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# The early history of freshwater fish production and consumption in Thailand

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The history of freshwater fish production and consumption in Thailand were reviewed in the late 1970s. While aquaculture had a history of more than a century in the country it had only started to expand relatively recently because of the abundance of wild fish in former times. Historical aspects of freshwater capture fisheries and freshwater aquaculture in Thailand, and the development of irrigation in Central Thailand which played an important role in facilitating the development of inland aquaculture in the country were reviewed. While dam construction led to the demise of the flood plain capture fishery, it provided a controlled water supply necessary for the subsequent development of aquaculture. The study informed the development of education and research in aquaculture at the Asian Institute of Technology (AIT). More recent developments in Thai aquaculture are outlined. Malnutrition in developing countries and fish in the Thai diet at the time of the study were also reviewed.

KEYWORDS

history, freshwater fish, freshwater fisheries, aquaculture, fish consumption

## 1 Introduction

The purpose of this publication, based on an unpublished report (Edwards et al., 1983a), is to make available rare and important historical information on the development of Thai aquaculture up to the start of the modern period of aquaculture development. Modern aquaculture may be considered to have developed since the landmark Kyoto Declaration of 1976, almost 50 years ago, which sought to recognize and appreciate the significant role that aquaculture plays in providing food security both through food supplies and economic and social well-being (FAO, 1976).

The historical development of fish production, both capture fisheries and aquaculture, and fish consumption in Thailand were reviewed in the late 1970s (AIT, 1994).

Although aquaculture had a history of more than a century in the country, it had only started to expand relatively recently in the country because of the abundance of wild fish in former times.

Sections below address historical aspects of freshwater fisheries in Thailand, freshwater aquaculture in Thailand, and the development of irrigation in Central Thailand which

played an important role in the facilitation of development of inland aquaculture in the country. Malnutrition in developing countries and fish in the Thai diet and its importance are also reviewed.

While dam construction led to the demise of the flood plain capture fishery, it provided a controlled water supply necessary for the development of aquaculture.

Pathumthani Province was selected in the late 1970s as a study area to investigate the feasibility of developing aquaculture as an integrated and complementary activity for small scale rice farmers. The area was then predominantly rural in character, with a year-round supply of water because of an irrigation system, and was close to the Bangkok Metropolis where surplus fish could be marketed.

## 2 Freshwater fisheries in Thailand

The freshwater fish fauna of Thailand was well developed in both number of species and abundance of fish (Smith, 1925; Smith, 1945; FAO, 1949). Fishing used a wide range of fishing gear: traps, baskets, cast nets, lift nets, dip nets, gill nets, encircling nets, seine nets, hooks, and spears. The major species consumed in terms of popularity and quantity were striped snakehead, *Channa striata*, anabantids, *Trichogaster pectoralis* and *Anabas testudineus*, catfish genera, *Clarias*, *Kryptopterus*, *Mystus*, and *Pangasianodon*, featherback, *Notopterus notopterus*, and tawes, *Barbonymus gonionotus* (Smith, 1925; Smith, 1945). Smith (1945) considered snakehead to be the commonest of the staple food fish of Thailand. Giant freshwater prawn, *Macrobrachium rosenbergii* was abundant (Smith, 1925).

The importance of wild fish for the welfare of the Thai people dated back many years according to an inscription, the earliest one known in the Thai language, dated 1293 A.D.: 'During the time of Prince Ram Khamhaeng this realm of Sukhothai has prospered. In the waters are fish, and in the field is rice. The lord of the realm takes them not. He would invest them in his people' (Bradley, 1909).

In Thailand there is a vast network of rivers and canals, especially in the Central Plains, and numerous swamps, reservoirs, and tanks (Smith, 1925; FAO, 1957; Bhukaswan, 1983). During the monsoon season waters rose and fish followed the flood waters, first into canals and smaller streams, and finally into swamps and paddy fields which provided spawning and feeding grounds. Flooding reached its height at the end of the rainy season Fishing activity was most intense as the flood waters receded. The entire inland population devoted a part of its time to fishing (Ingram, 1971).

The resource was renewed each year with the cycle of the monsoon: 'thus the Thai is supplied with an abundant source of food - all he had to do is dip it from the water' (FAO, 1966). The flood plains fishery attained its greatest development in the Central Plains where huge areas of flat land were inundated annually by the floods. It had been estimated that the Central Plains flood fishery supplied as much as 90% of the Thai commercial freshwater fish harvest, not including the vast subsistence fishery (FAO, 1965). Where water transportation facilities existed, large shipments of live fish were made to markets in Bangkok in rice barges filled with water (Anon, 1956).

Almost a century ago, Smith (1925) believed that the freshwater fisheries in Thailand had already passed their climax of development and that fish had decreased in abundance in all regions of active fishing in the country. He wrote; 'the rice-growing population who are the backbone of the country's wealth and prosperity require an abundance of fish food and they can no longer obtain a sufficiency from local waters'.

Increased fishing intensity as a result of rapid population growth must also have played a major role in the reduction of wild fish as practically the entire inland population devoted a part of its time to fishing" (Ingram, 1971). Fish production; as early as 1925, Smith wrote: 'That more apparatus is set, more fishermen are employed, and more labour is now involved that formerly there can be no doubt'.

A major reason for the decline in freshwater fish was the operation of large, wing traps across channels and canals as the flood waters receded from the plains, and also at the outlets of lakes and swamps that were major fish breeding grounds e.g., Bung Borapet in Central Thailand (Smith (1925). The wing traps were set across the current at the narrowest and deepest section of the water channels and directed fish into nets which were lifted by a windlass every 30 minutes to 1 hour, day and night, throughout the fishing season. The right to operate the traps was auctioned by the Government to the highest bidder for monopoly fishing (Tongsanga & Kessunchai, 1966; Bhukaswan, 1983).

It was believed that Thailand was no longer rich in freshwater fish due to overfishing, and if the use of wing nets continued year after year without management it would eventually lead to the destruction of the natural stock of fish (Tongsanga & Kessunchai, 1966). Wing nets were no longer operated since the construction of the irrigation system with dams and storage reservoirs had reduced the flood, but the control of the water regime over much of the floodplain had also decreased natural fish production (Welcomme, 1979; Charernphol, 1981; Bhukaswan, 1983).

It seems paradoxical that the construction of an irrigation network to increase the production of one staple, rice, should have led to the reduction in the production of a second staple, fish. Natural fish production had also undoubtedly been reduced by environmental changes caused by intensification of agriculture, urbanization, industrial development and road construction (FAO, 1965; FAO, 1966; Charernphol, 1981).

Farmers in various parts of the country, but especially along the canals in the Central Plain, used to keep trapping ponds for wild fish, and this was a secondary occupation to rice cultivation in some areas. The trapping ponds, 400-800 square metres in area, were deeper than the adjacent canal but connected to it by short, narrow channels through which fish entered into the ponds when the water level was high. The major species, *Anabas*, *Channa*, and *Clarias*, grew well on the large numbers of small forage fish that came in continually from the outside canal. Every 2-4 months the passages were blocked, the water bailed out, and the fish caught by hand nets.

Yields had already decreased drastically by 1950 and some of the trapping pond owners were the first to take up aquaculture (Anon, 1956; Indrambarya, 1962). There does appear to have been a phenomenal production of wild fish in the past due to the rich fish fauna, the warm climate, the vast network of waterways, and the

annual flood. However, there were strong factors that tended to keep fish production below its potential such as the long dry season and quick reduction in water volume, the excessive growth of aquatic macrophytes, and the dominance of predaceous fish (FAO, 1957). While the traditional Thai utilization of wild fish was adequate for the relatively small population of the past, more modern methods of fish production were required to contribute to the nutritional needs of the rapidly expanding Thai population.

## 3 Aquaculture in Thailand

Stocking fish in enclosed waters had seldom been practiced until as recently as the 1930s (FAO, 1957). However, there had been a remarkable development in aquaculture in the two decades from 1960-1980 with the annual production of freshwater aquaculture estimated to be 40,000 - 50,000 tonnes (Sidthimunka, 1982) and by 2003 it had reached 320,000 tonnes (FAO, 2006).

It is generally considered that Chinese immigrants introduced aquaculture into Thailand about 1910 (Smith, 1925; Smith, 1945; FAO, 1949; Anon, 1956; FAO, 1957). Common carp, *Cyprinus carpio*, was introduced first and soon afterwards fry and fingerlings of other carps were imported (FAO, 1957): bighead carp, *Aristichthys nobilis;* goldfish, *Carassius auratus*; mud carp, *Cirrhinus molitorella*; grass carp, *Ctenopharyngodon idellus*; silver carp, *Hypophthalmichthys molitrix*; and black carp, *Mylopharyngodon aetiops* (Smith, 1945). The fish were cultured by a few Chinese on a small scale in ponds, mostly in Bangkok, including ponds in today's Lumpini Park. There was a ready sale among the large immigrant Chinese population of familiar fish. Fish were stocked in polyculture and sometimes with native, striped catfish, *Pangasianodon hypophthalmus* (FAO, 1949; FAO, 1957).

Grass, chopped aquatic plants such as water spinach, *Ipomoea aquatica*, and rice bran, were fed to the fish and the ponds were fertilized with pig, buffalo, and cow manure. Overhanging latrines were also used to fertilize the ponds (FAO, 1949).

Fry were imported each year by boat from China (Smith, 1945; FAO, 1949); an estimated 1.1 x 10 to the 10 newly hatched carp fry and eggs were collected annually in China, with large quantities transported from Hong Kong to Singapore, Malaysia and Thailand. Considerable numbers of fish were transported e.g., in 1954 over 600,000 Chinese carp fingerlings were imported to Thailand (FAO, 1957). The fingerlings were transported on ships in large baskets or wooden tubs over 2 m tall with about a 2 m bottom diameter. About 50,000 fish 4-5 cm long were put into a tub half full of water. The surface of the water was kept in continuous motion during transportation, day and night since a few minutes negligence by a tired worker leaving the paddle idle would have caused complete fingerling mortality. Dirty water from the container was bailed out continually in small quantities and replenished with clean freshwater. Starting from 1948, fingerlings were air freighted to Bangkok (Lin, 1949) and subsequently produced in Thailand by induced spawning (Na Nakara, 1983).

The cultivation of native Thai fish occurred on a small scale before the introduction of Chinese carps into the country. Striped catfish was raised and fed enclosed by bamboo grids in rivers at Ayuthaya in the middle of the 19th Century (Bocourt, 1866). Small striped catfish or other high-priced fish were not sold immediately after capture but were artificially fed in floating bamboo cages and sold when grown in a primitive form of aquaculture (FAO, 1949). Cage culture of striped catfish continued to take place in Uthai Thani, Nakorn Sawan and Chainat provinces (Thiemmedh, 1961), and subsequently also the cultivation of the high-priced sand goby, *Oxyeleotris marmoratus*, using trash fish (Suwanasart, 1976). Striped catfish had also been raised in ponds for commercial sale and domestic consumption since the middle of the 19th century (Smith, 1945).The cultivation of a second native fish, snakeskin gourami, *Trichogaster pectoralis* may also predate that of Chinese carps. According to Smith (1925), a few ponds were maintained for growing snakeskin gourami, the favourite fish for culture although success was rarely if ever achieved; the ponds were not properly built so that they could not be drained and predators could not be eliminated.

H.M. Smith was invited by the Thai Government to review the fisheries resources of the country and to suggest methods for their conservation and development. He was Adviser in Fisheries to the Government from 1923 to 1935 (Smith, 1925; Smith, 1945; Indrambarya, 1983). His recommendation that a Thai Fisheries Department (DoF) be set up was implemented in 1926 (Anon, 1956). The DoF developed an aquaculture programme designed to fit the socio-economic background of the general population of the country to produce more protein food for the people (Anon, 1956). The DoF began to study the life history of snakeskin gouramy in 1932, and attempted to convince the people that it was simple to cultivate the fish. Snakeskin gourami was recommended because it is easy to grow, cheap to raise since it eats vegetable matter, grows fast, and has a good taste and few bones (Department of Agriculture, 1939; Indrambarya, 1981). Unfortunately, progress was slow since people were not sufficiently interested (Anon, 1956; FAO, 1957), presumably because there were still relatively abundant supplies of wild fish (CHaitiemvong, 1970).

At the request of the Thai Government a FAO agricultural mission visited the country in early 1948, and a second special mission for fisheries in late 1948 because of the economic and dietetic importance of fish in Thailand (FAO, 1948; FAO, 1949; Anon, 1956; FAO, 1957). In 1951 the Government requested technical assistance from FAO to help in the development of inland fisheries to increase fish production for food for the people. One task was to develop practical methods of fish culture. S.W. Ling served from 1951 to 1954 during which time a large fish culture scheme was implemented (Anon, 1956; FAO, 1957).

The tremendous subsequent development of aquaculture in Thailand, involving several species, has been the result of both the efforts of the Thai Department of Fisheries (DoF) and the readiness of Thai farmers to become involved in agricultural innovations. However, the stage had also been set by the marked decline in the supply of fish from natural waters and the realization that aquaculture could produce food fish to substitute for the diminished, natural supply (CHaitiemvong, 1970; Sidthimunka, 1982).

The large, fish culture scheme implemented by S.W. Ling in 1951 involved the promotion of tilapia. The DoF imported a few

*Oreochromis mossambicus* from Penang in 1949 and about 200 from Singapore about 1951 (Ling and Sidhthimunka, 1953). The fish was welcomed by the people as a food fish and within a comparatively, short time had created a deep interest in the country (FAO, 1957). About 4 million fry was produced by Government fishery stations in 1953 and during the mid-1950s it became the most popular pond fish in Thailand because of its fast growth and reproduction, and its good quality as a table fish (Anon, 1956). However, later there were reservations about the quality and flavour of its flesh (FAO, 1965; Sidthimunka, 1982) and it was no longer promoted by the Thai DoF.

There have been importations of other tilapias into Thailand. Tilapia was imported from Belgium in 1955 to determine if it could utilize aquatic weeds (Editorial Board, 1955); ecological studies were carried out in Chiengmai in 1964 (FAO, 1965; FAO, 1966) but the fish was not promoted. A hybrid between *Oreochromis mossambicus* and *O. hornorum* was also imported from Malaysia into Thailand and reported to be in use in the 1950's (Tropical Fish Culture Research Institute, 1957/58-1958/9); Chen, 1969). The tilapia which has been most widely cultivated since the late 1960's in Thailand is the Nile tilapia, *Oreochromis niloticus* (Sidthimunka, 1982). A gift of 50 fish was presented to King Bhumipol by Crown Prince Akihito of Japan in 1965. The fish were placed in a prepared pond in the grounds of the Dusit Palace and were a source of fry production from which the Nile tilapia cultivated throughout the country were derived (Sansrimahachai & Sintusen, 1976).

The DoF promoted rice/fish culture in north and central Thailand in the 1950's (Indrambarya, 1962; Pongsuwana, 1963) but were unsuccessful in that integrated rice/fish culture did not become common in Thailand (Sidthimunka, 1982). However, their efforts ultimately led to the development of a unique aquaculture system, the extensive cultivation of snakeskin gourami in former rice fields.

An attempt was made in 1954 to promote the cultivation of a wide variety of fish, common carp, Chinese carps, tilapia, walking catfish, sea bass, milk fish, and snakeskin gourami in the Lower Chiengrak-Klong Dan Irrigation area to the southeast of Bangkok where only one crop of rice was grown each year. The intention was to promote rice/fish farming so that the farmers could utilize their land for more than 6 months each year (Indrambarya, 1962). A few farmers conducted their own trials in an area with relatively saline soils close to the coastal dike which gave low rice yields. They stocked snakeskin gourami in the flooded fields and cut and piled grass and weeds in the water as green manure. The fish grew well and the fish culture system using former paddy fields extended in the irrigated coastal areas of Samut Prakan and Chachoengsao Provinces to 20,000 ha (Boonsom, 1981; Indrambarya, 1981). The current annual production of snakeskin gourami was then almost equal to that of the total freshwater fish production in Thailand (Boonsom, 1981; Sidthimunka, 1982).

Indrambarya (1981) considered snakeskin gourami to be the first native fish to be successfully cultivated in Thailand with its entire life history taking place in the modified rice fields since large fish were stocked in the flooded field as brood stock to initiate the cultivation cycle.

The initial emphasis of the DoF was the promotion of herbivorous and omnivorous fish (Anon, 1956) which led to the successful development of tilapia and snakeskin gourami culture. Farmers were also encouraged to grow fish with pigs, poultry, vegetables and fruit in integrated farming systems (Anon, 1956). An integrated farming experiment was conducted with the tilapia *Oreochromis mossambicus* in the 1950s to determine fish production in the tropics relevant to rural conditions. Ponds were fertilized with pig and chicken manure, water spinach was planted on the pond dikes, two compost piles of dry grass were placed in the corners of the pond, and the fish were fed rice bran and broken rice (Pongsuwana, 1955).

These concepts were incorporated into an extension pamphlet entitled, 'Culture tilapia - for food and profit' by S.W. Ling and translated into Thai by A. Sidthimunka (Ling & Sidhthimunka, 1953). The pamphlet was popular with first and second printings of 200,0000 and 110,000 copies, respectively (FAO, 1957). Farmers were also encouraged to raise fish in vegetable and fruit garden ditches but progress was slow due to difficulties in controlling predators and the water level (FAO, 1957).

Integrated livestock/fish farming became widespread in Central Thailand (Janesirisak, 1980; Wetchagarun, 1980; Edwards, 1983). Chamnian (1964) described integrated Clarias and chicken farming with one farm dating back to 1956. There were also integrated fruit/fish farms in Central Thailand (Wetchagarun, 1980; Edwards, 1983), and vegetable farms in Pathumthani Province raised striped catfish on vegetable waste (CHaitiemvong, 1970).

The DoF emphasized the artificial spawning of species which do not breed naturally in captivity to ensure adequate supplies of seed. Success was achieved with Chinese carps, striped catfish, walking catfish, and giant fresh water prawn (Sidthimunka, 1982). Seed production of commercially important freshwater species became more of a logistic than a technical problem.

The pond culture of striped catfish, an omnivorous feeder, was promoted by the Government (Thiemmedh, 1961) and was farmed in the Centra Plains (CHaitiemvong, 1970). Several private hatcheries produced millions of striped catfish fingerlings annually since 1974 (Potaros and Sitasit, 1976).

During the 1950s, farmers started to raise walking catfish *Clarias*, by collecting wild fry and transfering them to ponds (Tongsanga et al., 1963) but the supply was insufficient to meet the demand (Sidthimunka et al., 1968). The development of induced breeding methods for *Clarias* (Sidthimunka, 1972) enabled a rapid expansion of farmed production, which peaked at about 40,000 tonnes in 1973 although it subsequently declined markedly due to disease induced by poor water quality (Panayotou et al., 1982; Colman and Edwards, 1987). The cultivation of striped snakehead, *Channa striata* had suffered similar problems.

During the 1970-1980s, a most impressive aspect of Thai aquaculture was the development of more capital-intensive systems utilizing trash fish e.g., *Clarias* and *Channa* and pelleted feed e.g., *Macrobrachium*. The cultivation of the giant freshwater prawn, *Macrobrachium* rapidly increased, and the total farmed production in 1979 was probably greater than in any other country (New et al., 1980).

The incidence of the traditional farmer-based integration of livestock with filter feeding fish and farming striped catfish with slaughter house offal and agro-industrial factory processing wastes gradually declined.

The outbreak of highly pathogenic avian influenza (HPA1), commonly known as bird flu in late 2003/early 2004 led to a decline in integrated chicken/fish systems although there was no evidence that such systems had been involved in any outbreak (Edwards, 1991). Contract farming companies stopped providing day-old chicks to broiler farmers operating open systems although the Department of Livestock allowed some broiler farms to reopen with poultry quarters screened with plastic netting.

Concerns over the hygienic aspects of feeding fish with slaughter house offal and agro-industrial processing wastes led to them being used instead as ingredients in pelleted feed that was produced in factories and involved a heat process that eliminated potentially infectious bacteria and viruses.

More recently diverse species are farmed in several innovative systems with aquaculture playing an increasingly important role in food security and the economy (FAO, 2006). Freshwater aquaculture is mainly for domestic consumption with small-scale freshwater aquaculture crucial in providing the rural poor with high quality protein food for home consumption (Belton et al., 2009). The main freshwater species cultured are Nile tilapia (*Oreochromis niloticus*), hybrid catfish (*Clarias macrocephalus* X *C. gariepinus*), silver barb (*Barbodes gonionotus*), giant river prawn (*Macrobrachium rosenbergii)* and snakeskin gourami (*Trichogaster pectoralis*). Freshwater aquaculture includes culture in ponds, paddy fields, cages and ditches. Most farms are densely located in areas which have abundant water resources or which are irrigated.

Aquaculture in Thailand has expanded rapidly since 1980 with freshwater aquaculture production in 2003 reaching 320,000 tonnes (FAO, 2006). While the development of intensive methods of aquaculture was economically viable since they supplied high-priced luxury products for local urban and foreign markets, their relevance for widespread rural development was questionable since they were capital intensive. To some extent they had recently stolen the aquaculture limelight and directed attention away from a more pressing concern for Thailand, how to get small scale farmers involved in aquaculture on a widespread scale; the momentum of earlier decades towards achieving this goal had been dissipated.

## 4 Aquaculture R&D at AIT

Initial research and development (R&D) at AIT were reuse of human excreta (sewage and septage) (Edwards, 1980a; 1980b; Edwards, 1985). The first project involved reuse of campus sewage and subsequently septage, from Bangkok. Impressive production of about an extrapolated 7 tonnes/ha/year of *Oreochromis niloticus* was attained in septage fertilized ponds. Unfortunately, the technology was unable to be extended for Bangkok because of the large area of ponds required that would have been required and which also accumulated considerable sludge that would have required removal and disposal.

At the time the history of aquaculture in Thailand was being reviewed, a survey of fish farming occurrence and practice was carried out in Pathumthani Province in which AIT is located. The major finding of the survey was the presence of commercial aquaculture, medium to large-scale integrated livestock fish systems by mostly ethnic Thai-Chinese farming households; and ethnic-Thai small-scale rice farming households who mostly relied on borrow pit ponds to raise the level of the house above flood levels, with limited and mostly unsuccessful attempts to grow stocked fish because they were preyed upon by wild carnivorous fish such as snakehead and walking catfish that were able to enter the ponds during or after rainfall by slithering across the ground from nearby water bodies (Edwards, 1983). Livestock manure (ducks and buffalo) as a pond fertilizer was studied which led to studies on integrated farming.

As well as being of historic interest, the historical development of aquaculture in Thailand informed the development of education and research in aquaculture at the Asian Institute of Technology (AIT) (Edwards. A major aim of R&D was to help small-scale rice farmers produce adequate fish for domestic consumption using on-farm duck or buffalo manure to satisfy their animal protein requirement with surplus fish sold to increase their income (Edwards, 2000).

Scaled-down, small-scale integrated duck/fish trials for small-scale rice farmers were studied both on-campus and on-farm in Pathumthani Province and Udornthani Province in North East Thailand (Edwards, 1983; Edwards, 1986; Edwards et al., 1996).

The farmer-managed duck/fish trials were initially considered to be successful with about 100 kg of fish, *Oreochromis niloticus*, harvested from the 200 m square ponds in 8 months, an extrapolated fish production of almost 9 tonnes/ha/yr. Unfortunately, the cooperating farmers were unable to maintain the system without project support. While the farmers appreciated the fish harvested, they were unable either to source the relatively small amount of duck feed required nor were they able to market the daily production of about 25 duck eggs.

These results led to a subsequent assessment of the role of buffalo manure for pond culture of Nile tilapia in North East Thailand where buffaloes were still being used to plough fields; as well as on the AIT campus with manure obtained from a nearby slaughter house (Edwards et al., 1994a; Edwards et al., 1994b; Shevgoor et al., 1994). In the farmer-based trial in North East Thailand the farmers loaded about 4 tonnes of fresh buffalo manure into their 200 m square pond but obtained only about 20 kg of fish in 7 months. Clearly, the use of buffalo manure as a sole pond input could not be justified (Edwards et al., 1994a). Two factors led to the low fish production, its low nitrogen content and high tannin content which stained the pond water brown.

A major AIT R&D program was mass seed production of tilapia (*Oreochromis niloticus*) (Little et al., 1993). The production of large numbers of uniform sized fry enabled the intensification of tilapia farming and the technology has been adopted throughout the world (Belton et al., 2009).

An Outreach program through which small-scale aquaculture was promoted in collaboration with national institutions was established initially in North East Thailand (Edwards et al., 1996;

Pant et al., 2004; Pant et al., 2005) and subsequently in Cambodia and Lao PDR, and Vietnam (Luu et al., 2002).

## 5 Thai government development policy for promotion of small-scale aquaculture

National development has been guided by the National Development and Social Plan (NESDP) since 1961 (ADB, 2005). The principal strategic objective of the NESDP was to promote economic development by utilizing natural and human resources to increase production, generate employment and increase national incomes. As relevant examples The Fifth to the Eighth NESDPs with relevant stated goals for aquaculture were to (i) alleviate malnutrition (NESDP 5, 1982–1986); (ii) accelerate fish culture activities (NESDP 6, 1987–1991); (iii) increase opportunity for establishment of individual fishponds (NESDP 7, 1992–1996); and (iv) increase human resource capacity in managing integrated community fish ponds (NESDP 8, 1997–2001). Strategies focused on (i) developing and improving aquaculture techniques by conducting research to increase fish production and to reduce production costs; (ii) conducting research on fish species with high economic potential to improve their desirable characteristics, and to develop good practices for hatcheries and aquaculture farms; and (iii) providing technical services and certifying registered hatcheries and farms. The farmers were also influenced by market demand for fish, possibly a more important factor than government policy.

The Government also has Fisheries Acts, laws relating to fisheries and aquaculture in all waters of Thailand. These laws deal with various regulatory aspects that include conservation of national environmental quality, wildlife reservation and protection, and fisheries management.

As mentioned above, the DoF emphasized the artificial spawning of species which do not breed naturally in captivity to ensure adequate supplies of seed. Important development projects such as the Village Fish Pond Development Project (VFPDP) were carried out in North East Thailand, the poorest region of the country (ADB, 2005). The VFPDP supported fish production in community ponds, public waters and school ponds. Although referred to as village fish ponds, the water bodies were natural, improved or engineered multipurpose reservoirs.

## 6 Historical development of Thai agriculture

The historical development of Thai aquaculture was associated with that of agriculture. According to Ingram (1971), agricultural development could be divided into three main phases: prior to 1850, 1850 to 1950, and post 1950. In 1850 Thailand was sparsely populated with perhaps 5-6 million people, almost an order of magnitude less than 50 years ago, and practically all the population was engaged in agriculture, producing mainly rice.

The family was self-supporting as most people grew their own rice, fruit and vegetables; and caught and preserved their own fish. In most cases, they probably also grew their own tobacco, silk, and cotton. Farmers and their families worked just long enough to supply themselves with the necessities of life, which were kept to a modest level by custom, habit and climate. Rice was grown during the yearly inundation when seasonal rains flooded the fields, and water buffalo, which work well in a flooded environment, were the principal draft animal. Only a little more rice than required to feed the native population was grown in 1850, with export of surplus. According to van der Heide (1906) most people lived in self-supporting communities until the mid-19th Century.

The century long trend towards greater specialization in rice after King Mongkut opened up the country to external trade with the West had been broken since 1950. There was a new trend towards diversification of crops e.g., cassava, maize, sugarcane, kenaf, cotton (Ingram, 1971) but also of animal husbandry and aquaculture. Modern technology was increasingly being incorporated into food production. Although the share of agriculture in the GNP had fallen recently as the Thai economy had diversified and become more complex, agriculture remained the principal occupation of the great majority of people. Thailand was still a predominantly agricultural country and large areas were still static and dominated by tradition (Ingram, 1971). The country was no longer a monoculture economy based wholly on rice but rice was still the basic subsistence crop and a very high percentage of farmers grew at least some rice (Silcock, 1970).

Aquaculture production continued to increase in Thailand and in 2003, total production from freshwater aquaculture was approximately 320, 000 tonnes (FAO, 2006).

## 7 Development of irrigation in Central Thailand

The development of irrigation was a prerequisite for that of aquaculture. The Central Plain where most fish farms were subsequently developed consists of the triangular shaped delta of the Chao Phya River and its tributaries covering an area of 11,000 km2. The most outstanding agricultural feature of the Chao Phya delta is the cultivation of rice, and the area is the rice granary (Tomosugi, 1966) or rice bowl of the country (World Bank, 1980).

Before the development of the Greater Chao Phya Water Control Project, virtually the whole plain was covered by flood water during the monsoon season which made rice cultivation possible, although the area was parched during the dry season. The flooded Central Plain was also an important flood fishery. According to Smith (1945), 'The Menam Chao Phya is the outstanding physical feature of the country and it is to Thailand what the Nile is to Egypt'.

The Rangsit area to the north and north east of Bangkok was a largely uninhabited swamp before being opened up by irrigation schemes (Pendleton, 1946; Tomosugi, 1966). Tens of thousands of peasants subsequently settled in the area giving rise to the present day large-scale absentee land ownership system (Tomosugi, 1966).

A diversion dam was constructed across the Chao Phya River at the northern end of the Central Plains and a network of distribution canals to carry diverted water throughout the river delta.

Better control of water on rice fields was required which was attained by the construction of the Chainat Dam and its related subprojects and improvement in irrigation facilities in areas already canalized (Pendleton, 1946). Thailand was requested to increase the volume of rice exports because of world, food shortages following World War II and the FAO agricultural mission to Thailand also stressed the importance of the Chao Phya Project (FAO, 1948).

The Chainat Dam was built with the aid of a World Bank loan from 1952-1957 and distribution canals were completed in the early 1960's (Tomosugi, 1966; Small, 1973). The Chainat Dam could impound some surplus floodwater but a large storage dam, the Bhumiphol Dam, was subsequently built in the northern mountains (Silcock, 1970).

The Greater Chao Phya Water Control Project is the largest irrigation project in Thailand, covering 9,100 km. The development of irrigation in the Central Plains led to a decrease in natural fish production from greater flood control but the development of a more stable water supply in the area, a necessary prerequisite for the development of aquaculture on a widespread scale. The time was opportune to convert rice farmers from catchers of wild fish to fish farmers.

## 8 Rural development in developing countries

At the time of the study in the late 1970s a 'dual economy' in almost all developing countries had developed with about 15% of the population in the modern sector largely confined to one or two big cities, and the remaining 85% existing in rural areas and small towns (Schumacher, 1974). A call was made for the main focus of the development strategies of developing countries to meet the basic human needs of the entire population of a given country and not to provide Western levels of consumption for a privileged minority (Aziz, 1978). More meaningful alternatives were required to increase production by the rural poor. The need to pay greater emphasis to agriculture including aquaculture was clear.

The agricultural sector in developing countries then received no more than 18-20% of total investment even though the rural population of most developing countries is 50-90% of the total population. It was also not enough to just invest more money into agriculture since it was the medium and large-scale farmers with more land and better access to credit, technology and marketing facilities who benefitted most. A strategy of development for the small-scale farmer was needed to increase the productivity of the small-scale farmer (Aziz, 1978; World Bank, 1980) which the aquaculture program of the AIT responded to. Thailand had experienced a period of unprecedented rapid economic development for the preceding two decades but more than 11 million of the 44 million population, based on 1977 data, remained in absolute poverty with more than 90% of the poverty households located in rural areas.

## 9 Malnutrition in developing countries

In most developing countries including Thailand, protein-energy malnutrition (PEM) constituted a major public health problem. The diet in the greater part of the tropics comprises mainly a local, staple cereal or tuber, with only a small amount of animal protein. Population pressure in many countries has severely depleted the traditional, wild sources of animal protein including fish in many parts of Asia (Davey & Wilson, 1971. As animal products are consumed in increasing amounts as affluence rises (Tracey, 1974), it appeared logical to attempt to increase the supply of a traditional and desired food item such as fish.

Poverty and associated malnutrition were then widespread in rural areas in Thailand (Viravaidhya et al., 1981). Protein-calorie malnutrition was the most serious form of malnutrition in the country (NESDB et al., 1977-81; Tontisirin and Winichagoon, 1982). Rice, the staple in the Thai diet, contributed about 2/3 of the total calories and was the main source of protein (Pisolyabutra and Viravaidhaya, 1974). The meal pattern consisted mainly of cooked rice with moderate amounts of vegetables and small amounts of fish, meat, or eggs that functioned more as appetizers than main items of the diet. Dishes were prepared with strongly flavoured, sauces and spices such as fermented fish and chili, which made the rice more palatable. Fermented fish was the major source of animal protein for most rural Thais (Bisolyaputra & Bocobo, 1957; Chandrapanond, 1957; Pisolyabutra & Viravaidhaya, 1974).

While the Thai rice-based diet had a satisfactory protein-calorie ratio for adults, pregnant and lactating women, infants and pre-school children were vulnerable to malnutrition. The calorie density of the low-fat rice-based Thai diet was so low that many children were even physically incapable of consuming enough food to meet their calorie requirements (Burkhalter, 1974a; NESDB et al., 1977-81). Early malnutrition would lead to a small brain size which would impair learning capacity and intelligence, traits which were widely observed in Thai rural areas (Mongkolsmai, 1979). Malnourishment was also an underlying or associated cause of death in Thai children (Burkhalter, 1974b; Mongkolsmai (1979). A survey by the Thai Ministry of Public Health revealed that a mean of 55.6% of preschool children (2-5 years old) in rural areas suffered from protein-energy malnutrition. The incidence was even 37.0% in the fertile Central Plain and as high as 57.4% in Northeast Thailand (Tontisirin & Winichagoon, 1982).

## 10 Fish in the Thai diet

Fish had an important role in many Asian countries where it was the traditional source of animal protein in the diet. Fish comprised more than 50% of the animal protein in the diet of many countries in the region, including Thailand, in the late 1970s (Josupeit, 1981).

The mean Thai fish consumption was 22.9 kg/caput/yr (Josupeit, 1981). The Thai daily protein requirement was 37.6 g/caput/day of which 1/3 or 12.5 g/caput/day should have been from animal sources (NESDB et al., 1977-81). Assuming that fish are

edible and the edible portion is protein (NESDB et al., 1977-81), consumption of 22.9 kg/caput/year would provide 7.9 g animal protein/caput/day or 63% of the daily animal protein need. Since there was widespread protein-calorie malnutrition in rural areas in Thailand, the implication was fish in the market economy were inequitably distributed in the country (Bhumiratana, 1979; Mongkolsmai, 1979).

The main source of total calories and total protein in the Thai diet was cooked rice with only moderate amounts of vegetables, and with fish, meat, or eggs in such small amounts that they functioned as appetizers (Pisolyabutra and Viravaidhaya, 1974). Strongly flavoured sauces and spices such as fermented fish and chili made the rice more palatable.

Fish were eaten fresh when abundant and were also preserved by drying, salting or fermenting for the coming dry season (Bocourt, 1866; Smith, 1925; Smith, 1945; Anon, 1956; FAO, 1957; FAO, 1966). Fermented fish was the major source of animal protein for most rural Thais during the dry season (Bisolyaputra & Bocobo, 1957; Chandrapanond, 1957; Pisolyabutra & Viravaidhaya, 1974).

There are many references in the literature to the importance of fish in the Thai diet (van der Heide, 1906; Smith, 1925; Smith, 1945; Pendleton, 1946; FAO, 1948; FAO, 1949; Anon, 1956; Bisolyaputra & Bocobo, 1957; Chandrapanond, 1957; FAO, 1966; Ingram, 1971; Pisolyabutra & Viravaidhaya, 1974).

The great importance of fish in the Thai diet may illustrated by quotations from the literature: "fisheries … produce the principal animal food consumed by the Siamese people … there is an enormous consumption of fish in the households of peasants, and probably the chief value of the freshwater fisheries lies in providing a cheap, readily available and nutritious animal food for the millions of farmers and small tradesmen and their families" (Smith, 1925); "it is hardly an exaggeration to state that in every household in Thailand some kind of fresh-water fish - whether fresh, dried, or smoked - is eaten every day" (Smith, 1945); "for the majority of Thai people, fish is of dietetic importance second only to rice" (FAO, 1949); "the staple diet of the Thai population consists of rice and fish" (Stahlie & Netravisesh, 1957); "the most common animal food stuff used by these people [rural people] is fish, which can be obtained locally … other kinds of meat are seldom eaten" (Chandrapanond, 1957); 'the people of Siam traditionally have had two basic foods: rice and fish' (Ingram, 1971).

## 11 Discussion

Thailand had an abundance of freshwater fish, with snakehead, a carnivore, the commonest staple food fish because of the abundance of small cyprinid prey species of fish. Central Thailand was a vast floodplain during the monsoon season and the entire inland population devoted a part of its time to fishing especially as the flood waters receded, providing an abundant source of food. Besides the subsistence fishery of the rice faming households, large shipments of live fish were made to Bangkok in rice barges filled with water. However, by the early decades of the 20th century the freshwater fisheries had decreased in abundance to such an extent that the rice-growing population who were the backbone of the country's wealth and prosperity could no longer obtain sufficient fish. Natural fish production was reduced by intensification of agriculture, urbanization, industrial development and road construction as well as by overfishing of the expanding rural population.

Although the construction of an irrigation network led to an increase in production of one staple, rice, it led to the reduction in the production of a second staple, fish. However, the construction of an irrigation system provided a stable source of water, a prerequisite for the subsequent development of aquaculture. While the wild fishery provided adequate fish for the relatively small population of the past, aquaculture was required to contribute fish to the rapidly expanding Thai population.

The historical development of aquaculture in Thailand is also reviewed because its understanding may provide insight into the potential for its development in other countries with similar contexts to those then occurring in Thailand. It is instructive to consider the development of aquaculture in relation to capture fisheries in a couple of other South East Asian countries. North Vietnam had a floodplain fishery from the Red River but overfishing from increasing population pressure had also reduced the availability of wild fish as a staple food. Traditional borrow pits to provide earth to raise the house above the flood level were stocked with Chinese and Indian major carps once these had been successfully bred artificially. While Cambodia had a major capture fishery on the Mekong and Tonle Sap Rivers and the Tonle Sap Lake, a system of holding and further growing catfish in floating cages had a history of at least 50 years at the time of the study.

## Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

## Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

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