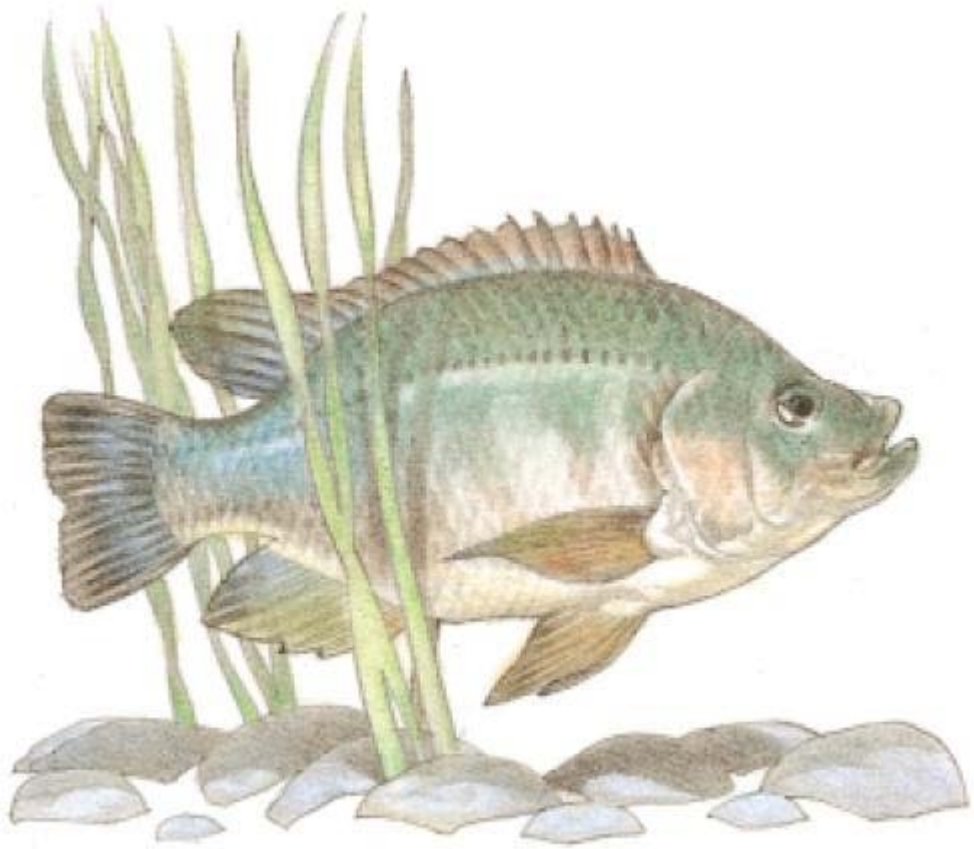
Desk-study on the Potential Effects of Nile Tilapia Introductions on Biodiversity with Special Reference to Vietnam

Report commissioned by NORAD



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20th January 2005

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1.1 Classification of the tilapias

The word "tilapia" originates from the term used by the San people of south-western Africa. "Tilapia" is a common name used to refer to a large group of fish species from several genera within the family Cichlidae.

In her major monograph, which is considered to be the most authoritative work on the tilapias, Trewavas (1983) reclassified these fishes into fourteen genera. Stiassy (1991) and McAndrew (2003) have reviewed the classification more recently and suggested some minor modifications.

The three most significant tilapia genera in terms of fisheries and aquaculture are *Tilapia*, *Sarotherodon* and *Oreochromis*. The *Tilapia* are substrate breeders whilst the *Sarotherodon* are bi-parental or paternal mouth-brooders and the *Oreochromis* are maternal mouth-brooders.

The Nile tilapia originally described by Linnaeus as *Tilapia nilotica* in 1758 and Trewavas reclassified it as *Oreochromis niloticus* in 1983 as referred above. Trewavas's taxonomic conclusions are supported by more recent research using gene sequencing of mitochondrial NADH (Klett and Meyer, 2002).

1.2 Some biological characteristics of Nile tilapia

Male Nile tilapias are generally larger, more brightly coloured and aggressive than females. Aggressive behaviour among males is associated with the establishment of territories for reproduction where they build distinctive spawning pits and among females with parental care, such behaviour occurs in connection with breeding (Turner & Robinson, 2003). Nile tilapia are maternal mouthbreeders and females tend to move away from the spawning pits when the young hatch, and they care for the offspring for about 3 weeks until they reach a size of about 14 mm (Trewavas, 1983). Breeding appears to take place throughout the year in tropical conditions, but may be reduced during periods of lower temperatures in cooler climates.

Although Nile tilapias have relatively low fecundity, parental care ensures that the majority of their eggs survive to the juvenile stage. Low fecundity is further offset by the ability to spawn multiple broods throughout their year-round reproductive season. These reproductive characteristics thus give this species a competitive advantage over many other fishes.

Nile tilapias are also notable for their ability to start breeding at a young age and small size. But this is an undesirable characteristic from the point of view of aquaculturists since it easily results in ponds with large numbers of small stunted individuals using energy on reproduction instead of growth.

Juvenile Nile tilapia preferentially feed on zooplankton, but as they grow larger they increasingly filter-feed or suction-feed mainly on phytoplankton. Bacteria, periphyton and detritus particles are also ingested, but these form a

less significant part of their diet. Nile tilapias have long coiled guts, typical of herbivores. However, Nile tilapia will also feed willingly on fishmeal based diets in captivity and intensive aquaculture systems.

The maximum length of Nile tilapia is reported to be 60 cm, and the maximum weight 4.3 kg. Their age is up to 9 years (www.fishbase.org).

1.3 Aquaculture of Nile tilapia throughout the world

Tilapia are second only to carp as the most widely farmed fishes on a global scale, and by 2002 the world harvest of farm-raised tilapia had exceeded 1,200,000 tons (see Annex 1 showing a graph of production by main countries based upon FAO data http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp).

Nile tilapia is an ideal species for aquaculture because they are hardy fishes, with a wide environmental tolerance, and they reach sexual maturity at a relatively young age, which allows for rapid population growth. However, under unfavourable conditions, such as limited food and space, they mature and breed at much smaller sizes than usual. This is known as "stunting", and is undesirable in aquaculture as it results in large numbers of fish that are of sub-optimal size for the seafood market (Lorenzen, 2003). Efforts to overcome the problem have included hybridisation between tilapia species to produce all-male or sterile offspring. These hybrid fish are commonly marketed as ‘red tilapia’.

Oreochromis niloticus has less of a tendency to produce stunted populations than *O. mossambicus,* and it also has good growth characteristics and taste, so for these reasons has been used instead of the latter in many regions.

Oreochromis niloticus is also widely used for producing mono-sex hybrids together with such species as *O. mossambicus*.

Nile tilapia has been very extensively transported around the world for aquaculture purposes and has achieved pan-tropical status. As a subtropical species this fish can also breed in the natural waters of some of the cooler temperate countries to which it has been introduced.

In aquaculture, genotypes, also known genetically improved species, are an effective means to increase production. The GIFT project (Genetic Improvement of Farmed Tilapia) was initiated by ICLARM (now the WorldFish Center) since 1988. Pullin and Capili (1988) asserted that many cultured stocks of tilapia were actually worse than the wild populations due to inbreeding. This was also observed in Vietnam by Thien et al. (2001). Partners from ICLARM, the Philippines and from Norway cooperated to develop methods for selective breeding of Nile tilapias. Gupta and Acosta (2004) have recently made a review of this successful project.

Nile tilapias have been depicted as a "poor man's" fish (Mair, 2003) and a suitable species for combating poverty. However, tilapia is also fast becoming a "rich people's fish" which is produced in intensive systems with high

technology and fishmeal-based diets. It has gained acceptance in Japan (in sushi dishes), the United States and Europe, such that it is now exported in increasingly large quantities from poor countries to rich: thereby generating foreign exchange, but perhaps not always benefiting the poorest people in poor countries directly or significantly.

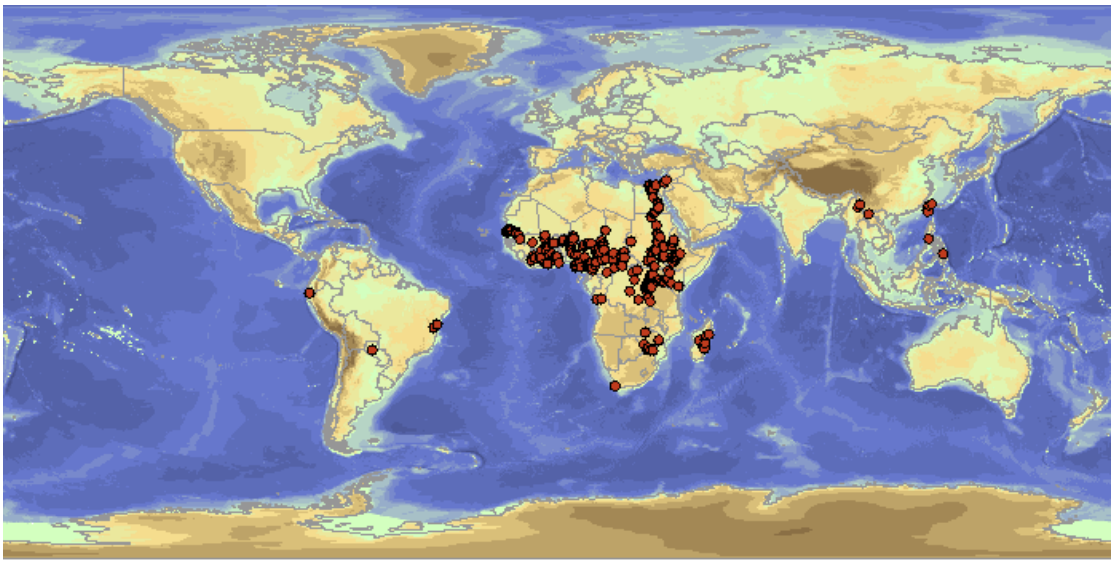
However, while acknowledging the important strides in relation to aquacultural productivity that have significant socio-economic benefits, there are concerns that these genetically modified Nile tilapias may adversely affect natural populations and local ecosystems. Kautsky et al (1997) documented the "ecological footprint" and important implications for sustainability of tilapia farmed by different aquaculture methods.

1.4 Geographical distribution: original and present

The original distribution of *Oreochromis niloticus* is from within Africa: an area extending along the Nile from below Albert Nile to the delta; Jebel Marra; Lake Chad basin and the rivers Niger, Benue, Volta, Gambia and Senegal.

FishBase lists 19 countries in which Nile tilapia occur naturally, and 64 countries into which it has been introduced; a total of 83 countries. (http://www.fishbase.org/Country/CountryList.cfm?ID=2&genusname=Oreochromis&speciesname=niloticus%20niloticus)

The present main distribution of Nile tilapia is shown by data from FishBase (http://www.fishbase.org/Summary/SpeciesSummary.cfm?ID=2&genusname=Oreochromis&speciesname=niloticus%20niloticus#) plotted on a map produced by the Kansas Geological Survey, but is obvious that this database and map need to be updated:



http://drysdale.kgs.ku.edu/website/Specimen_Mapper/mxmapit.cfm?xmlsource=http://64.95.130.5/map/kgs/temp/06430320050118.xml

Supplementary biodiversity data is also supplied by the Swedish Museum of Natural History, the University of Kansas Biodiversity Research Center and the Museum of Comparative Zoology, Harvard University.

The Global Biodiversity Information Facility (http//:www.gbif.net) contains records of *Oreochromis niloticus* from the following 47 countries: Belgium; Brazil; Burkina Faso; Burundi; Cameroon; Central African Republic; Chad; China; Congo, Democratic Republic of the; Costa Rica; Cuba; Côte d'Ivoire; Dominican Republic; Egypt; Ethiopia; Gambia; Ghana; Haiti; India; Indonesia; Israel; Kenya; Madagascar; Mali; Mauritania; Mauritius; Mozambique; Myanmar; Niger; Nigeria; Paraguay; Peru; Philippines; Rwanda; Réunion; Saudi Arabia; Sierra Leone; Singapore; Somalia; South Africa; Sudan; Taiwan; Tanzania; Togo; Uganda; United States; Zimbabwe. It is interesting that Vietnam is not included in this list, or for that matter Norway where there are several Nile tilapia experiments underway.

According to the FAO Register of International Introductions of Inland Aquatic Species, introduced *Oreochromis niloticus* is widespread in lakes in Vietnam (http://www.fao.org/docrep/X5628E/x5628e0c.htm#oreochromis%20niloticus%20l.:%20cichlidae)

1.5 Impacts on biodiversity of alien invasive tilapias

There are four broad categories of ecological impacts of alien invasive species on biodiversity, these maybe characterised as:

- basic species interactions such as predation and competition
- genetic impacts
- disease impacts
- habitat alteration

Lessons from the experiences of other countries concerning the impacts of introduced Nile tilapia on biodiversity may be learned, so we have attempted to summarise some of the main scientific findings published on this topic. The main observations have been in the first of the four categories outlined above, and it is clear that insufficient information is available about the other three.

Selected examples from the literature, which show that Nile tilapias have been observed or suspected to have impacts on indigenous species, include the following publications:

- Welcomme (1988) and Jalal and Rouf (1997) reported that introductions of Nile tilapia in Bangladesh were successful in terms of fisheries and aquaculture production, but that they had negative consequences for local species of freshwater fishes.

- Amarasinghe and de Silva (1996) feared negative long-term impacts of introduced Nile tilapias in the large Victoria dam reservoir on indigenous species in freshwaters of Sri Lanka.

- De Iongh and Van Zon (1993) recorded that Nile tilapias replaced native species in Thailand, and reported them to be a pest in open waters after excessive reproduction success.

- Bleher (1994) Juliano et al. (1989) reported that Nile tilapia were reintroduced to the Philippines in 1972 from Thailand and in 1973 from Israel. They have become widely cultured throughout the country, especially in Laguna de Bay area in Manila and in Central Luzon. They conclude that the tilapias have played a part in the extinction of cyprinids in Lake Lanao, Mindanao, and have contributed to driving the endemic "sinarapan" of Lake Buhi to the edge of extinction.

- Sreenivasan (1991) reported concern over the impacts of introduced tilapias into India on local freshwater fish species.

- Eldredge (2000) summarised the status of non-indigenous freshwater fishes introduced into Pacific and Hawaiian islands, and expresses particular concern over tilapias.

- De Vos & van den Audenaerde (1990) concluded that the introduction of tilapia might have been the reason for the decimation or extinction of three autochthonous cyprinid species (*Barbus microbarbis, B. neumayeri* and *Varicorhinus ruandae*) in Lake Luhondo, Rwanda.

- According to FAO (1997), Nile tilapia were reintroduced in 1978 to Mexico causing the displacement of endemic species, and resulted in their own over-population and stunting.

- McKaye et al (1995) made an account the ongoing problems caused by tilapia introductions into Lake Nicaragua, which is the largest tropical lake outside of Africa. It contains at least 16 species of native cichlids, including *Amphilophus labiatus*, *Astatheros longimanus*, *Hypsophrys nicaraguensis*, and *Amphilophus rostratus*. These fishes are a large component of the native fishery and a vital resource to one of the New World's poorest countries. In the early 1980s, in an attempt to increase the catchable fish, tilapias were introduced. In just a few years, native fishermen saw a dramatic shift in the fish composition of the lake. By 1990, at some places in the lake, exotic tilapia constituted as much as 54% of the fish being caught. And recently numbers of native cichlids are declining even more dramatically (Coleman, 2001).

- Welcomme (1984) recorded that Nile tilapia introduced into Lake Itasy, Madagascar, hybridised with the formerly introduced *O. macrochir*, which led to the disappearance of the latter.

- Ogutu-Ohwayo (1990) documented the decline of native fishes in east African lakes due to introductions of Nile perch and Nile tilapia.

- Lowe-McConnell (2003) reports that Nile tilapia that have escaped into coastal brackish water habitats in Malaysia, India and other Asian countries have negative impacts on important species including *Chanos chanos* (milkfish) and *Mugil cephalus* (stripped mullet).

- Kairo and Ali (2003) review the threats of invasive species into the Caribbean, including mention of Nile tilapia.

- Perez (1996) investigated the impacts of escaped tilapia in Venezuela.

- In the United Sates there are programmes to try to eradicate escaped tilapia in river and lake systems as they are regarded as dangerous pests. They have had serious impacts on native centrarchids and other fish species (Peterson et al., 2004).

- Arthington and Bludhorn (1996) report on competition between tilapia and indigenous species for food and breeding territories with the subsequent danger for fish populations in the Darling River system.

- Pullin et al. (1997) and Lowe-McConnell (2003) summarise the environmental impacts (positive and negative) of introduced tilapias internationally.

- Mattson (2004) reported that the Mozambique tilapia has established populations in the Mekong delta, where they cause problems in shrimp farms (but this does refer to Nile tilapia).

2. Status and Importance of Nile tilapia in Vietnam

(This section was contributed by Niels Svennevig with minor editing)

2.1 The history of tilapia introductions to Vietnam

Tilapia was the first alien species introduced to Vietnam in 1951. This was *Oreochromis mossambicus* coming from Chinese Taipei/Thailand and/or Philippines. But this species never became popular due to low productivity, as the growth was inferior due among others small breeding size and high fecundity creating crowding. The species however got quite established also in natural waters and larger extensive ponds – especially in the coastal areas.

Then in 1973 *O. niloticus* was introduced to southern Vietnam from Chinese Taipei and it was transferred in 1975-77 to the north (RIA-1). Up to 1980 it gained popularity, but then due to improper broodstock management and 'natural' hybridisation with *O. mossambicus* the performance became inferior and the 'local strain' lost its popularity (Thien et al. 2001). Production was at its peak about 8,000 tons/yr.

In 1994 the GIFT strain of Philippines and an Egyptian strain were introduced to RIA-1 as part of the dissemination project (DEGITA) at ICLARM (now World FishCenter) under ADB financing. Under this project Bangladesh,

China and Thailand also received the two strains for evaluation. Also during 1994-96 the Chitralada strain was introduced from Thailand under the assistance of the AIT outreach program. The latest 'edition' of the GIFT tilapia was introduced several consecutive years by ICLARM. A Swansea strain was also imported from England during 1997-1999, but the result is unknown to the consultant.

The four strains – local (hybrid), GIFT, Egyptian and Chitralada – were tested by RIA-1 and RIA-2 in HCMC with the finding that the GIFT and Chitralada strains showed the best performance both in the north and in the south – in freshwater as well as brackish water.

Many imports of *O. niloticus* have been made during the period – also by farmers in the south regularly importing GIFT tilapia, GenoMar supreme tilapia and the Thai Chitralada as well as tilapia from China. Often the imports are mono-sex tilapia fry for grow-out. Further imports have been red tilapia from Cuba and Philippines and *O. aureaus* from Philippines, the latter during 2002 by the Extension Center of MOFI to be used for crossing with *O. niloticus* to produce mono-sex. With the development of the selected tilapia strains at RIA-1 (NorViet tilapia) and the dissemination to provincial hatcheries however the regular imports of the farmers have become less frequent.

2.2 The status of tilapia production in Vietnam

Present tilapia production, which mainly originates from O. niloticus, is estimated at 30,000-40,000 tons with ¾ of it taking place in southern Vietnam while the rest in the northern part. No significant productions take place in the central region.

Tilapia is gaining increasing importance in the output from freshwater farming and probably now constitute 5-7% of this production. The target is that the tilapia is to enter as export diversification from the other important export production of especially the south (the 'cat fish' basa and tra).

Most farming takes place in ponds, while only smaller productions take place in cages in rivers or reservoirs. Likewise there are a few reservoirs that are stocked regularly but the productions here are not very successful.

According to the ambition of the Ministry of Fisheries production should increase to 200,000 tons by 2010 and to achieve this relatively large amounts of Governmental funding are invested in tilapia research and dissemination.

2.3 Regulations on import of live fish to Vietnam

There are several regulations regarding import/export of live fish. The decrees are in Vietnamese and are revised yearly, but overall they are not enforced very strictly especially during the last years. But with the creation of a new fish-veterinarian department within NAFIQACEN, which also takes care of product safety, and with the new fisheries law there is expected to come many new decrees and the enforcement is likewise expected to be stricter.

The decrees are very formal or general and do not always use the correct Latin species names – e.g. it says that *Pampus argenteus* is permitted imported alive - while this surely is *Trachinotus blochii* (which looks 'alike' and is hatchery produced).

There are restrictions for export of live fish – such as groupers have to be more than 500g, *Seriola quinqueradiata* more than 20cm etc – i.e. all are regulations made to prevent export of wild caught fry – which actually still takes place in quite large scale.

Therefore in Vietnam at present it is said that everything is possible. If wanting to import a 'normal' species – i.e. one already present in Vietnam – naturally or introduced - there is no need to ask for permission from MOFI, but one needs to have customer clearance and a quarantine certification, which is issued by Dept of Environment and resource protection under MOFI.

If the species to be imported is not on the list, i.e. a new species to Vietnam permission has to be requested from MOFI and the procedure is as follows:

- Application for importation
- The species document (biological, picture etc.)
- Having permission from Investment Dept of MOFI
- At the import border station (land, airport, harbour), the fish will be requested quarantined by the authorities. This quarantine can take place at the importers own facilities and should last till a 'negative' result comes from NAFIQACEN.
- If a new species is imported their biology/performance has to be followed for at least one cycle by an institute (this normally never takes place in real unless it is a research project).

In reality the quarantine procedures are not followed strictly and it has also shown possible to introduce whatever new species to the country, if the species could be argued/justified to have farming potential. Both institutes and private companies can get import permissions.

The following decrees are available in Vietnamese:
1. Procedure for quarantine of live fish
2. Procedure for import new species of fish
3. List of species allowed and not allowed to import and export to/from VN

According to the new Fisheries Law (made with the NORAD support), apart from the quarantine issues in the Article 32 it says in Para 2: New fish fry imported for the first time shall be approved in writing by the Ministry of Fisheries

2.4 Tilapia occurrence in the wild in Vietnam

As described earlier many deliberate releases have been made especially to freshwater reservoirs – but opposite situation in e.g. Sri Lanka where natural sustained populations have been created by stock releases which support

quite intensive fisheries, this has never been achieved in Vietnam. Reasons for this are speculative but it is told that possibly the temperatures are too low at the bottom of the reservoirs – others claim that the natural occurring predators are too efficient. The latter could possibly be partial reason as the fish fauna in the Vietnamese reservoirs seems much more diverse than in Sri Lanka.

Interviewing an ichthyologist Mr. Binh at RIA-1 who has worked on mapping the freshwater fish fauna of northern Vietnam he claims never to have seen any large number in natural freshwaters. This he attributes partly that the waters are not optimal for tilapia (at least in northern part) – and partly because the heavy fisheries taking place with electricity and chemicals on any wild fish stock. Only in less populated areas one can find single tilapia specimens in natural water bodies

From several sources it is said that in brackish water bodies in e.g. Quang Ninh, Hai Phong and Nha Trang tilapia can be quite common. This is basically small *O. mossambicus* or hybrids. This is attributed the seawater tolerance of this species as well as its large fecundity – and small size (which prevents it from being a real target species in fisheries). In the north it is however seen that survival in shallow ponds or water bodies is not good and this is also considered a factor limiting tilapia going feral.

Around HCMC there are also larger populations especially in the areas of the larger fry producers using extensive ponds fertilized by human wastewater.

In several lakes in e.g. Hanoi there are large populations of tilapia – but these typically originate from deliberate stockings performed by the companies or cooperatives having the user rights of the lakes. The released typically include many carp species and the tilapia the purpose to perform aquaculture. However during recent years this is diminished as the other economic interests of the lakes such as tourism etc is taking over.

Apart from the above only case story have been seen by the consultant at the hatchery at Cuo hoi in a temporary brackish water beach pond. This had population of snakehead (*Channa striata*) predating on three spot gourami (*Trichogaster trichopterus*) and tilapia. The latter was found in small schools of some 20 specimens – and of max 12cm sizes – and thus most likely again are *O. mossambicus*.

Dr Tuan, Vice-director of RIA-1 made a report on impact of alien species in Vietnam to MOSTE (Ministry of Science and Technology) in 2002. He considers that the main impact of introduction of *O. mossambicus* on the wild fauna is in competition in ‘space’ due to the very invasive behaviour of that species, i.e. e.g. the high fecundity. Often ‘thousand brother’ societies develop where it gets established – meaning that the average size is simply constrained by the high number of individuals – meaning high competition for food. This would of course have an impact on the natural species.

However the negative impact seen with many introduced carp species is not seen with the tilapia – and these are that there is no crossing with natural occurring species – i.e. no loss of gene pool, and then so far it seems that there has not been any introduction of new parasites or disease in association with the tilapia imports.

At the moment very few *O. niloticus* are seen in the natural water bodies, though this is expected to become an issue when the culture of this species becomes more popular. Still the fecundity of this species is much lower than *O. mossambicus* and there are no reports on adverse environmental impacts of *O. niloticus* in Vietnam at present.

3. Relevant International Conventions and Agreements

(This section was contributed by Odd Terje Sandlund with minor editing)

Vietnam has ratified a number of international environmental conventions with a bearing on the issue of introductions of invasive alien species. Of particular relevance in this context are the Convention on Biological Diversity (CBD) and the Ramsar Convention on Wetlands. Norway, as well as Vietnam's neighbours, are also Parties to these Conventions, which have quite explicit paragraphs concerning invasive alien species. Thus, both Vietnam and Norway have international obligations regarding the prevention and management related to invasive alien species. These obligations should guide the policies of all Parties to the Conventions. In international development collaboration, both the national policies of the recipient country as well as the principles for support from the donor country should be guided by the Conventions to which both partners are committed. Although both the CBD and the Ramsar Convention promote “sustainable use” as well as “conservation”, they both heavily emphasise the precautionary approach to all actions that may pose a threat to biodiversity and environment.

3.1 Convention on Biological Diversity

The Convention on Biological Diversity (CBD) contains a specific obligation to all Parties concerning alien, or non-native, species, in Article 8 (h):

> *Each Contracting Party shall, as far as possible and as appropriate: (h) prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species.*

Vietnam became a Signatory to the CBD in May 1993, and ratified (i.e., became a Party to) the Convention in November 1994. Norway signed the Convention in June 1992, and it was ratified by the Storting (Parliament) in 1993. Similarly, all of Vietnam's neighbouring countries are Parties to the Convention, as are indeed nearly all the countries of the World. They therefore share the associated obligations. The implementation of the Convention is governed by the Conference of the Parties (CoP), and the Decisions of the CoP constitute binding obligations for all Parties to the Convention. The CoP may request scientific and technical advice from the Subsidiary Body on Scientific, Technical and Technological Advice of the

Convention (SBSTTA), which draw on expertise from all countries and regions, as appropriate (cf. www.biodiv.org).

The issue of “alien species”, or in current terminology rather “invasive alien species”, has been addressed by CBD’s CoP on several occasions; most importantly CoP VI (April, 2002; decision VI/23), CoP V (May, 2000; decision V/8), and CoP IV (May, 1998; decision IV/1C). CoP Decision IV/4, dealing with inland water ecosystems also contains recommendations to Parties regarding alien species.

Decision VI/23 is the most recent CoP document placing obligations on all Parties to the Convention regarding invasive alien species. In the Guiding Principles annexed to this decision, a precautionary approach is recommended in all actions that may lead to introduction of non-native species. A precautionary approach is necessary because the pathways and impacts of introduced alien species are unpredictable. Aquaculture is listed among the common pathways for unintentional introductions of alien species, and countries are encouraged to minimize the risk of such introductions.

The activities of the CBD regarding marine and coastal biodiversity are focused through the "Jakarta Mandate on Marine and Coastal Biological Diversity", which was adopted in 1995. Through its programme of work, adopted in 1998, and reviewed and updated in 2004, the Convention focuses on integrated marine and coastal area management, the sustainable use of living resources, marine and coastal protected areas, mariculture, and alien species.

In Annex 1 “Elaborated programme of work on marine and coastal biological diversity” to CoP Decision VII/5 “Marine and coastal biological diversity”; Programme element 5 deals with “Invasive alien species”. The goal of this programme element is “To prevent the introduction of invasive alien species into the marine and coastal environment, and to eradicate to the extent possible those invasive alien species that have already been introduced.” In this document, mariculture is not specifically mentioned as one potential pathway for introduction of invasive alien species, but among research priorities associated with mariculture is listed “the impact of escaped mariculture species on biodiversity”.

3.2 Global Invasive Species Programme

The international programme “Global Invasive Species Programme” (GISP) was established in 1997 to address global threats caused by Invasive Alien Species (IAS), and to provide support to the implementation of Article 8(h) of the Convention on Biological Diversity. Programme partners are a number of international organisations and NGOs, in particular UNEP and the Secretariat of the CBD, and funding comes from i.a. the World Bank, UNESCO, national governments (i.a., Norway), and private foundations. GISP is currently seeking funding for a capacity building project regarding invasive alien species prevention and management, and Vietnam is among the seven countries identified as partners in this project (cf. www.gisp.org).

Leading international competence on the issue of invasive alien species is also available through the Invasive Species Specialist Group (cf. www.issg.org), under the auspices of IUCN.

3.3 Ramsar Convention

Vietnam is also a Contracting Party to the Ramsar Convention ("Convention on Wetlands of International Importance especially as Waterfowl Habitat"), as are Norway and a total of high number of countries in the World. The policy of the Ramsar Convention in relation to invasive alien species is specifically outlined in Resolution VII.14 from the 7th Conference of the Contracting Parties, May 1999 (cf. www.ramsar.org). There is a close collaboration between the Ramsar and CBD conventions, and in both cases, the precautionary approach is recommended when dealing with alien species.

3.4 Code of Conduct for Responsible Fisheries

In 1995 the FAO adopted the Code of Conduct for Responsible Fisheries (http://www.fao.org/fi/agreem/codecond/codecon.asp).

Although not a binding international agreement, the Code of Conduct *"sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity. The Code recognizes the nutritional, economic, social, environmental and cultural importance of fisheries and the interests of all those concerned with the fishery sector. The Code takes into account the biological characteristics of the resources and their environment and the interests of consumers and other users. States and all those involved in fisheries are encouraged to apply the Code and give effect to it."*

In its Article 9 – "Aquaculture development", the Code of Conduct specifically mentions non-native species and the potential impact of aquaculture on the local ecosystems.

- Section 9.1.2: "States should promote responsible development and management of aquaculture, including an advance evaluation of the effects of aquaculture development on genetic diversity and ecosystem integrity, based on the best scientific information."
- Section 9.2.3: "States should consult with their neighbouring States, as appropriate, before introducing non-indigenous species into transboundary aquatic ecosystems."
- Section 9.3.1: "In particular, efforts should be undertaken to minimize the harmful effects of introducing non-native species or genetically altered stocks used for aquaculture including culture-based fisheries into waters, especially where there is a significant potential for the spread of such non-native species …..".

Practical implementation of the Code is assisted by a series of "FAO Technical Guidelines for Responsible Fisheries". The issue of invasive alien

species in relation to aquaculture and capture fisheries is treated in Technical Guideline no. 2 “Precautionary approach to capture fisheries and species introductions”, no. 5 “Aquaculture development”, and no. 6 “Inland fisheries”.

3.5 Consequences for regulatory and monitoring systems

Presently, *O. niloticus* appears not to have established major populations in natural rivers or reservoirs in Vietnam. However, there are two major reasons for still maintaining the precautionary approach:

- The issue of "successful" establishment of a non-native species is related to the so-called "propagule pressure", i.e. the number of introduced individuals and the number of attempted introductions. Thus, if any species is deliberately or accidentally introduced over and over again to a lake or river, it will eventually establish a reproducing population.
- The "invasiveness" of the species may change over time. An introduced species that looks harmless may eventually turn into a pest after many years. This may be due to adaptation to the local environment, evolutionary change of the introduced species, or changes in the local environment.

The available Vietnamese decrees relating to import (and export) of live fish are probably directed towards regulating aquaculture trade rather than protecting the environment or native biodiversity. This does not indicate that the decrees are not quite adequate. The problem is, however, to achieve effective enforcement. A second problem is, in Vietnam as in almost every country of the World, the deficient co-operation and lack of harmonized policies between the institutions responsible for the environment, and the economic sector departments. Development of a modern and adequate legislation (including regulations/decrees) will require coordination between the various Ministries and Departments dealing with fisheries, trade and environment. Implementation of the proposed GISP capacity building project (see above) regarding invasive alien species prevention and management in Vietnam would have a potential to contribute to this (cf. www.gisp.org).

Both Vietnam and Norway are obliged to apply the precautionary principle in relation to aquaculture, through their ratification of the CBD and Ramsar Conventions. In general terms, this would require that a number of actions should be considered.

- Develop technologies for feasible aquaculture with native species. This issue should at least be evaluated in terms of feasibility and potential.
- Introduction of alien species into natural or semi-natural systems in order to create a resource base for a commercial, subsistence or recreational fishery, should be avoided. Such technologies should always be based on native or locally occurring species.
- For non-native species or genotypes, sterile or one-sex broodstock for aquaculture should be developed, and regulations to prohibit use of any other broodstock should be enforced. This technology appears already to be in place for some of the tilapia strains. The best solution from a conservation point of view would be sterile fish. One-sex fish may be able

to hybridise with closely related alien species already present (e.g., O. mossambicus).

- Through national planning, identify areas or watersheds where aquaculture should not occur due to risk of destructive introduction of alien species for local biodiversity. Particularly valuable or vulnerable habitats or ecosystems in terms of biodiversity, endemism, etc., should be protected from aquaculture based on alien species or genotypes.
- Develop technologies to prevent or minimize escaping from aquaculture operations. In all aquaculture operations, both equipment and practices can be improved to reduce the number of escapees. The feasibility of this approach would depend partly on the state of the present technology and the investment capacity of fish farmers
- When escapees establish populations in a natural locality, it is usually, for all practical purposes, irreversible. Extinguishing an established population normally involves environmentally destructive methods, or is too costly to be feasible. Any fishing or other exploitation activities in the locality should, however, be focused at the alien species to keep its population at a minimum.

An important element in the prevention and management of invasive alien species is monitoring. In relation to aquaculture, it is necessary to monitor both the vector (i.e. the activities related to aquaculture), and the ecosystems where escapees might establish populations. The various stages in the aquaculture operations where information is needed in order to take necessary management actions would include:

- Import/export of life fish/organisms. This information is normally available from trade statistics.
- Inland transport/transfer of live fish. This may require additional effort on the part of extension services, fish farmers' organizations, etc.
- Technical performance of aquaculture operations in relation to prevention of escapes. Information on this may be collected by extension services, whose staff should also be trained to advise fish farmers on how to reduce the number of escapees.
- Occurrence of escaped fish/organisms in recipient ecosystems. This usually requires special and costly efforts, and may be restricted to a few selected areas of high importance.

Monitoring programmes are costly and complex, and funding of the required data collection is a major problem also in developed countries. Thus, modalities should be found where data are obtained through co-operation with other institutions or organizations, such as aquaculture and agriculture extension services, fish farmers' organisations etc.

4. Further recommendations for regulations and monitoring

In addition to the proposed actions in the section " Consequences for regulatory and monitoring systems" immediately above in section 3.5, we wish to draw attention to the following recommendations of international relevance.

The FAO Inland Water Resources and Aquaculture Service have produced highly relevant guidelines in the form of "Codes of practice on species introductions" which we reproduce in the box below. They are available at: http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/resources/aqua/introspec/codesofpractice.htm

The International Council for the Exploration of the Sea (ICES) and the European Inland Fishery Advisory Commission have developed codes of practice on the use of introduced species. These codes generally apply to the purposeful movement of aquatic species, for example, in fisheries, biological control, aquaculture, and for research. There are also guidelines and policy concerning species introduced inadvertently through ballast water or on ships' hulls.

The basic Code requires that:

1. the entity moving an exotic species develop a PROPOSAL, that would include location of facility, planned use, passport information, and source of the exotic species;
2. an independent REVIEW that evaluates the proposal and the impacts and risk/benefits of the proposed introduction, e.g. pathogens, ecological requirements/interactions, genetic concerns, socio-economic concerns, and local species most affected would be evaluated;
3. ADVICE and comment are communicated among the proposers, evaluators and decision makers and the independent review ADVISES to either accept, refine, or reject the proposal so that all parties understand the basis for any decision or action, thus proposals can be refined and review panel can request additional information on which to make their recommendation;
4. if approval to introduce a species is granted QUARANTINE, CONTAINMENT, MONITORING, AND REPORTING PROGRAMMES are implemented, and
5. the ONGOING PRACTICE of importing the (formerly) exotic species becomes subject to review and inspection that check the general condition of the shipments, e.g. checking that no pathogens are present, that the correct species is being shipped.

The Code is general and can be adapted to specific circumstances and resource availability, but it should not lose any of the above requirements nor should it lose the rigor at which the requirements are applied. For example, a regulatory agency may require a proposal to contain a first evaluation of the risk/benefits and this evaluation would then be forwarded to an independent review or advisory panel; or the advisory panel could make the first evaluation of a proposal. Similarly, states may require quarantine procedures to be explicitly described in the proposal before approval is granted.

NACA and FAO (2000) have published the Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and The Beijing Consensus and Implementation Strategy. These may be accessed from: http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/X8485E/X8485E00.HTM

FAO have also produced a useful brochure on "Introduced Species in Fisheries" downloadable at: ftp://ftp.fao.org/fi/brochure/alien/y4710e.pdf

Wittenberg and Cock (2001) have produced a useful "toolkit" by on "best prevention and management practices for invasive alien species". This is available at: http://www.gisp.org/downloadpubs/Toolkiteng.pdf

Turner (1988) developed useful procedures for transfers of aquatic organisms for European waters. Bartley et al (1996) drafted a framework for responsible use of introduced species, and Bartley and Casal (1998) summarised the impacts of introductions on aquatic biodiversity.

Useful information and lessons may be drawn from the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 1994: http://www.oceansatlas.com/world_fisheries_and_aquaculture/html/resources/aqua/introspec/img/itmo.pdf

5. Conclusions

This report attempts to summarise existing scientific knowledge relevant to considerations of the potential effects of Nile tilapia introductions on biodiversity with special reference to Vietnam.

Nile tilapia is an excellent species for aquaculture that is well suited to conditions in Vietnam, especially in the warmer southern parts. They have been introduced to the country many years ago and on several occasions and are currently being bred in RIA-1 for selection towards greater tolerance of colder water. These efforts will probably have significant benefits in terms of increased production and socio-economic effects. It is also noteworthy from the region that Thailand is the fourth largest producer of Nile tilapia in the world, Indonesia the fifth and Lao PDR the sixth.

However, we urge caution concerning the potential longer-term problems that Nile tilapia may cause for biodiversity, especially when they (inevitably) escape into the wild.

We also highlight relevant international conventions to which both Vietnam and Norway are signatories, and the responsibilities and commitments that ensue.

A number of practical recommendations are made in section 3.5 and some additional relevant sources of information are highlighted in section 4.

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Annex 1. Terms of Reference

Received from NORAD attached to their letter of 6th January 2005, with reference number 842.1 2005-00020 MN/NÆR/KIB entitled **"GLO-2035 Noragric – Oppdrag tilapia/biodiversitet".**

In an e-mail dated 8th January 2005 from Kirsten Bjøru to Ian Bryceson, the date for submission was extended to 20th January 2005.

Terms of Reference

Desk-study on the Potential Effects on Biodiversity of Nile Tilapia Introductions with Special Reference to Vietnam

Introduction

The Project "Building advanced research and education capacity for Research Institute for Aquaculture No. 1" is assisted by Norwegian Agency for Development Co-operation (NORAD) and started in the end of 1998 after signing the Agreement between the governments of Norway and Vietnam on 18th November 1998.

One of the Project's outputs involves genetic improvement of Nile tilapia (*Oreochromis niloticus*) strains and their introduction into aquaculture in rural areas of Vietnam. The intention is to breed and produce Nile tilapia that can withstand lower temperatures.

Nile tilapia has obvious advantages as a fish highly suitable for aquaculture due to its ease in breeding, general hardiness and market acceptance. It is also a herbivore and detritus-feeder. Aquaculture production of tilapia is growing faster than for any other species and it now ranks globally as the sixth largest in terms of annual production, surpassing salmon which is ranked seventh. It is widely cultured throughout many Asian countries, sometimes in polyculture with Asian carp species or brackishwater shrimp. However, concern has been expressed about the possible negative impacts on biodiversity that might be caused by deliberate further introduction of Nile tilapia, which originates from Africa, into new and wider aquaculture areas due to its tendency to escape into surrounding natural aquatic environments as an "invasive alien species".

Purpose

This desk-study is intended to elucidate considerations related to possible impacts of Nile tilapia on biodiversity in natural aquatic environments in Vietnam in case of their wider introduction in aquaculture and subsequent escapes as invasive alien species.

Scope of Work

The study will be divided into three principle components:

- an international overview of Nile tilapia occurrence, its aquaculture and review of reported impacts that it has had on biodiversity;
- the status and importance of Nile tilapia culture in Vietnam and observations on its occurrence in natural environments in the country;
- considerations in relation to international agreements and conventions to which Vietnam and Norway are signatories relevant to Nile tilapia introductions in Vietnam, and what practical consequences these should have for relevant regulatory and monitoring systems in Vietnam.

Implementation

Three independent consultants with knowledge about (i) Nile tilapia occurrence and aquaculture internationally, (ii) in Vietnam and (iii) on biodiversity agreements and conventions will carry out parallel desk-studies on these three aspects of the overall question raised in the "Purpose".

The consultants are:

- Ian Bryceson, Noragric, Norwegian University of Life Sciences, Ås
- Niels Svennevig, SINTEF Fisheries and Aquaculture, Trondheim
- Odd Terje Sandlund, NINA, Trondheim

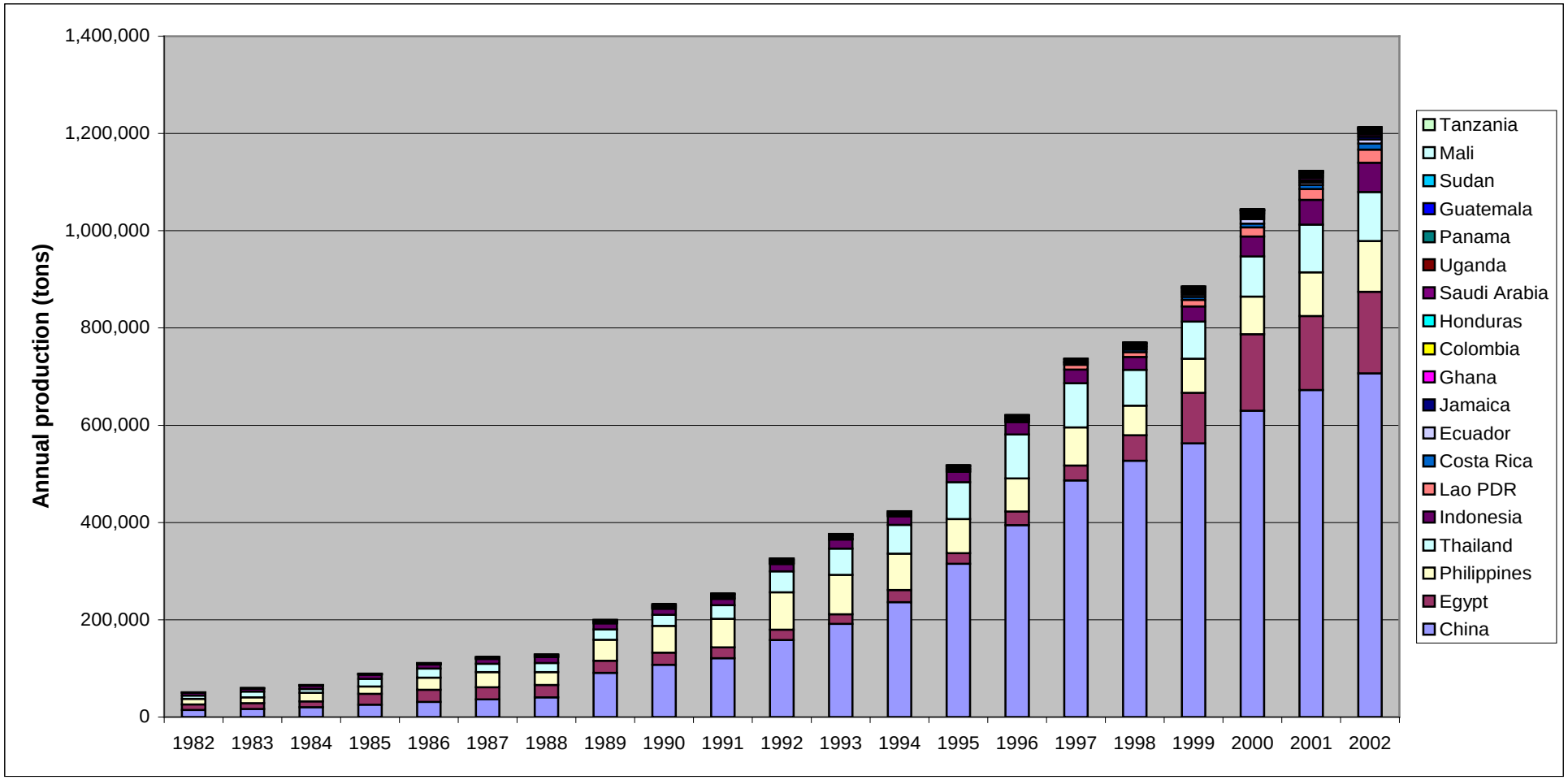
Ian Bryceson shall primarily address the first component in the "Scope of Work" and synthesise the three studies into a single report. Niels Svennevig shall primarily address the second component and Odd Terje Sandlund the third one.

Timing and Reporting

The three consultants will complete their respective desk-studies by Monday, 11th January 2005 and Ian Bryceson will submit the unified combined study to NORAD by 14th January 2005.

Each consultant will use five working days for this assignment, and Ian Bryceson will use two additional days to synthesise and combine the studies into a single report.

Annex 2. Aquaculture production of *Oreochromis niloticus* by main countries



Data from FAO Fishstat Plus (2005)