
[10] Hughes 2002

reflect the fact that large volumes of fecal matter from fish culture can contaminate receiving waters, just as do animal residues from livestock and waste from industrial production. While either figure for the volume of waste could be assimilated by the lake as a whole, either figure would equally result in severe contamination at the point of origin, sheltered bays with no current to disperse said waste. According to Moore and Jennings (2000): "in all cases involving large scale cultivation, however, there have been consequences for the natural environment....transmission of diseases and parasites, and impacts on wild counterparts. This suggests that such aproaches should not automatically be regarded as providing a panacea..."

5) Environmentally-minded aquaculture development in Nicaragua

Hughes[12] mentioned the efforts of the Global Aquaculture Alliance to promulgate appropriate practices for aquaculture. The guiding principles for this organization include the following points (www.gaalliance.org/prin.html), which we consider to be overlooked historically in Nicaraguan "tilapia" farming. :

"2. Shall utilize only those sites for aquaculture facilities whose characteristics are compatible with long-term sustainable operation with acceptable ecological effects, particularly avoiding unnecessary destruction of mangroves and other environmentally significant flora and fauna."

Lake Apoyo, Lake Nicaragua, and virtually every other natural water body in Nicaragua harbor environmentally significant fauna. [13] In the U.S." exotics have been a factor in 68% of fish extinctions". [14] Introductions of "tilapia" in other lakes have been specifically cited in the extinction of native fish species. [15] Unless clear evidence exists that "tilapia" use in natural waters will not harm native fauna or flora, the precautionary principle requires that cage culture and other activities that lead to "tilapia" releases into the wild in Nicaragua should be strictly avoided.

"7. Shall take all reasonable steps to ascertain that permissible introductions of exotic species are done in a responsible and acceptable manner and in accordance with appropriate regulations."

Regulations to control introductions of exotic species are not yet in place in

[12] 2002
[13] Waid et al. 1999; McKaye et al. 2001
[14] Bright 1998
[15] Witte et al. 1992, Goldschmidt 1996, etc.

Nicaragua, although ample information exists that indicates "tilapia" compete directly for resources with native cichlids, destroy their habitats through eradication of vegetation, digging and changes in water clarity, carry and transmit parasites, and under some conditions, predate upon native fishes. [16] "Tilapia" introduced into natural waters are extremely dangerous to native fish species. The introduction of Nile "tilapia" has been blamed specifically for the extinction of two native species of fishes in Lake Victoria.[17] Unless we can positively identify what constitutes responsible and acceptable introductions of "tilapia" in Nicaragua, we should avoid their use in cage cultures in natural waters in all situations. Given the information at hand, there is no way to abide by the two principles noted above.

The destructive nature of the activities of "tilapia" in natural waters, evidently unappreciated by many aquaculturists, is becoming increasingly understood in a growing body of peer-reviewed scientific literature summarized in van den Berghe (2002). We agree with Hughes (2002) that more study is needed. Therefore, no exotic fish species should be introduced into any natural Nicaraguan waters without first conducting extensive long-term studies of the species and ecosystem in question. At present, the situation is best summed up by Chris Bright (1998) who was referring to the general problem of bioinvasion:

"What will this creature do if it lands in that spot? About all we can say with assurance is this: if it is causing trouble somewhere you don't want it anywhere else. Bioinvasion may be the least predictable of all major forms of environmental disruption. It may also be the hardest to fix" because with most forms of environmental disturbance such as air pollution, the problem stops when the offending activity ends or shortly thereafter, *"so while an oil spill that occurred twenty years ago is probably not a pressing concern today, there are hundreds of invasions that began more than a century ago and are desperately urgent problems right now. This 'biological pollution' is smart pollution. It adapts, it looks for ways to survive, and instead of diminishing over time it usually entrenches itself."* Thus "... *as presently practiced, aquaculture offers a ... short term payoff, but we are assuming long term ecological risks that we cannot yet even calculate."*

While we demonstrate that the arguments of Hughes in support of "tilapia" cage culture in natural waters are flawed, we understand his positive motive in looking

[16] reviewed in McCrary et al. 2001
[17] Goldschmidt 1996: 229; Witte et al. 1992

toward aquaculture to solve world protein shortages. One approach that does not involve the problems attendant with introducing species is investing in research using native species in aquaculture.

In addition to calling for more studies on the ecological impacts of "tilapia" in Nicaragua it is wise to look at the experiences of other countries worldwide, but especially in the Central American region. Negative effects of "tilapia" have been reported not just for Nicaragua, but also for Belize, Cuba, El Salvador, Guatemala, Honduras, Costa-Rica and Mexico.[18] Furthermore, the research Dr. Hughes is calling for, is giving the same answers in neighboring Costa-Rica as in Nicaragua. Jorge Cabrera in Costa Rica is also calling for an assessment of the true impact of "tilapia," given that at this point, "tilapia" is "*endangering all species serving as food for other fish*" and *"[a]t this moment, the damage to Costa Rican Aquatic ecosystems is serious. Native species are in full blown decline."* [19]

We also agree with Hughes that "tilapia" aquaculture promises to generate vital income for Nicaragua, but only if undertaken in a responsible manner. The past decades of experience in this country, however, have resulted in many negative consequences for the natural aquatic ecosystems, and these mistakes should not be repeated or promulgated. Environmentally minded "tilapia" aquaculture can certainly be performed in Nicaragua, but it must be done in physical isolation from natural aquatic ecosystems.

Regarding the use of external donor supported funding, the first question that needs to be addressed is: How can well-financed aquaculture concerns that have been made aware of the damages they cause, be allowed to come to Nicaragua with public and private backing from the Norwegian Government to conduct practices which are **specifically banned** in their home country? In Norway, the laws regarding species introductions are so strict that one cannot even move **native** species between different bodies of water. Fishes of the same species from different lakes and rivers are genetically distinct stocks with specific local adaptations and must be kept separate. Here in Nicaragua, there is mounting evidence that EACH lake has unique endemic species, [20] so it would seem that the same principle needs to be applied. This is a compelling argument in itself for restricting non-indigenous fish introductions, especially of fish known to have negative consequences.

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[18] Gutierrez 2002

[19] Cabrera 2001 in Hernandez et al. 2002

[20] McKaye and Stauffer 2002, McKaye et al. 2002

The second question that needs to be addressed is: Why has the Nicaraguan Ministry of the Environment, MARENA, permitted such practices in the face of controversy, while ignoring evidence that suggests a cause for concern for the country's aquatic biodiversity?

While the promised short-term gain touted in the press is greatly exaggerated,[21] even modest gains may be tempting in impoverished countries. Unfortunately, such short-term gains may subsequently lead to very expensive mitigation efforts that dwarf the initial profit. For example, the costs associated with containment and eradication efforts of introduced species in the U.S. alone, is estimated at 136 billion dollars PER YEAR, India spends $116 billion per year, even Brazil spends 50 billion dollars per year in an effort to control introduced species including "tilapia" whose introduction is banned in Brazil.[22] By comparison, the 10 million dollars per year Nicaragua might realize by the most optimistic estimates from large scale "tilapia" culture in open water, warrants extreme caution. Those making introductions both "legally" and illegally, should be held financially responsible for necessary mitigation or containment measures, as well as be fully apprised of the potential dollar costs of necessary mitigation measures. We furthermore suggest that a mechanism be set in place for making those responsible for encouraging or effecting such introductions pay for the consequences of their actions.

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[21] van den Berghe 2002

[22] Pimentel 2000, in Hernandez et al. 2002

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Response to "Tilapia: The biological solution"

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Resumen

En su artículo de refutación a van den Berghe, Hughes reconoce que no puede rebatir la vasta mayoría de las 49 referencias citadas o la evidencia presentada para respaldar el caso en contra de la introducción de la cultura o cultivo de la tilapia en cualquier cuerpo de agua natural de donde ésta no es nativa. Los pocos aspectos que él sí cuestiona son refutados aquí:

1. La tilapia ha causado mayores decrecimientos en las poblaciones de la familia cichlidae (peces de agua dulce) del lago de Nicaragua.
2. Toda la evidencia señala a la tilapia como el factor principalmente responsable por la desaparición de la vegetación en la Laguna de Apoyo.
3. Visto desde cualquier ángulo, la cantidad de materia fecal que se anticipa a partir de las propuestas de proyectos de acuacultura en el lago de Nicaragua, tendrá impactos locales inaceptables.
4. Los costos para la mitigación de introducciones desastrosas sobrepasan enormemente los beneficios potenciales. Por lo tanto, la cultura de la tilapia debería ser permitida solamente en lagos artificiales que no tengan ningún contacto posible con los ecosistemas naturales. Además, se debe implementar mecanismos para hacer que quienes fomentan o causan estas introducciones se hagan financieramente responsables de contener y mitigar los impactos negativos.

A series of publications has resulted recently from the increased interest in the issue of the environmental consequences from "tilapia" aquaculture in natural waters of Nicaragua.[1] We appreciate the opportunity to respond, and hope to clarify various aspects of the discussion, which seemingly have pitted aquaculturists against biologists in Nicaragua, sometimes citing even the same data to different ends.

1) Lake Nicaragua fisheries catch information.

Commercial catches for recent years have been cited by both Hughes (2002) and van den Berghe (2002) to shed light on whether "tilapia" introductions into Lake Nicaragua have directly led to reduced fisheries productivity. Unfortunately, the data mentioned, in neither case, is useful for determining whether "tilapia" introductions in Lake Nicaragua led to reduced fisheries productivity, because the data cited do not begin before the introductions occurred, and most importantly, the data cited do not present any history of catches per unit effort, or any standard sampling results. As a result, the data cannot be used to determine fisheries productivity during any time period, much less during the period in question. Thus, there is no way to directly infer from the commercial catch data alone that native fish stocks have improved or worsened in response to introductions of "tilapia."

The only interpretable data published to date regarding fisheries productivity in Lake Nicaragua for the period of interest are based on experimental catch data rather than productivity of commercial fishing. These experimental catch data clearly show that native cichlid populations in Lake Nicaragua have been reduced by 80% where "tilapia" have colonized.[2] The catch levels of native cichlids in the lake showed a strong negative correlation with catches of "tilapia" in all sampled locations in the lake.

Therefore, the primary conclusions that can be drawn from published, peer-reviewed literature and commercial fisheries statistics in Nicaragua is that "tilapia" introductions in natural waters have severely damaged the national fisheries industry as well as reduced biodiversity in these ecosystems.

2) Lake Nicaragua experimental catch data.

Hughes (2002) criticized the McKaye studies, stating "... *there exists the possibility that the Russian study fished in zones where 'tilapia' had not yet become estab-*

[1] McKaye et al. 1995; McKaye et al. 1998
[2] McKaye et al. 1995; McKaye et al. 1998
[3] McKaye et al. 1995; McKaye et al. 1998

lished." In this case, Hughes has misinterpreted the procedure and purpose of the study cited.[3] The Russian data, taken in **1983** from several locations throughout the lake, was utilized as a baseline indicator of productivity prior to colonization of the lake by "tilapia". Later sampling in1991-92 using a similar protocol showed a tremendous reduction in abundance of native cichlids in the regions of the lake where "tilapia" had become established. In contrast, in regions such as around Ometepe Island, where "tilapia" had not yet become established, 1991-2 gillnet catches were remarkably similar to those found in the pre-"tilapia" conditions of the Russian study. These results suggest that native cichlid populations are similar to historical numbers where "tilapia" had not colonized the lake, but drastic reductions in native cichlids occurr where "tilapia" had become established (Fig 1).[4]

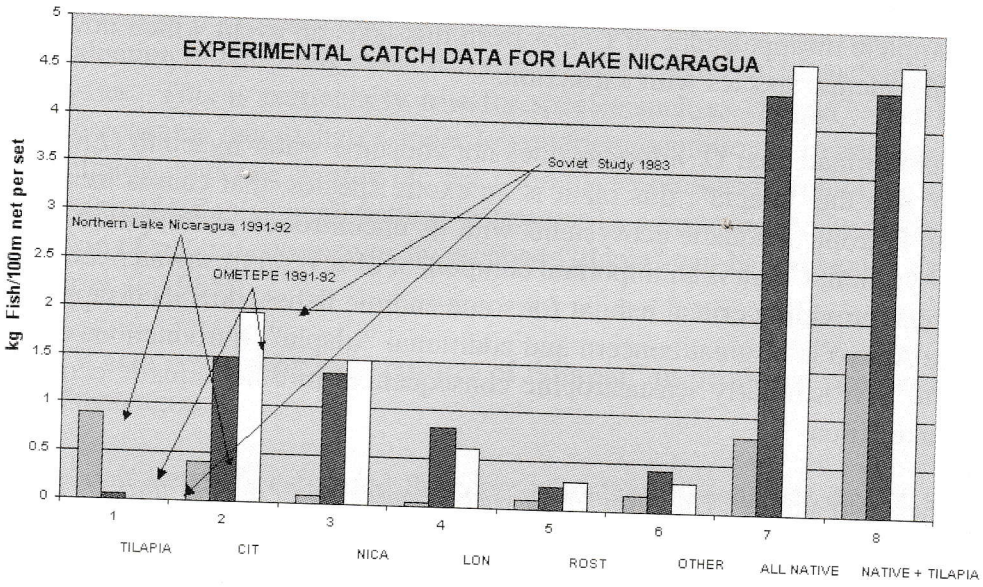

Figure 1: Native fish declines in areas of "tilapia" invasion. By 1991-92 Northern Lake Nicaragua had "tilapia" making up the bulk of the cichlid fish biomass. This corresponded to drastic reductions in both individual native cichlid species (cit= Amphilophus citrinellum, nic=Hypsophrys nicaraguense, lon=Astatheros longimanus, rost=Amphilophus rostratus, other mostly Parachromis dovii, P. managuense), and all species combined, and even the total cichlid fish biomass including "tilapia" was less than half compared to before "tilapia" were introduced. Ometepe serves as the control because "tilapia" were just beginning to make an appearance there, shown by the low biomass of "tilapia", yet native cichlids were at levels comparable to the soviet study prior to "tilapia" introduction. Overall, the effect of the "tilapia" has been to not only radically reduce the native fish population, but to reduce the overall biomass available to fisheries. All data are wet weights of fish per set for 100m of experimental gillnet with 25m of each of four mesh sizes: 1/2 inch, 1 inch, 2 inch, and 4 inch, replicating the methods in the Soviet study.

[4] McKaye et al. 1995; McKaye et al. 1998

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