Tilapia Culture

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Tilapia Culture

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875 Massachusetts Avenue
7th Floor
Cambridge, MA 02139
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E-mail: cabi-nao@cabi.org

A catalogue record for this book is available from the British Library, London, UK.

Library of Congress Cataloging-in-Publication Data

El-Sayed, Abdel-Fattah M., 1950-
Tilapia culture / Abdel-Fattah M. El-Sayed.
p. cm.
Includes bibliographical references (p.) and index.
ISBN-13: 978-0-85199-014-9 (alk. paper)
ISBN-10: 0-85199-014-2 (alk. paper)
1. Tilapia. I. Title

SH167.T54E42 2006
639.3′774--dc22

2005012005

Typeset in Baskerville by AMA DataSet Ltd, UK.
Printed and bound in the UK by Biddles Ltd, King's Lynn.

Contents

Foreword

It seems highly fitting that a truly comprehensive book on tilapia culture should be authored by a scientist at the Alexandria University in Egypt, a country where, arguably, the farming of tilapia has its roots. I do not use the word 'comprehensive' glibly, for Dr El-Sayed brings together information on everything from the history of tilapia culture to the latest production practices being used around the world, covering everything from soup to nuts, or, in this case, morphology to socio-economics. The author has extensively mined the literature as well as obtaining additional information and photographs through his contacts with a number of aquaculturists from virtually all the tilapia-producing regions around the globe. The result is an excellent volume that will serve several purposes. It can be used as an introduction to this fascinating group of fishes for the interested layman, but primarily will serve as a valuable resource for those who are engaged in tilapia research or production, as well as those who teach about aquaculture.

Tilapia aquaculture is somewhat unique in that it occurs in virtually every type of water system in utilization today. Tilapia are produced in everything from ponds fertilized with manure to closed recirculating systems. Production occurs in freshwater and in brackish to ocean salinities. The types of production systems in use today are described in considerable detail and span the gamut from subsistence culture to high-tech aquaponics. Subsistence culture has improved the nutritional plane of large numbers of people in developing nations, while more intensive culture systems produce fish that are now commonly seen on the menus of highly rated white-tablecloth restaurants.

Aquaculture, in general, has been on the receiving end of numerous criticisms over the past several years, and tilapia culture has not escaped the eyes of the critics. Dr El-Sayed devotes an entire chapter to environmental impacts and discusses how those impacts can be reduced. In these days when sustainability and responsible aquaculture are on the minds of so many, discussion of the issues he addresses is of vital importance.

Finally, what with the explosion of literature on tilapia that has appeared in recent years, the publication of a book that brings everything together is extremely timely. Examination of the table of contents should convince the prospective reader that *Tilapia Culture* does a very good job of covering all aspects of the subject and should quickly become a standard reference work on the topic.

Robert R. Stickney
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Preface

Tilapia are currently known as 'aquatic chicken' due to their high growth rates, adaptability to a wide range of environmental conditions and ability to grow and reproduce in captivity and feed on low trophic levels. It is thus no surprise that these fish have become an excellent candidate for aquaculture, especially in tropical and subtropical environments. Tilapia culture is believed to have originated more than 4000 years ago, but very little information is available on their culture during those ancient times. The first trials of tilapia culture were recorded in Kenya in the 1920s. Since then, tilapia culture has been established in many tropical and subtropical regions, and even in areas beyond their native ranges, where they have been introduced for various purposes. As a result, considerable attention has been paid to tilapia culture during the past three decades. Consequently, tilapia culture is currently practised in more than a 100 countries all around the globe. A plethora of information has also been generated and published in specialized periodicals on the biology and culture of tilapia during the second half of the last century. Key books have also been published on these fish during the last two decades, in addition to the excellent proceedings of the International Symposium on Tilapia in Aquaculture (ISTA), where six proceedings have already been produced. The World Aquaculture Society (WAS) has also contributed significantly to tilapia culture with an excellent series of Tilapia Culture in the Americas and also through the annual 'tilapia update' series, prepared by R. Stickney and published in *World Aquaculture* magazine, which summarizes published papers on tilapia culture.

However, most tilapia farmers, farm owners/managers, researchers and graduate students in developing countries, where over 90% of farmed tilapia are produced, have little or no access to the accumulating information on tilapia culture. The present book is an attempt to pull together, as far as possible, the scientific publications on tilapia culture in a single volume for the benefit of this target audience. It is hoped that this book will provide these target groups with access to published information, especially in areas where the access is lacking. This task was not easy, because the information published on tilapia was too much and too wide to be collected in a single book. Therefore, I must admit here that I was somewhat selective in my endeavour. Selection was made for those publications that were directly related to the practices and enhancement of tilapia culture. Considerable attention was paid to the most recent research published during the past decade. In fact, over 550 references, representing over 55% of the total references cited in the book, were published during 1995–2004. Moreover, about 30% of those references appeared during 2000–2005.

The book includes 12 chapters covering almost all aspects of tilapia culture. Each chapter ends with a number of 'closing remarks' summarizing the main points covered in the chapter. The book begins with a historical review of global and continental tilapia culture, current state, production and future potential, with emphasis on the major cultured species and major producers. In Chapter 2, the basic biology of tilapia, including taxonomy, body shapes, geographical distribution, introductions and transfers, gut morphology and feeding habits, has been briefly reviewed. Chapter 3 describes the environmental requirements of tilapia. Optimum and critical ranges/levels of temperature, salinity, pH, dissolved

oxygen, ammonia and nitrite, photoperiod and turbidity are reviewed. Chapter 4 deals with the culture of tilapia in semi-intensive systems. Full details are presented on pond fertilization, supplemental feeding, polyculture and integrated farming systems. Chapter 5 covers the intensive culture of tilapia in earthen ponds, tanks, raceways, cages, recirculating systems and aquaponics. Chapter 6 discusses tilapia nutrition, including protein, lipid, carbohydrate, vitamin and mineral requirements. Feed sources, digestibility, inclusion levels and feeding methods and frequencies are also described. Reproduction and seed production of tilapia are covered in Chapter 7, with special emphasis on broodstock management, production of monosex tilapia, seed production and larval rearing under different culture systems. Stress and diseases that infect tilapia, both in the wild and in aquaculture environments, including bacterial, parasitic, fungal, viral and non-infectious diseases, in addition to disorders caused by pollution, are discussed in Chapter 8. Chapter 9 deals with the harvesting, processing, marketing and economics of farmed tilapia. The role of tilapia culture in rural development in developing countries is discussed in Chapter 10. Chapter 11 looks at the recent technological innovations in tilapia culture. Modern technologies in reproduction and genetics, namely transgenesis, gynogenesis, androgenesis, cloning, production of genetically male tilapia (GMT) and genetically improved farmed tilapia (GIFT), are all reviewed. The global expansion of tilapia farming at an exceptionally high rate is very likely to pose environmental and socio-economic threats. Chapter 12 considers the environmental impacts of tilapia culture and the best management methods to reduce those impacts.

I hope the reader who is interested in aquaculture in general, or involved in tilapia culture in particular, will find this book useful. I hope also that the objectives for which the book was written have been achieved. Finally, I would very much welcome any feedback from my colleagues and fellow readers.

Professor Abdel-Fattah M. El-Sayed
Alexandria, Egypt, April 2005

Acknowledgements

I would like to thank the following, who have provided me with photographs, reprints, data, advice and unpublished information by personal communication. However, the responsibility for all of the content of the book resides with me as author.

Ahmed H. Al-Harbi: Fish Culture Project, Natural Resources and Environment Research Institute, King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia.
Donald S. Bailey: University of Virgin Islands, Agricultural Experimental Station, Kingshill, Virgin Islands, USA.
Ibrahim S.H. Bilal: Department of Aridland Agriculture, College of Food Systems, United Arab Emirates University, Al-Ain, United Arab Emirates.
Randall E. Brummett: World Fish Centre (ICLARM), Humid Forest Ecoregional Centre, Yaoundé, Cameroon.
James Diana: School of Natural Resources and Environment, University of Michigan, Ann Arbor, Michigan, USA.
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Gamal O. El-Naggar: World Fish Centre, Regional Research Centre for Africa and West Asia, Abbasa, Abu Hammad, Sharkia, Egypt.
Kevin Fitzsimmons: Department of Soil, Water and Environmental Science, Environmental Research Laboratory, University of Arizona, Tucson, Arizona, USA.
General Authority for Fisheries Resources Development (GAFRD): Madeenet Nasr, Cairo, Egypt.
Dao H. Giap: Aquaculture and Aquatic Resources Management, School of Environment, Resources and Development, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand.
Lake Harvest: Lake Kariba, Zimbabwe.
C. Kwei Lin: Aquaculture and Aquatic Resources Management, School of Environment, Resources and Development, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand.
David C. Little: Institute of Aquaculture, University of Stirling, UK.
Ismail Radwan: Kafr El-Shaikh Fish Farming Cooperative Society, Al-Hamool, Kafr El-Shaikh, Egypt.
James E. Rakocy: University of Virgin Islands, Agricultural Experimental Station, Kingshill, Virgin Islands, USA.
Mahmoud Rizk: World Fish Centre, Regional Research Centre for Africa and West Asia, Abbasa, Abu Hammad, Sharkia, Egypt.
Thesthong Samrit: Aquaculture and Aquatic Resources Management, School of Environment, Resources and Development, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand.

Magdy Soliman: Faculty of Veterinary Medicine, University of Alexandria, Alexandria, Egypt.
Robert R. Stickney: Texas Sea Grant College Program, Texas A&M University, College Station, Texas, USA.
Yang Yi: Aquaculture and Aquatic Resources Management, School of Environment, Resources and Development, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand.

I would also like to thank **Ram C. Bhujel:** Aquaculture and Aquatic Resources Management, School of Environment, Resources and Development, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand; **Gina Conroy:** Maracay, Estado Aragua, Venezuela; **Ahmed M. Darwish:** Harry K. Dupree Stuttgart National Aquaculture Research Center, United States Department of Agriculture, Agriculture Research Service, Stuttgart, Arkansas, USA; and **László Szathmári:** University of West Hungary, Faculty of Agriculture and Food Sciences, Hungary, for providing me with photographs, even though I could not include those photographs in the book. Thanks are also due to **Elham Wassef:** National Institute of Oceanography and Fisheries, Alexandria, Egypt, for reading the draft text and making some valuable editing corrections. The effort made by **Essam Abdel-Mawla:** National Institute of Oceanography and Fisheries, Alexandria, Egypt, in editing many of the photographs included in the book is highly appreciated.

Finally, I could not have finished this task without the patience and support of my wife Azza and my daughters Israa and Ayat.

1

Current State and Future Potential*

1.1. Historical Review

Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants, in freshwater, brackish-water and seawater environments. Capture fisheries, on the other hand, are the exploitation of aquatic organisms by the public as a common property resource, with or without appropriate licences. Aquaculture's contribution to total global fisheries landings was very low during 1950–1970, ranging from only 638,577 Mt (3.2%) in 1950 to 5.2% in 1970. Global aquaculture production continued to grow to 9.6% in 1980 and 16.3% in 1990. In the 1990s and early 2000s, this production grew at an outstanding rate to reach an annual rate of 32.1% in 2000, 34% in 2001 and 35.2% in 2002 (Fig. 1.1). The average annual compounded growth rate of aquaculture production was 9% per year during 1970–2000, compared with only 1.3% for capture fisheries (Tacon, 2003). Half of total global aquaculture production in 2002 was finfish (25,728,611 Mt).

Tilapia are freshwater fish belonging to the family Cichlidae. They are native to Africa, but were introduced into many tropical, subtropical and temperate regions of the world during the second half of the 20th century (Pillay, 1990). The introduction of tilapia into those areas was for: (i) farming as food fish; (ii) recreational fishing; (iii) aquatic weed control; and (iv) research purposes. Tilapia have many attributes that make them an ideal candidate for aquaculture, especially in developing countries. These include:

1. Fast growth.
2. Tolerance to a wide range of environmental conditions (such as temperature, salinity, low dissolved oxygen, etc.).
3. Resistance to stress and disease.
4. Ability to reproduce in captivity and short generation time.
5. Feeding on low trophic levels and acceptance of artificial feeds immediately after yolk-sac absorption.

Tilapia culture is believed to have originated some 4000 years ago, about 1000 years before carp culture was introduced into China (Balarin and Hatton, 1979). However, other than biblical references and illustrations from ancient Egyptian tombs, very little information is available on their culture during those early times. Current Food and Agriculture Organization (FAO) aquaculture production statistics indicate that about 100 countries practise tilapia culture, since these countries reported tilapia production from aquaculture in 2002 (FAO, 2004). The global development of tilapia culture has passed through three distinctive phases (Fig. 1.2): before 1970; from 1970 to 1990; and from 1990 to now.

BEFORE 1970. The contribution of tilapia production to total global aquaculture production before 1970 was very minor, representing less than 1% of total production. For example, tilapia production in 1969 was only 24,633 Mt, representing 0.76% of total aquaculture production (3,238,079 Mt). Very few countries practised

*Unless otherwise indicated, all data presented in this chapter are derived from FAO *Fishstat Plus* (2004).

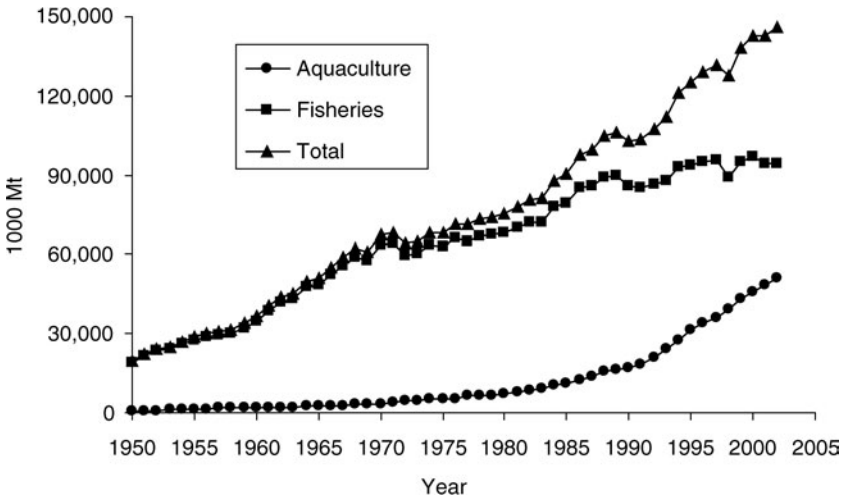

Fig. 1.1. Global fisheries and aquaculture production (1000 Mt) during 1950–2002.

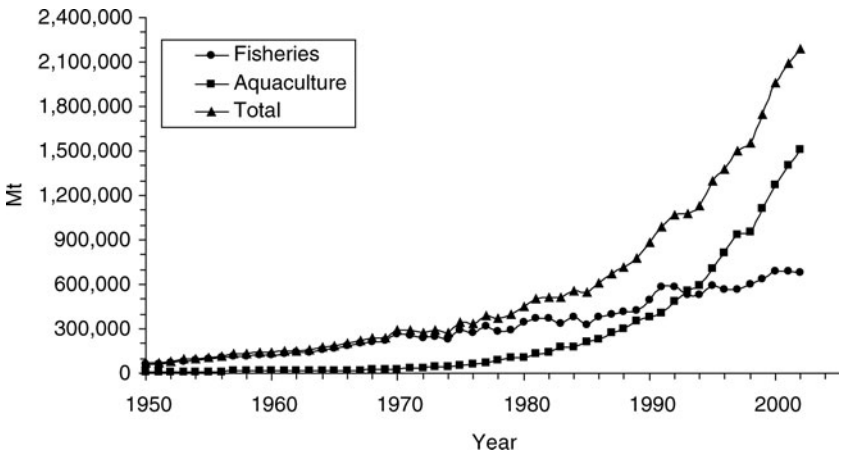

Fig. 1.2. Global production (Mt) of tilapia from aquaculture and capture fisheries during 1950–2002.

tilapia culture during that period. Only seven countries reported tilapia production in 1950, increasing to 12 countries in 1969. Taiwan, China, Egypt, Nigeria, Israel and Thailand were the major tilapia producers. The insignificant contribution of tilapia production during that period was mainly because aquaculture in general, and tilapia culture in particular, was not known as a food production system in most countries.

FROM 1970 TO 1990. Tilapia culture was gradually expanding worldwide during the period from 1970 to 1990. The number of countries practising tilapia culture increased significantly to reach 78 countries in 1990, compared to only 12 countries in 1969. However, tilapia production in many of those countries was very limited. According to FAO aquaculture production statistics, out of those 78 countries, 40 countries produced less than 100 Mt/year each. The production of farmed tilapia gradually increased to reach 383,654 Mt by 1990, representing 2.28% of total aquaculture production in 1990. During that period, the annual growth of tilapia production fluctuated between $< 6\%$ and $> 28\%$, with an average of 14.2%.

FROM 1990 TO NOW. Tilapia culture has witnessed a huge expansion during the past decade. As a result, the number of countries practising tilapia culture has reached over 100, as mentioned earlier. The production of farmed tilapia has also increased more than 390% to jump from 383,654 Mt in 1990, representing 2.28% of total aquaculture production, to 1,505,804 Mt in 2002, representing 2.93% of total production. The average annual growth of tilapia production during that period approached 12.2%.

1.2. Global Tilapia Production

1.2.1. Capture fisheries

Global landing of tilapia from capture fisheries increased progressively during the 1950s to the 1980s. During the 1990s and early 2000s, the landings were almost stable, fluctuating around 585,000–680,000 Mt/year (Fig. 1.2). Africa is by far the most important tilapia producer from capture fisheries, where it contributed about 70% of global landing in 2002, followed by Asia (18%), North America (9%) and South America (3%) (Figs 1.3 and 1.4). Therefore, it is no surprise that, among the world's top ten tilapia producers from capture fisheries, six are African countries. In addition, Egypt and Uganda, the first and second largest world tilapia producers, landed over 138,000 and 98,000 Mt in 2002, representing 20% and 14% of global landings (Fig. 1.5). The top ten producers included three Asian countries (Thailand, the Philippines and Sri Lanka) and one North American country (Mexico).

Among all tilapia species, Nile tilapia (*Oreochromis niloticus*) is the most important identified species in capture fisheries. In 2002, the production of that species approached 253,871 Mt, representing 37% of total production. Other identified species include Mozambique tilapia (*Oreochromis mossambicus*), blue tilapia (*Oreochromis aureus*), jaguar guapote (*Parachromis managuensis*) and mango (Galilee) tilapia (*Sarotherodon galilaeus*). However, most tilapia catches are not identified. For example, 59% of the catch in 2002 was reported under 'unidentified' cichlids, 'mouthbrooding' cichlids and 'unidentified' tilapias.

1.2.2. Aquaculture

As pointed out earlier, the production of farmed tilapia increased from 28,260 Mt in 1970 to 1,505,804 Mt in 2002. However, these values may

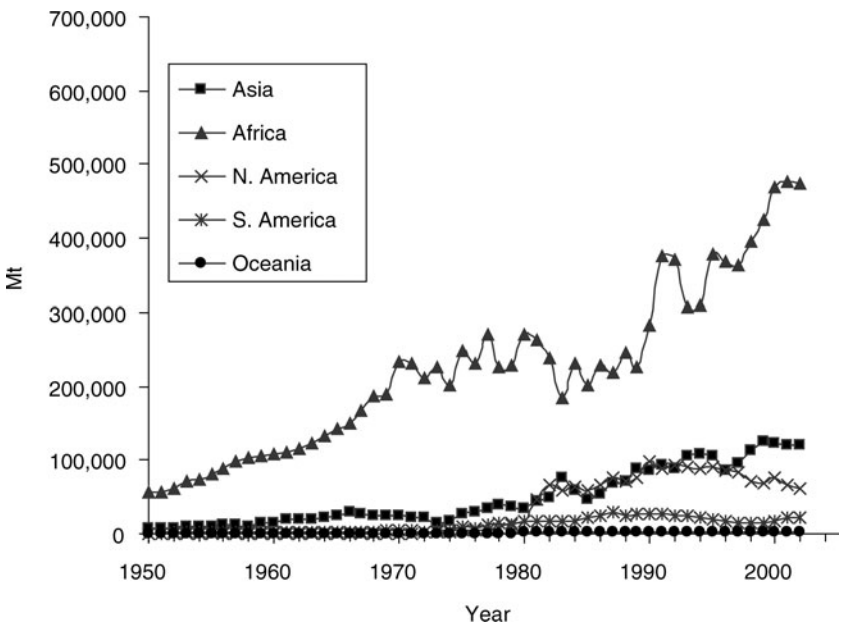

Fig. 1.3. Tilapia capture (Mt) by region during 1950–2002.

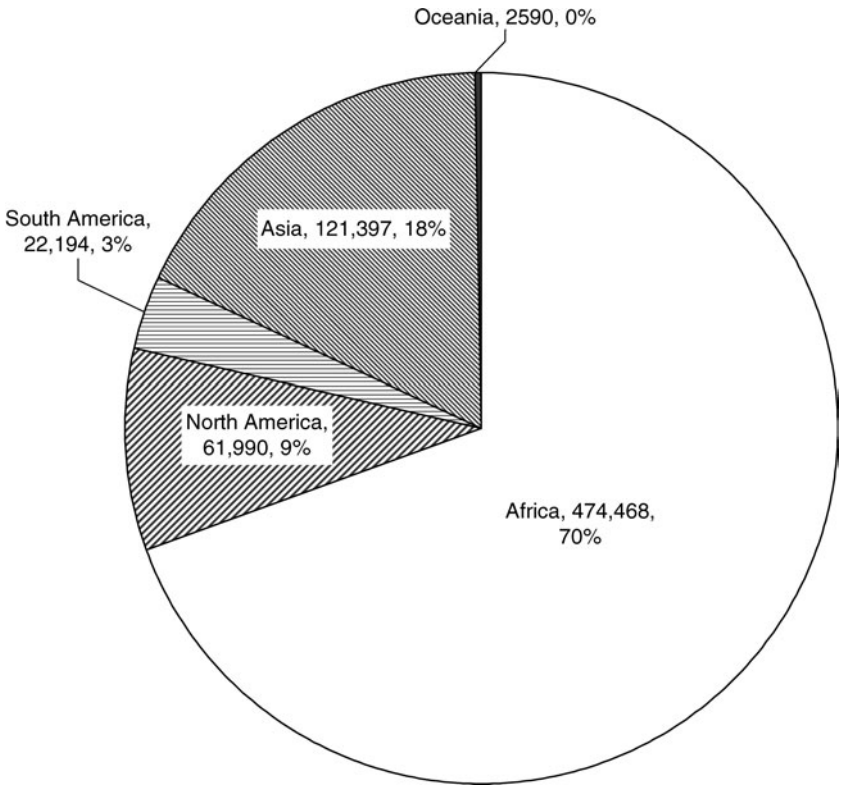

Fig. 1.4. Tilapia production from capture fisheries (Mt, %) by region in 2002.

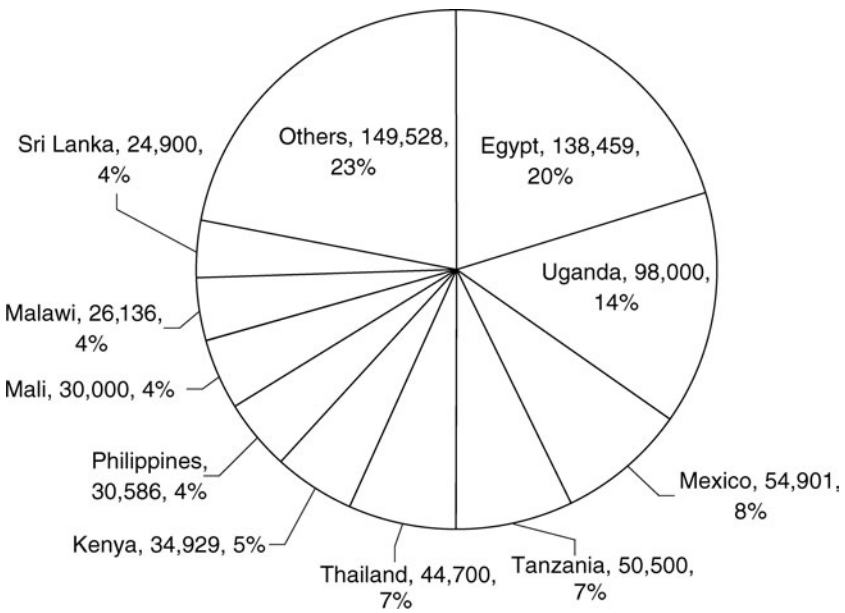

Fig. 1.5. Top ten producers of tilapia from capture fisheries (Mt, %) in 2002.

be much less than the actual amounts produced. The under-reporting of tilapia production can be attributed to the following:

1. The reproductive characteristics of tilapia. The simple, frequent and asynchronous reproduction of tilapia makes the estimate of total production of these fish almost impossible.
2. The poor management of evaluating and utilizing tilapia. The large amounts consumed by tilapia farmers' families and the amounts that are locally marketed informally may make production statistics incorrect and unreliable. For example, it has been reported that about 20% of aquaculture production in rural China is consumed by farmers' families. The global production of farmed tilapia may, therefore, be higher than the officially reported quantities.

The global production trends of farmed tilapia can be divided into two distinctive phases:

- During the 1950s to 1970s tilapia culture grew at a relatively slow rate, where farmed tilapia production was much lower than that of capture fisheries (Fig. 1.2).
- In the 1980s to 1990s, tilapia culture expanded at a much wider and more rapid rate, where the gap between tilapia landings from capture fisheries and aquaculture continued to narrow, until the production of farmed tilapia exceeded the landings from capture fisheries in 1993 (Fig. 1.2). Since then, tilapia culture has been growing at a very high rate, while tilapia landings from capture fisheries are about stable.

Since tilapia can tolerate a wide range of water salinity, they are currently farmed in freshwater, brackish-water and even seawater environments, but freshwater tilapia aquaculture dominates. The production of tilapia from freshwater systems reached 1,312,776 Mt in 2002, representing 87.2% of total farmed tilapia production.

The value of farmed tilapia has also witnessed a great increase during the past two decades. The value increased from about US$154 million in 1984 to US$1800.7 million in 2002. As expected, the value of Nile tilapia represented between 60 and > 70% of the total market value of farmed tilapia during the past decade (Fig. 1.6).

1.2.3. Major producers

Despite the fact that more than 100 countries practised tilapia farming in 2002, only five countries (China, Egypt, the Philippines, Indonesia and Thailand) dominated world production.

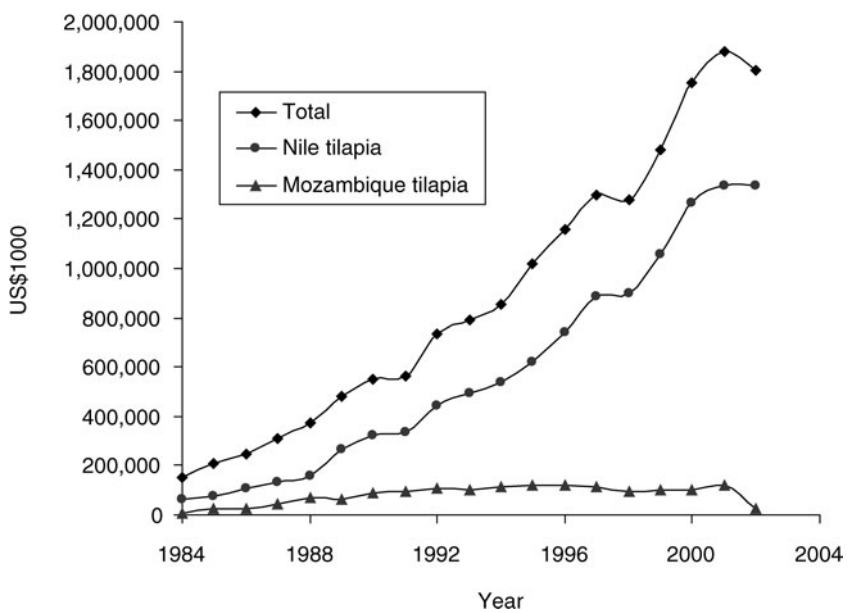

Fig. 1.6. The value of important farmed tilapia (US$1000) during 1984–2002.

Those countries yielded 87% of global tilapia production in 2002. China alone produced 706,585 Mt in 2002, representing 50% of total production, followed by Egypt (12%), the Philippines (9%), Indonesia (8%) and Thailand (7%) (Fig. 1.7). However, the value of farmed tilapia in China in 2002 was only US$706.6 million, representing only 2.15% of the total value of aquaculture production in China (US$32,827 million). This is mainly because tilapia is produced in China as a low-value food fish and used typically for local consumption in rural areas. The values of farmed tilapia in selected major producer nations are given in Fig. 1.8.

1.2.4. Major cultured species

Among cultured fishes of the world, tilapia rank third in terms of production, only after carps and salmonids. According to FAO statistics, 16 tilapia/cichlid groups, in addition to unidentified cichlids, have been used for aquaculture production. However, commercial tilapia culture is currently restricted to about ten species (Table 1.1). Nile tilapia is, by far, the most important farmed tilapia species in the world. It represented more than 80% of total tilapia production during 1970–2002. Nile tilapia also ranked sixth in terms of global farmed fish production in 2002, after silver carp, grass carp, common carp, crucian carp and big-head carp (Fig. 1.9). Mozambique tilapia comes second, with a production of 54,146 Mt in 2002, representing 3.6% of the production of total farmed tilapia. Three-spotted tilapia (*Oreochromis andersonii*), blue tilapia, redbreast tilapia (*Tilapia rendalli*) and longfin tilapia (*Oreochromis macrochir*) are also gaining some popularity in certain parts of the world. The contribution of other tilapia species to global tilapia production is insignificant, while unidentified tilapias represent a significant proportion of the production. In 2002, that category amounted to 227,741 Mt, representing 18.7% of total tilapia production.

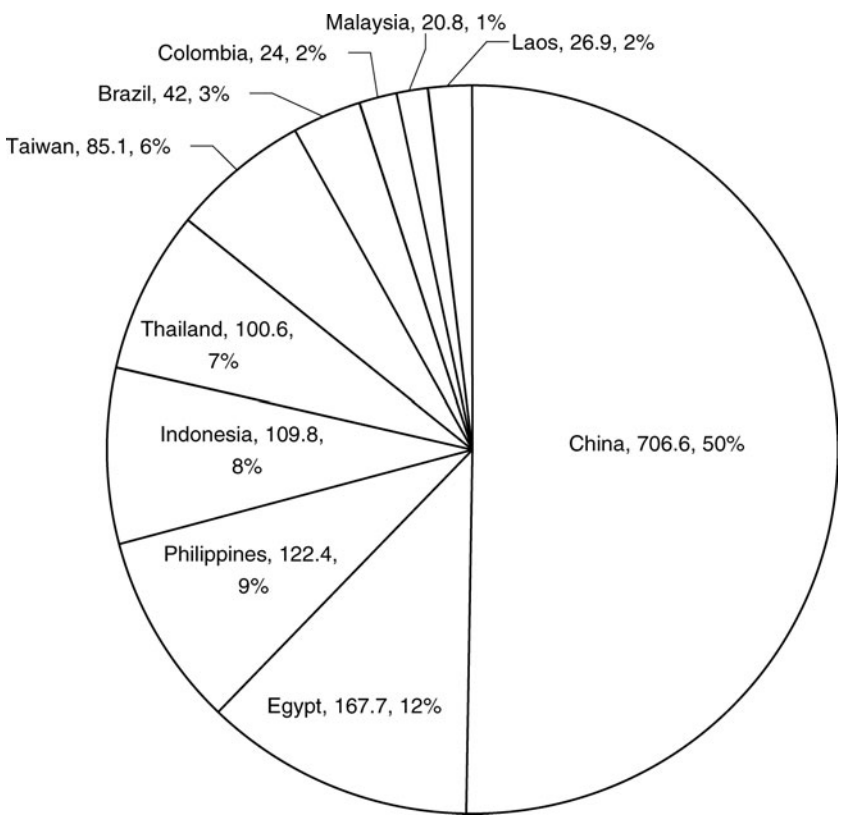

Fig. 1.7. Top ten producers of farmed tilapia (1000 Mt, %) in 2002.

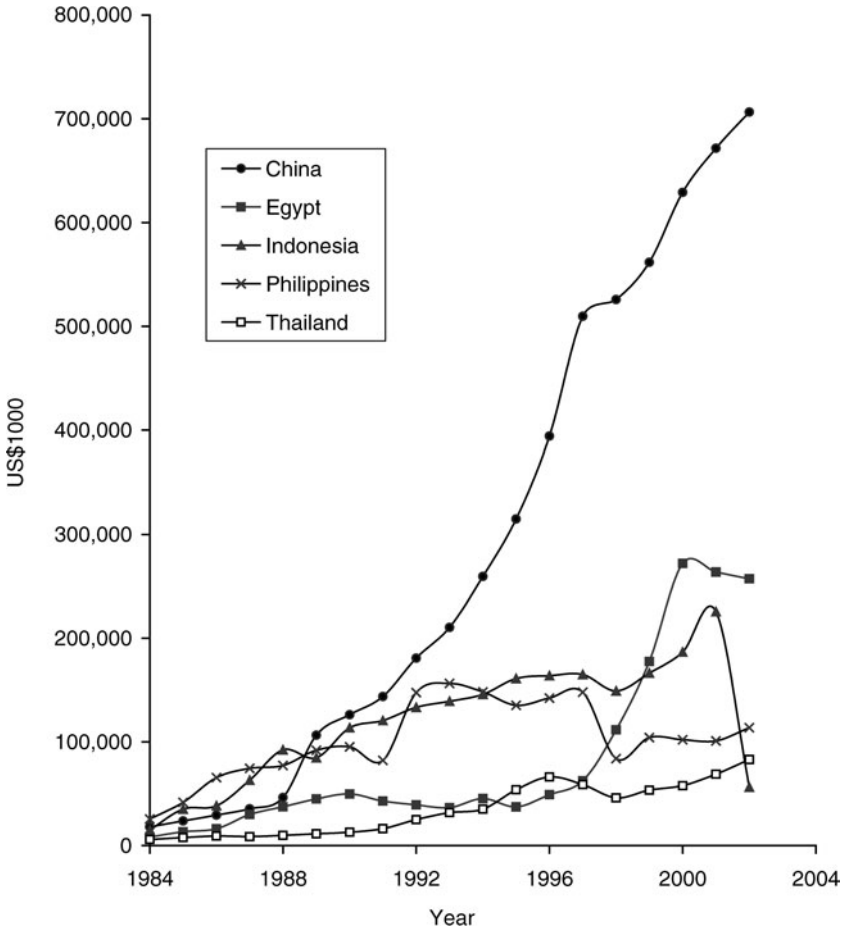

Fig. 1.8. The value of farmed tilapia (US$1000) for selected major producers during 1984–2002.

1.3. Tilapia Production in Asia

Asia is the largest tilapia producer in the world, accounting for 79% of the production of global farmed tilapia in 2002. Tilapia is farmed mainly in freshwater environment in Asia. In 2002, about 95.5% of total farmed tilapia production came from freshwater environments. Twenty-one Asian countries, mainly in South Asia and the Far East, reported tilapia production in 2002. Tilapia culture in Asia has witnessed three developmental phases:

1. 1950–1980: During this early period, tilapia culture was practised on a very small scale and grew at slow rates. The production gradually increased from only 4,810 Mt in 1950 to reach 88,011 Mt in 1980.

2. 1981–1991: The production of tilapia witnessed a sharp increase from 109,301 Mt in 1981 to reach 353,686 Mt in 1991, with an over 300% increase.

3. 1992–now: This period was characterized by an outstanding expansion and development of tilapia culture in Asia. As a result, tilapia production jumped from 421,649 Mt in 1992 to 1,191,611 Mt in 2002 (Table 1.2).

The growth rate in the production of farmed tilapia in Asia during 1950–2002 was among the fastest in world, with an overall average of 20.5% annually. It is noteworthy that the recorded production of tilapia in Asia is lower than the real production, because the production of some other Asian countries, such as Vietnam, Bangladesh,

Table 1.1. Major cultured tilapia species and species production (Mt) in the world during 1950–2002 (from FAO, 2004).

Species	1950	1960	1970	1980	1990	1992	1994	1996	1998	2000	2001	2002
Nile tilapia	1,590	7,736	12,058	41,357	233,601	320,092	425,500	623,652	772,706	1,047,885	1,126,927	1,217,055
Mozambique tilapia	. . .	1	1,186	12,640	42,912	49,327	51,872	56,311	45,822	49,418	59,264	54,146
Three-spotted tilapia	. . .	. . .	. . .	27	1,000	1,800	2,200	2,661	2,689	2,750	2,700	2,700
Blue tilapia	. . .	. . .	. . .	1,012	3,748	3,455	2,368	2,425	844	1,277	1,135	1,350
Redbreast tilapia	. . .	. . .	. . .	. . .	105	524	803	1,043	839	853	877	860
Longfin tilapia	. . .	. . .	. . .	. . .	60	230	350	404	207	210	210	210
Sabaki tilapia	. . .	. . .	. . .	. . .	1	< 0.5	20	20	103	83	63	165
Redbelly tilapia	. . .	. . .	. . .	. . .	8	10	18	20	100	201	201	161
Jaguar guapote	. . .	. . .	. . .	. . .	6	9	31	152	37	40	42	42
Unidentified tilapias	4,128	9,594	15,016	53,500	102,204	104,703	112,203	126,018	130,270	171,617	212,376	227,741
Total	5,718	17,331	28,260	108,536	383,654	488,527	595,535	812,850	953,659	1,274,389	1,404,904	1,505,804

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

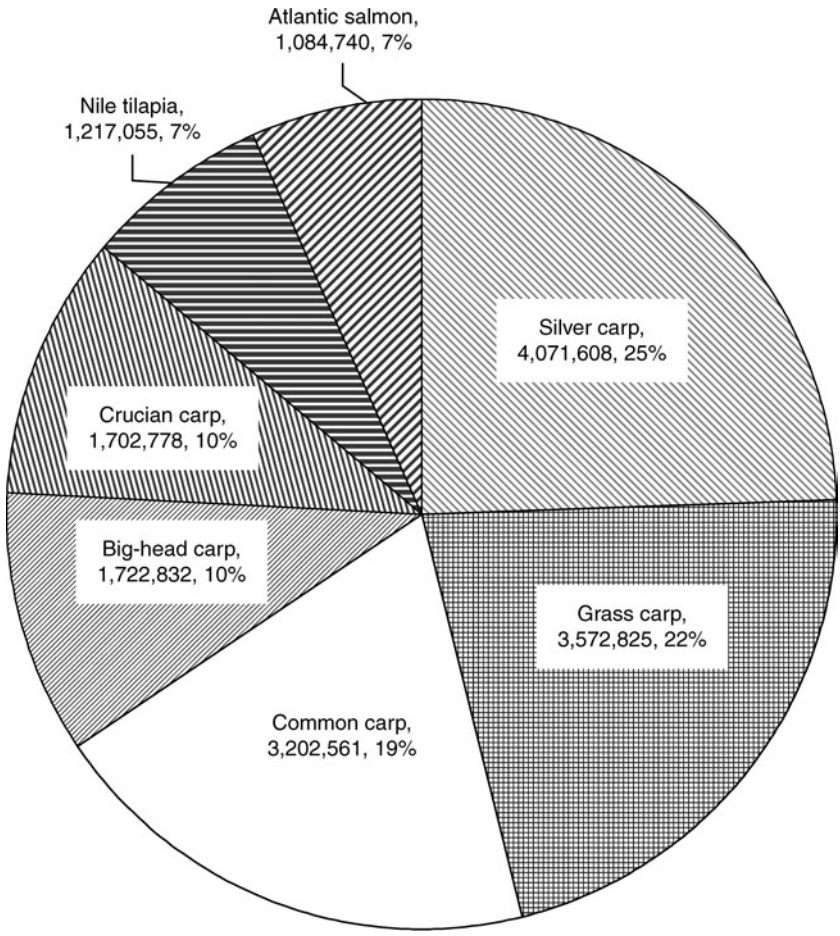

Fig. 1.9. Global production of major farmed fish species (Mt, %) in 2002.

India and Pakistan, was not included in production statistics. In addition, a considerable proportion of produced tilapia is consumed by fish farmers and their families, leading to underestimation of tilapia production in Asia.

1.3.1. Major producers

Despite the fact that Asia is the most important tilapia producer in the world, only 21 Asian countries practise tilapia culture (Table 1.3), with China being the largest producer. In 2002, China contributed about 60% of total Asian tilapia production. When the contribution of China is discounted, the contribution of Asia to global tilapia production declines from 79% to only 32.2% in 2002. All the production of tilapia in China comes from freshwater culture, mainly from semi-intensive culture systems. The production trend in China can be divided into two phases (Fig. 1.10):

- **1950–1988**: During this period, the production of tilapia increased slowly from 660 Mt in 1950 to 39,000 Mt in 1988. Chinese production was exceeded by other Asian countries such as Taiwan, Indonesia and the Philippines.
- **1989–now**: From 1989 onward, the production of farmed tilapia in China increased at an exceptionally high rate, with an average annual growth rate of over 20%. As a result, China currently dominates tilapia production in Asia.

Table 1.2. Continental production (Mt) of farmed tilapia during 1950–2002 (from FAO, 2004).

Year	1950	1960	1970	1980	1990	1992	1994	1996	1998	2000	2001	2002
Africa	908	3,399	4,723	12,456	33,094	35,715	38,164	40,077	67,421	177,202	174,985	193,240
Asia	4,810	13,932	23,337	88,011	333,016	421,649	521,914	715,602	814,407	997,046	1,124,602	1,191,611
N. America	0	0	200	7,963	14,891	18,020	22,308	24,730	25,522	33,418	37,753	45,089
S. America	0	0	0	103	2,307	12,732	12,728	31,849	45,716	66,087	66,966	75,328
Oceania	0	0	0	0	105	211	221	272	393	456	398	346

Table 1.3. Production (Mt) of farmed tilapia by country in Asia during 1950–2002 (from FAO, 2004).

Country	1950	1960	1970	1980	1990	1992	1994	1996	1998	2000	2001	2002
Brunei	. . .	. . .	. . .	. . .	1	3	3	10	20	14	. . .	52
Cambodia	. . .	. . .	. . .	. . .	170	230	200	230	330	370	359	376
China	660	5,003	5,828	9,000	106,071	157,233	235,940	394,303	525,926	629,182	671,666	706,585
Hong Kong	. . .	. . .	450	2,120	1,195	980	161	442	1,058	613	641	411
Indonesia	100	100	1,191	14,901	53,768	59,945	64,431	75,473	65,894	85,179	105,106	109,768
Israel	20	95	1,400	2,512	4,795	3,368	5,631	6,399	6,696	7,059	8,217	7,819
Japan	. . .	. . .	. . .	2,392	5,825	4,697	2,125	1,479	885	434	434	400
Jordan	. . .	. . .	. . .	. . .	40	16	67	135	263	563	540	515
Republic of Korea	. . .	. . .	. . .	. . .	650	437	448	998	796	787	609	588
Kuwait	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	70	30	16	16
Laos	. . .	. . .	20	176	1,250	1,345	1,400	2,000	9,549	18,928	22,499	26,872
Lebanon	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	25
Malaysia	. . .	< 0.5	12	366	1,145	4,632	8,507	11,177	12,625	18,471	16,253	20,757
Myanmar	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1,000
The Philippines	. . .	70	1,417	13,214	76,142	91,173	90,341	79,415	72,023	92,579	106,746	122,390
Saudi Arabia	. . .	. . .	. . .	. . .	1,926	2,191	2,220	3,614	3,315	3,968	3,981	2,019
Singapore	. . .	. . .	. . .	. . .	. . .	. . .	. . .	45	150	37	52	142
Sri Lanka	. . .	. . .	. . .	1,097	4,500	3,500	2,500	2,500	3,500	4,390	3,130	3,670
Syria	. . .	. . .	. . .	102	596	1,126	991	1,588	1,372	2,626	3,195	2,571
Taiwan	3,900	8,200	11,287	33,712	52,047	47,226	47,435	44,756	36,126	49,235	82,781	85,059
Thailand	130	464	1,732	8,419	22,895	43,547	59,514	91,038	73,809	82,581	98,377	100,576
Total	4,810	13,932	23,337	88,011	333,016	421,649	521,914	715,602	814,407	997,046	1,124,602	1,191,611

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

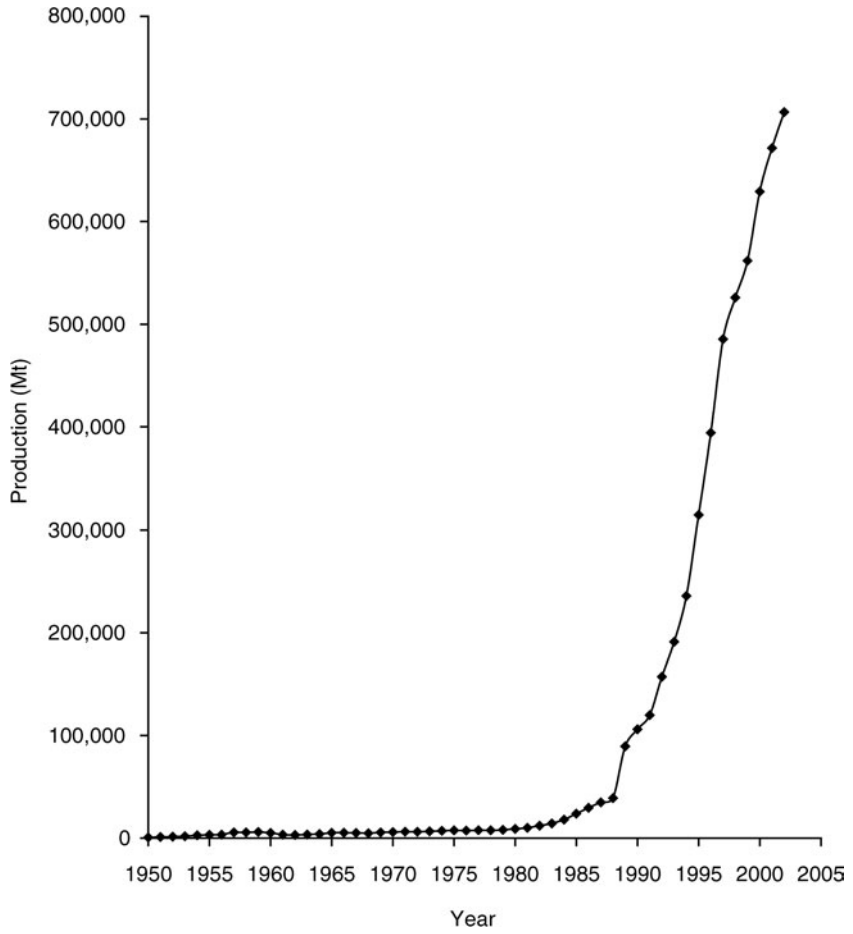

Fig. 1.10. Production (Mt) of farmed tilapia in China during 1950–2002.

Tilapia culture is also growing at a very high rate in some other Asian countries, including the Philippines, Indonesia, Thailand and Taiwan. These four countries, together with China, yielded 94% of Asian tilapia production in 2002. Tilapia farming in other Asian countries, such as Saudi Arabia, Israel, Jordan, Syria, India, Bangladesh and Vietnam, has started to gain considerable attention in recent years.

1.3.2. Major cultured species

It has been reported that Mozambique tilapia was the first tilapia species to be introduced to Asia, into the Indonesian island of Java, in 1939 (Guerrero, 2001). Subsequently, the species was introduced into other Asian countries, during the 1940s to the 1960s, and was considered a prime candidate for aquaculture in Asia. Thus, the average annual production of this species increased at a rate of 26.7% during 1970–1980, compared with 13.1% for Nile tilapia. However, Mozambique tilapia may have suffered from inbreeding problems due to the small number of the original population of founder stocks. The acceptability of Mozambique tilapia to tilapia farmers was also limited because of the problem of overcrowding and poor growth. The dark colour of this fish also reduces its marketability and consumers' acceptance. Subsequently, Nile tilapia attracted attention in the 1960s and early 1970s as an ideal

aquaculture substitute for Mozambique tilapia. Currently, Mozambique tilapia is a major culture species only in Indonesia. The Indonesian supply of that species in 2002 was 49,331 Mt, representing 93% of total production of farmed Mozambique tilapia in Asia (and 91.1% of global production). The dominance of the species in Indonesia continued until the late 1990s, when Nile tilapia started to take over. For example, Mozambique tilapia accounted for 57.8% of tilapia production in 1999. Its contribution declined in the following years to reach about 52% of total tilapia production in 2001. In 2002, the production of Nile tilapia in Indonesia exceeded that of Mozambique tilapia and reached 60,437 Mt, representing 55% of total tilapia production. This means that commercial culture of Mozambique tilapia in Asia will probably stop within the next few years.

Nile tilapia currently dominates tilapia culture in Asia, with a production of 1,001,302 Mt in 2002, representing 84% of total tilapia production in the continent (Table 1.4). In terms of countries, 11 Asian countries reported Nile tilapia production in 2002, compared to six countries in 1980. On the other hand, only five countries reported Mozambique tilapia culture in Asia in 2002, with a production of 53,000 Mt, representing 4.4% of total tilapia production. The contribution of other tilapias, including blue tilapia, Galilean tilapia (mango tilapia) (*S. galilaeus*), Wami tilapia (*Oreochromis hornorum*), Zill's tilapia (redbelly tilapia) (*Tilapia zillii*) and redbreast tilapia (Congo tilapia) (*T. rendalli*), is not significant. These species have been introduced to Asia mainly for research and experimental purposes.

In addition to the species mentioned, introgressive hybridization between Nile tilapia and Mozambique tilapia has been reported in several Asian countries. All-male hybrids of Nile tilapia and blue tilapia are also widely cultured in China and Taiwan. Red tilapia, which is generally a hybrid of Mozambique tilapia and Nile tilapia and/or blue tilapia, is also commonly cultured in many Asian countries, including China, Taiwan, Thailand, Indonesia and the Philippines. The hybrids are characterized by high growth rates, preferred colour and high consumer acceptance. Tilapia hybrids and other 'unidentified' tilapia groups accounted for 11.5% of the total production of farmed tilapia in Asia in 2002.

1.4. Tilapia Production in Africa

Despite the fact that tilapia are African fish, tilapia culture in Africa is relatively new, with a low contribution to world tilapia production, being 12.8% in 2002. Farmed tilapia production in Africa, however, has sharply increased during the past few years (Table 1.2). Generally, the trend in tilapia production in Africa can be divided into three phases:

1. **1950–1984**: During this 35-year period, the production of tilapia slowly grew from 908 Mt in 1950 to 15,747 Mt in 1984.
2. **1985–1997**: Production jumped from 15,747 Mt in 1984 to 28,724 Mt in 1985, and continued to grow at a relatively slow rate to reach 43,946 Mt in 1997.
3. **1998–now**: Tilapia production increased from 43,946 Mt in 1997 to 67,421 Mt in 1998, with an increase in growth rate of 53.4%. Another huge increase in tilapia production occurred during 1999–2002, with 119,416, 177,202, 174,985 and 193,240 Mt produced in 1999, 2000, 2001 and 2002, respectively. The average annual growth of tilapia production during the period 1998–2002 was 47.3%, excluding the year 2001, which showed a slight decrease compared to 2000, or 37.6% if the production of the year 2001 is included.

1.4.1. Major producers

In 2001, 32 African countries reported production of farmed tilapia; however, in 2002, some of these countries reported no production. Unlike Asia, most of farmed tilapia production in Africa comes from brackish-water environments. In 2002, tilapia production from brackish water amounted to 138,923 Mt, representing 71.9% of total African tilapia production. Farmed tilapia output in Africa is dominated by a single country: Egypt (Table 1.5). The production of farmed tilapia in Egypt accounted for 86.8% (167,735 Mt) of total production of tilapia in Africa in 2002. If the contribution of Egypt is discounted, Africa's contribution to global tilapia output would decline from 12.8% to only 1.7%. Tilapia culture in Egypt is practised mainly in brackish-water environments in the northern lakes areas along the Mediterranean coast. In 2002, the production of tilapia from brackish-water systems in Egypt reached 138,456 Mt, representing

Table 1.4. Major cultured tilapia species and species production (Mt) reported in Asia during 1950–2002 (from FAO, 2004).

Species	1950	1960	1970	1980	1990	1992	1994	1996	1998	2000	2001	2002
Blue tilapia	. . .	. . .	. . .	. . .	< 0.5	< 0.5	< 0.5	< 0.5	. . .	. . .	. . .	. . .
Mozambique tilapia	. . .	1	1,186	12,637	42,664	48,806	51,489	55,733	44,879	48,532	58,095	53,000
Nile tilapia	890	5,636	9,464	31,781	200,814	296,748	391,204	584,640	700,964	853,630	937,524	1,001,302
Sabaki tilapia	. . .	. . .	. . .	. . .	. . .	. . .	20	20	103	83	63	165
Unidentified tilapias	3,920	8,295	12,687	43,593	89,538	76,095	79,201	75,209	68,461	94,801	128,920	137,144
Total	4,810	13,932	23,337	88,011	333,016	421,649	521,914	715,602	814,407	997,046	1,124,602	1,191,611

… denotes that data are not available, unobtainable or not separately available but included in another category.

Table 1.5. Production (Mt) of farmed tilapia by country in Africa during 1950–2002 (from FAO, 2004).

Country	1950	1960	1970	1980	1990	1992	1994	1996	1998	2000	2001	2002
Burkina Faso	. . .	. . .	. . .	. . .	3	2	< 0.5	30	40	5	5	5
Burundi	. . .	. . .	. . .	. . .	30	50	55	50	55	100	100	100
Cameroon	. . .	. . .	. . .	25	80	50	45	50	60	40	100	210
Republic of Central Africa	. . .	. . .	. . .	76	100	337	250	140	80	120	125	. . .
Democratic Republic of Congo	. . .	. . .	. . .	. . .	700	730	650	600	1,833	2,073	2,738	2,959
Republic of Congo	. . .	. . .	. . .	. . .	240	191	121	106	140	200	200	. . .
Côte d'Ivoire	. . .	. . .	. . .	. . .	32	44	109	933	495	967	870	725
Egypt	700	2,100	2,500	9,000	24,916	21,505	25,214	27,854	52,755	157,425	152,515	167,735
Ethiopia	. . .	. . .	. . .	. . .	30	20	30	35	10	< 0.5	< 0.5	. . .
Gabon	. . .	. . .	. . .	. . .	2	5	23	59	150	533	102	83
Ghana	. . .	. . .	94	251	280	300	330	350	1,350	3,712	4,400	4,400
Guinea	. . .	. . .	. . .	. . .	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	. . .
Kenya	. . .	. . .	. . .	70	405	467	502	500	87	222	412	421
Liberia	. . .	. . .	. . .	. . .	< 0.5	< 0.5	< 0.5	< 0.5	. . .	19	12	12
Madagascar	. . .	. . .	. . .	. . .	40	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Malawi	. . .	. . .	. . .	30	50	30	28	20	22	500	532	620
Mali	. . .	. . .	. . .	. . .	10	20	58	35	35	19	350	708
Mauritius	. . .	. . .	. . .	. . .	8	12	32	71	40	44	30	20
Mayotte	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1	2	3	3	. . .
Mozambique	. . .	. . .	. . .	. . .	15	12	116	4	< 0.5	< 0.5	< 0.5	77
Niger	. . .	. . .	. . .	. . .	36	8	17	11	12	15	21	40

Continued

Table 1.5. *Continued.*

Country	1950	1960	1970	1980	1990	1992	1994	1996	1998	2000	2001	2002
Nigeria	208	1,299	2,129	2,952	3,795	7,525	5,500	3,259	4,471	2,705	2,626	4,496
Rwanda	. . .	. . .	. . .	23	154	45	50	90	120	252	381	542
Réunion	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	75	88	68	60
Senegal	. . .	. . .	. . .	. . .	5	5	31	53	3	9	10	22
Sierra Leone	. . .	. . .	. . .	2	20	20	25	30	30	30	30	. . .
South Africa	. . .	. . .	. . .	. . .	30	55	60	15	70	110	200	200
Sudan	. . .	. . .	. . .	. . .	234	200	200	1,000	1,000	1,000	1,000	1,000
Swaziland	. . .	. . .	. . .	. . .	. . .	. . .	. . .	47	49	38	40	. . .
Tanzania	. . .	. . .	. . .	. . .	375	350	150	200	200	210	300	630
Togo	. . .	. . .	. . .	. . .	22	150	150	21	25	102	120	25
Uganda	. . .	. . .	. . .	. . .	32	42	108	40	200	600	1,550	1,957
Zambia	. . .	. . .	. . .	27	1,400	3,500	4,280	4,403	3,942	4,020	3,980	3,980
Zimbabwe	. . .	. . .	. . .	. . .	50	40	30	70	70	2,041	2,165	2,213
Total	908	3,399	4,723	12,456	33,094	35,715	38,164	40,077	67,421	177,202	174,985	193,240

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

82.5% of total tilapia production in the continent. Tilapia culture is also practised in some other countries, including Nigeria, Ghana, Zambia, the Democratic Republic of Congo and Zimbabwe (Table 1.5). The contribution by the rest of African countries is insignificant.

1.4.2. Major cultured species

Seven tilapia species or species groups are used for aquaculture in Africa (Table 1.6). Nile tilapia is by far the most widely cultured species. Nile tilapia was reportedly cultured in 23 African countries out of 32 countries that practised tilapia culture in Africa in 2001. It also accounted for 92.5% of total tilapia production in Africa in 2002. The culture of other tilapia species, namely three-spotted tilapia (Zambia), redbreast tilapia (Malawi), Mozambique tilapia (Malawi), redbelly tilapia (Liberia) and mango tilapia (Liberia), was reported in 2002, though production was very limited. In addition to the species, a considerable proportion of tilapia production is reported under 'unidentified' tilapia and tilapia hybrids. This category comes second after Nile tilapia in terms of production. The production of unidentified tilapias in 2002 amounted to 10,405 Mt, representing 5.4% of total tilapia production.

1.5. Tilapia Production in South America

Tilapia culture is relatively new in South America. It started on a small scale, mainly for subsistence farming, in the early 1970s. The first FAO record of tilapia production in the region was reported in Colombia in 1971, with only 1 Mt of Nile tilapia. The progress of tilapia culture in South America can be divided into three phases:

1. **1971–1982**: During this period, tilapia culture was practised in only two countries, Colombia and Peru, with very little production, ranging from 1 Mt in 1971 to 182 Mt in 1982.
2. **1983–1991**: During this period, the number of countries practising tilapia culture increased gradually to six countries in 1991. Nevertheless, tilapia production was still very low and was dominated by one country: Colombia (87.5%).
3. **1992–now**: The production of cultured tilapia in South America increased from 3475 Mt in 1991 to 12,732 Mt in 1992, with a 266% increase. Another jump occurred in 1995, where the production approached 30,032 Mt, with a 136% increase. The production continued to increase at a high rate, to reach 75,328 Mt in 2002, which represented 5% of global production of farmed tilapia. Consequently, the number of countries practising tilapia culture increased to ten (Table 1.7). The average annual growth rate of tilapia production during 1996–2002 was 15.7%. More than 99% of tilapia production comes from freshwater environments.

1.5.1. Major producers

As mentioned earlier, Colombia was the only country practising tilapia culture in South America in the 1970s, while Peru reported tilapia production starting 1979. In 1980, total production of tilapia was only 103 Mt but increased to 2307 Mt in 1990. In 2002, ten countries reported tilapia production. Interestingly, the first record of tilapia production in Brazil appeared in 1995. During 1995–2002, tilapia production in that country increased from 12,014 Mt to 42,003 Mt. This means that Brazil has one of the fastest growth rates of tilapia production in South America, with an average annual growth rate of 20%. As a result, Brazil contributed 55.8% (42,003 Mt) to tilapia production in the continent in 2002.

Departing from the FAO tilapia production statistics, Kubitza (2004) reported that farm-raised tilapia in Brazil reached 57,000 Mt in 2002. Moreover, he stated that, at present, production is estimated at about 70,000 Mt. Colombia and Ecuador are the second and third major tilapia producers, with a production amounting to 24,000 Mt (31.9%) and 8181 Mt (10.9%) in 2002. Brazil, Colombia and Ecuador accounted for 98.5% of total tilapia production in 2002. This means that the current production of tilapia in the other South American countries is not significant (Table 1.7).

1.5.2. Major cultured species

One of the major problems associated with tilapia culture in South America is that most cultured tilapias are not identified. Many tilapia strains and hybrids are currently used for aquaculture, with minimal control and regulation. As a result, most

Table 1.6. Major cultured tilapia species and species production (Mt) in Africa during 1950–2002 (from FAO, 2004).

Species	1950	1960	1970	1980	1990	1992	1994	1996	1998	2000	2001	2002
Blue tilapia	. . .	. . .	. . .	. . .	12	24	. . .	. . .	. . .	. . .	. . .	. . .
Longfin tilapia	. . .	. . .	. . .	. . .	60	230	350	404	207	210	210	210
Mozambique tilapia	. . .	. . .	. . .	. . .	30	68	75	57	96	55	145	130
Nile tilapia	700	2,100	2,594	9,447	26,996	23,827	27,641	31,667	56,981	165,665	162,711	178,762
Redbelly tilapia	. . .	. . .	. . .	. . .	8	10	18	20	100	201	201	161
Redbreast tilapia	. . .	. . .	. . .	. . .	100	503	803	1,028	839	853	877	860
Three-spotted tilapia	. . .	. . .	. . .	27	1,000	1,800	2,200	2,661	2,689	2,750	2,700	2,700
Unidentified tilapias	208	1,299	2,129	2,982	4,888	9,253	7,077	4,240	6,508	7,454	8,130	10,405
Total	908	3,399	4,723	12,456	33,094	35,715	38,164	40,077	67,421	177,202	174,985	193,240

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

Table 1.7. Production (Mt) of farmed tilapia by country in South America during 1980–2002 (from FAO, 2004).

Country	1980	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Brazil	. . .	. . .	. . .	. . .	. . .	. . .	12,014	15,700	16,845	24,062	27,104	32,459	35,830	42,003
Colombia	93	2,040	3,040	11,050	11,046	11,084	16,057	14,026	16,112	17,665	19,842	22,870	24,000	24,000
Ecuador	. . .	21	33	876	912	68	< 0.5	< 0.5	1,730	1,730	4,400	9,201	5,169	8,181
Venezuela	. . .	4	127	400	700	1,103	1,650	1,700	1,936	2,010	2,320	970	1,250	560
Guyana	. . .	30	50	75	100	159	160	160	170	180	369	369	370	370
Peru	10	186	200	250	181	205	< 0.5	47	< 0.5	. . .	. . .	8	223	122
Suriname	. . .	. . .	. . .	. . .	. . .	1	1	1	1	1	50	130	54	54
Bolivia	. . .	. . .	. . .	51	79	68	70	55	40	30	30	30	30	35
Paraguay	. . .	26	25	30	30	40	80	150	210	38	38	40	40	. . .
Argentina	. . .	. . .	. . .	. . .	. . .	. . .	. . .	10	10	. . .	. . .	10	. . .	3
Total	103	2,307	3,475	12,732	13,048	12,728	30,032	31,849	37,054	45,716	54,153	66,087	66,966	75,328

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

tilapia production in South America is reported in the 'unidentified' category. Out of the 75,328 Mt of tilapia produced in 2002, 62,723 Mt were 'unidentified' tilapias (83.3%). Nile tilapia is the second most important cultured category, where it accounted for 16.5% (12,422 Mt) of total tilapia production in 2002. Other tilapia/cichlids, including *Cichlasoma*, green terror (*Aequidens rivulatus*), Mozambique tilapia, redbreast tilapia and velvety cichlids are also cultured in South America, but on a very small scale, with negligible production (Table 1.8). The culture of *Cichlasoma* stopped completely after 1993, while that of green terror, redbreast tilapia and velvety tilapia stopped in the late 1990s.

1.6. Tilapia Production in North America and the Caribbean

Mozambique tilapia were introduced into the Caribbean in 1947 and first came to the USA in 1954 (Fitzsimmons, 2001a). Tilapia culture in North America and the Caribbean is therefore relatively new, beginning in the 1960s and 1970s, on a small scale, mainly for subsistence objectives. The first FAO record of tilapia production appeared in 1970, with 200 Mt from Mexico. During 1984–2002, the production increased progressively at an annual growth rate of 12.75%, to reach 45,089 Mt in 2002 (Table 1.9), which represented about 3% of global tilapia production. More than 99% of tilapia production in North America and the Caribbean comes from freshwater environments.

1.6.1. Major producers

Twenty countries from North America and the Caribbean reported tilapia production in 2002. Unlike Asia, Africa and South America, where a single country in each continent dominates tilapia production, no single country dominates the production in North America and the Caribbean (Table 1.9). Instead, Costa Rica, the USA, Mexico and Jamaica together accounted for 78.7% of tilapia production in 2002 (29.3%, 20%, 16.1% and 13.3%, respectively). Countries such as the Dominican Republic, Guatemala, Honduras, Panama, Cuba and El Salvador are also paying considerable attention to tilapia culture. The production of the rest of North American countries is not significant.

1.6.2. Major cultured species

Nile tilapia is the main tilapia species cultured in North America and the Caribbean. It represented about 54% of tilapia production in the region in 2002. Blue tilapia and the cichlid *Cichlasoma* are also important aquaculture species. On the other hand, the production of Mozambique tilapia has declined from 1747 Mt in 1999 to 733 Mt in 2002. As in the case of South America, several tilapia hybrids and strains are also produced in the region. Therefore, a considerable proportion of produced tilapia is reported in the 'unidentified' category. In 2002, 'unidentified' tilapia represented 38.3% of total tilapia production in the region (Table 1.10).

1.7. Future Potential

1. The ever-increasing global growth rate of tilapia culture, accompanied by the continuous introductions of these fish into new geographical areas, reflects a positive future for tilapia culture. Tilapia are expected to play a substantial role as a food fish to meet the needs of the poor for animal protein in developing countries and will probably become an important cash crop in those countries. More value added for tilapia products will also come from developing countries. This will encourage foreign companies to invest in joint ventures in the main producing countries. It is also expected that the increase in tilapia imports will continue.

2. The genetically improved Nile tilapia developed by the International Center for Living Aquatic Resources Management (ICLARM) and the YY males developed by the University of Wales, Swansea, to produce genetically male tilapia (Mair *et al.*, 1997) will probably become a breakthrough in tilapia culture in the near future. Distribution of these tilapia strains has already begun in many countries around the world.

3. China is very likely to continue dominating global tilapia production. In addition, a significant expansion in tilapia farming in other Asian countries, such as Cambodia, Vietnam, Laos and Thailand, is likely to occur (Dey, 2001). It is also

Table 1.8. Major cultured tilapia species and species production (Mt) in South America during 1993–2002 (from FAO, 2004).

Species	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cichlasoma	355	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Green terror	< 0.5	< 0.5	< 0.5	< 0.5	. . .	. . .	. . .	. . .	. . .	. . .
Mozambique tilapia	100	159	160	160	170	180	184	184	183	183
Nile tilapia	3,863	2,925	3,817	3,378	3,328	4,185	7,844	13,143	9,506	12,422
Redbreast tilapia	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	. . .	. . .	. . .	. . .
Unidentified tilapias	8,730	9,644	26,055	28,311	33,556	41,351	46,125	52,760	57,277	62,723
Velvety cichlids	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	. . .	. . .	. . .	. . .	. . .
Total	13,048	12,728	30,032	31,849	37,054	45,716	54,153	66,087	66,966	75,328

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

Table 1.9. Production (Mt) of farmed tilapia by country in North America and the Caribbean during 1970–2002 (from FAO, 2004).

Country	1970	1980	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Costa Rica	. . .	18	232	1,200	1,350	2,360	2,790	3,800	4,100	4,100	5,398	6,588	8,100	8,500	13,190
Cuba	. . .	1,012	3,733	3,313	3,425	2,337	2,363	2,096	2,418	1,888	540	1,060	730	480	500
Dominican Republic	. . .	. . .	100	374	400	218	1,311	985	177	344	446	445	994	1,666	2,084
El Salvador	. . .	. . .	4	17	36	105	151	196	93	138	278	141	56	29	405
Guatemala	. . .	. . .	161	201	540	486	638	774	1,751	2,074	1,647	3,352	2,361	2,501	2,501
Honduras	. . .	6	120	119	173	184	102	172	190	232	102	135	927	1,900	2,874
Jamaica	. . .	20	3,364	3,100	3,200	3,300	3,400	3,500	3,450	3,400	3,360	4,100	4,500	4,500	6,000
Martinique	. . .	. . .	36	35	50	62	65	30	13	10	10	10	8	8	8
Mexico	200	6,907	5,000	4,500	4,600	4,800	5,439	1,482	4,800	8,318	5,398	7,023	6,726	8,845	7,271
Nicaragua	. . .	. . .	3	4	4	4	4	5	52	45	15	16	24	64	64
Panama	. . .	. . .	49	83	65	77	109	186	115	102	55	634	900	1,181	1,181
Puerto Rico	. . .	. . .	3	164	85	48	43	48	24	6	6	3	15	18	3
Trinidad and Tobago	. . .	. . .	2	3	3	4	4	15	15	13	13	12	21	6	6
USA	. . .	. . .	2,041	2,041	4,082	5,670	5,888	6,838	7,242	7,648	8,251	8,051	8,051	8,051	9,000
Total	200	7,963	14,891	15,158	18,020	19,657	22,308	20,143	24,730	28,458	25,522	31,573	33,418	37,753	45,089

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

Table 1.10. Major cultured tilapia species and species production (Mt) in North America and the Caribbean during 1970–2002 (from FAO, 2004).

Species	1970	1980	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Black-belt cichlid	. . .	. . .	6	9	16	120	135	140	78	89	30	32	30	32	32
Blue tilapia	. . .	1,012	3,736	3,317	3,431	2,343	2,368	2,103	2,425	1,890	844	1,324	1,276	1,133	1,350
Cichlasoma nei[a]	. . .	. . .	. . .	. . .	. . .	. . .	35	21	66	71	11	14	11	1,066	1,330
Jaguar guapote	. . .	. . .	6	6	9	36	31	40	152	168	37	48	40	42	42
Mozambique tilapia	. . .	. . .	60	225	240	131	. . .	< 0.5	91	168	517	1,747	497	691	733
Nile tilapia	. . .	26	3,530	3,381	3,551	3,674	3,658	3,868	3,845	3,972	10,333	12,771	15,143	16,941	24,324
Redbreast tilapia	. . .	. . .	5	19	21	11	. . .	. . .	15	15	. . .	. . .	. . .	. . .	. . .
Unidentified tilapias	200	6,925	7,548	8,201	10,752	13,342	16,081	13,971	18,058	22,085	13,750	15,637	16,421	17,848	17,278
Total	200	7,963	14,891	15,158	18,020	19,657	22,308	20,143	24,730	28,458	25,522	31,573	33,418	37,753	45,089

[a]Not included elsewhere.

. . . denotes that data are not available, unobtainable or not separately available but included in another category.

expected that the traditional non-acceptance of tilapia in some Asian countries, such as India, Pakistan and Bangladesh, will change, and the interest in tilapia culture in those countries will increase. Therefore, the production of farmed tilapia in Asia is very likely to bloom further in the future.

4. The production of tilapia for export is also expected to receive considerable attention. In parallel, a new focus on consumer's preference and product quality will emerge (Dey, 2001). Quality will become a limiting factor for the competition among tilapia producers (see Chapter 9 for further details on tilapia export and import).

5. The availability of huge freshwater resources, environmental conditions suitable for tilapia culture and culture inputs in many countries in the Americas (Brazil and Mexico, for instance) make the future of tilapia culture in those regions very bright. Thus, it is no surprise that tilapia production in those regions is expected to reach 500,000 Mt by 2010 and 1,000,000 Mt by 2020 (Fitzsimmons, 2001a). Brazil and Mexico are very likely to become the major tilapia producers in the Americas. Nile tilapia (mainly sex-reversed, all-males) will dominate the production in the future. More tilapia processing and filleting, in addition to new tilapia products, will also occur globally, especially in the Americas, for domestic markets as well as for international markets.

6. Unlike Asia and the Americas, the future of tilapia culture in Africa is not clear. The shortage of freshwater resources, culture inputs and technical experience are the main handicaps for tilapia culture development in Africa. These factors may limit the future expansion of tilapia culture in the continent. However, tilapia culture may still play a significant role in rural development in Africa if it is integrated with other plant/animal farming systems.

1.8. Constraints

Despite the bright future of tilapia culture in many parts of the world, there are a number of constraints that might restrict the development of this industry:

- The inadequate knowledge of tilapia farmers in many developing countries of biological, technical, environmental and social factors related to tilapia culture. Understanding these factors is critical for improving farmers' skills and increasing farm productivity and sustainability.
- Lack or shortage of funds and technical assistance in many developing countries, especially in Africa and Latin America.
- Poor fingerling quantity and quality, especially in Asia and the Americas, where most farmed tilapia are derived from very small founder stocks.
- Poor extension service programmes, especially in remote rural areas, where tilapia culture is expected to expand.
- The continuous increase in the cost of culture inputs, such as fingerlings, feeds, fertilizer, fuel, labour, etc., which reduces the profitability of tilapia culture enterprises.