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Introduced Species and Aquaculture

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Abstract The yield from global capture fisheries is the current main sources of seafood for human consumption but has reached a plateau since 1990, and is not expected to have any further significant growth. Aquaculture contributions have increased significantly since 1970 and now account for more than 32.3% of all fish consumed worldwide in 2004 (FAO, 2006). From 1950 to 2004, a total of 442 aquatic species have been cultured at least one time in the world (FAO 2006). In 2003, of these species, 314 had production of one tonne or more.

Problems associated with the culture of local species led culturists in many regions of the world to seek related non-indigenous species as alternatives (Stickney, 2001). Aquaculture, then, has become the main cause of the introduction of non-indigenous species, accounting for 38.7% of introduced species recorded in the Food and Agriculture Organization (FAO) database (Garibaldi and Bartley 1998). The practice of culturing non-indigenous species has existed for many years to take advantage of existing markets, as well as available technology and resources. Almost 10% of global aquaculture production came from introduced species (Garibaldi and Bartley 1998). The pressure to culture non-indigenous species has increased, given expanding aquaculture production and increasing demand for diversified seafood from consumers.

Aquaculture farms in the United States currently produce more than 100 different species of aquatic plants and animals; most major aquatic species cultured in the U.S. are not native to their farm sites (Naylor et al., 2001). Non-indigenous species have been introduced for farming in particular regions because of the immediate social and economic benefits. Some non-indigenous species, however, have quickly adapted to their new environment, have become established, and now compete with indigenous species for limited habitats.

Biological invasions are recognized as serious threats to marine biodiversity and ecosystem structure and function (Frisch and Murray, 2002). In addition, introduction of non-indigenous species for aquaculture has resulted in numerous unintentional introductions of pathogens, parasites, and pest species (Galil, 2000).

This presentation will review and provide several cases for the significance of introduced species to total aquaculture production. The culture of marine shrimp will be used as an example to explain the impacts on surrounding environments in both physical and biological aspects. To keep the contribution of introduced species in aquaculture a positive one, certain measures must be developed to avoid any negative impacts. Thus, mitigation strategies and monitoring capabilities for introduced species are very important.

Introduction

According to statistical data released by the Food and Agriculture Organization (FAO) in 2006, aquaculture contributed to 32.3% of the total global seafood supply (excluding aquatic plants) in 2004 (Fig. 1). Total seafood supply in 2004 was 150 million mt, of which 45 million mt came from aquaculture and 95 million mt from capture fishery. Even though the main source of the world's seafood is still from capture fisheries, the total yield from this source has been in a plateau since 1990, and no further significant growth is

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expected in capture fisheries.

Thus, it has been predicated that the world increasingly will have to rely on aquaculture in the future to match rising seafood consumption. Lester Brown at Worldwatch Organization stated (2001) that fish farming might soon overtake cattle ranching as the world's largest food source (http://www.naia.ca/faq.asp). Jacques Cousteau (1973) stated "we must plant the sea and herd its animals, using the sea as farmers instead of hunters" and encouraged farming of the sea because of the earth's burgeoning human population. Aquaculture, in fact, is the fastest growing sector of worldwide agriculture with an annual growth rate of 8.9% during the period of 1970 to 2002, compared to 2.8% for livestock and 1.2 % for capture fisheries production (FAO, 2004).

Issues, such as preservation of environmental conditions, however, have challenged the expansion of aquaculture. The quality of seafood has also been closely watched by the public. A report by Hites et al. (2004), for example, pointed out that organic contaminants in farmed salmon would create poor public perception toward aquaculture.

From 1950 to 2004, a total of 442 aquatic species have been cultured at least once in the world (FAO 2006). Problems associated with the culture of local species led culturists in many regions of the globe to seek related non-indigenous species as alternatives (Stickney, 2001). With the expansion of aquaculture production and the increasing demand for diversified seafood from consumers, the pressure to culture non-indigenous species has only increased. There were many reasons identified as the cause of introduction which included aquaculture, aquarium trade, biological control, boats and ships, channels, canals and locks, live bait, nursery industry, scientific research institutions, schools and public aquariums, recreational fisheries enhancement, and restaurants, seafood retail and processing (Copping and Smith 2005). Aquaculture is the main cause of non-indigenous species introduction, accounting for 38.7% of introduced species recorded in the database of the FAO (Garibaldi and Bartley 1998).

The practice of culturing non-indigenous species has existed for many years to take advantage of existing markets, as well as available technology and resources. Bartley and Casal (1998) reported that introduced species contributed about 17%

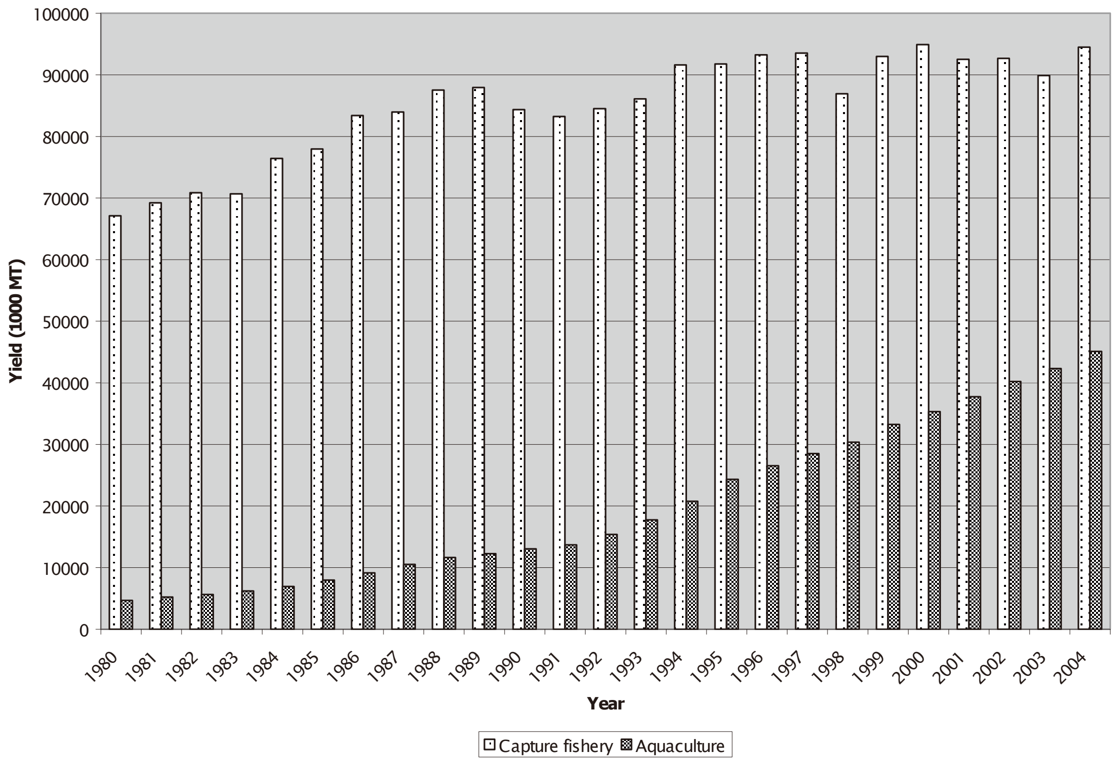

Fig. 1. Production from capture fishery and aquaculture between 1980 and 2004.

of total global fish production in 1996. While the use of introduced species has increased aquaculture production, it also might threaten aquatic biodiversity, transfer disease, alter habitat, and compete with native species on food and space. The estimated loss from introductions was about $137 billion annually in the U.S. in 2003 (Goldsborough 2003).. According to a U.S. congressional report (1993), introduction of the zebra mussel resulted in a $3 billion loss. This paper presents the significance of the contribution made by introduced species to the total global production of several major cultured species. Given current production trends, it is anticipated that the world will have to continually rely on introduced species to increase aquaculture production. At the same time, however, we have to devote part of our effort to conserving biodiversity and otherwise reducing the potential adverse effects of introducing alien species.

R.L. Welcomme in the early 1980s initiated a database on introductions of aquatic species (DIAS) at FAO. This initial database, focused on freshwater species, became the basis for the 1988 FAO Fisheries Technical Paper No. 294 (Welcomme 1988). Currently, DIAS includes additional taxa, such as mollusks, crustaceans, and marine species. Building on this knowledge, Froese and Pauley (1997) developed a FishBase program, which included more information about species introduction. This report compares the production data from the native and new locations for a few cultured and introduced species, such as tilapia, rainbow trout, Atlantic salmon, common carp, and marine shrimp. Marine shrimp farming is used as an example to demonstrate adverse effects that can result from species introduction.

Species introduced as a new species

The rationale behind the introduction of a species to a new location as a target farming species usually includes existing culture technology, existing market demand, and anticipated high profit. Fish farmers expect a quick profit, since a species that can be mass produced with exising technology and already has proven market demand should require no additional investments in technology and market development. On the other hand, species can also be introduced with the intention to supplement food supplies, after researchers determine that environmental conditions are suitable for an introduced species and that production costs are lower than those for other species. This type of introduction is usually carried out by government or nonprofit organizations. The following species are familiar to many consumers, but they are an alien species to many locations where they have been introduced for aquaculture purposes.

1. **Tilapia** (*Oreochromis mossambicus, and O. niloticus*) are native to Africa but were brought to many countries after the first introduction to Java in 1939 (Atz, 1954; Riedel, 1965). The major producers for both tilapia species today are located in Asia. In 2004, total production was 1,495,744 mt for Nile tilapia and 46,665 mt for Mozambique tilapia. Production sharply increased after 1980 (Fig. 2). The farmers in Asia produced 1.29 million mt of tilapia, but farmers in Africa produced only 210,000 mt or 16 % of total worldwide production (Fig. 2). Many domesticated strains were developed at many farming locations. Demand for tilapia has grown continually during the past few years.
2. **Atlantic salmon** (*Salmo salar*) is found in the North Atlantic from New England to Ungava Bay on the west, Iceland, Greenland, and from northern Portugal to the Kara Sea on the east (Laird and Needham, 1990). Farming of this species is done mainly in Norway and Scotland, and in Chile where no native species were found. The first introduction of Atlantic salmon eggs to Chile was in 1916, but the first privately owned salmon farm was not started until between 1975 and 1980 (Wurmann 2007). Production really started to bloom was the 1990s. In 2004, Chile produced 349,329 mt or about 72% of total production in Norway or 28% of total worldwide production (Fig. 3). If its current growth rate of salmon production continues, Chile in a few years may overtake Norway as the nation with the highest

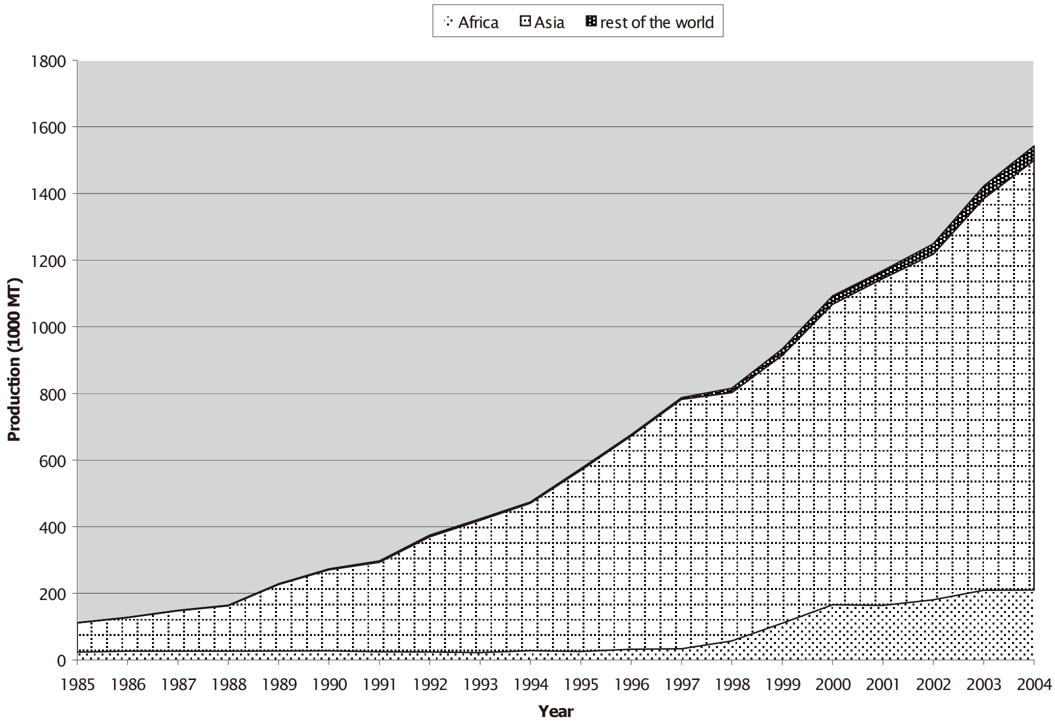

Fig. 2. Production of tilapia from Africa, Asia, and the rest of the world.

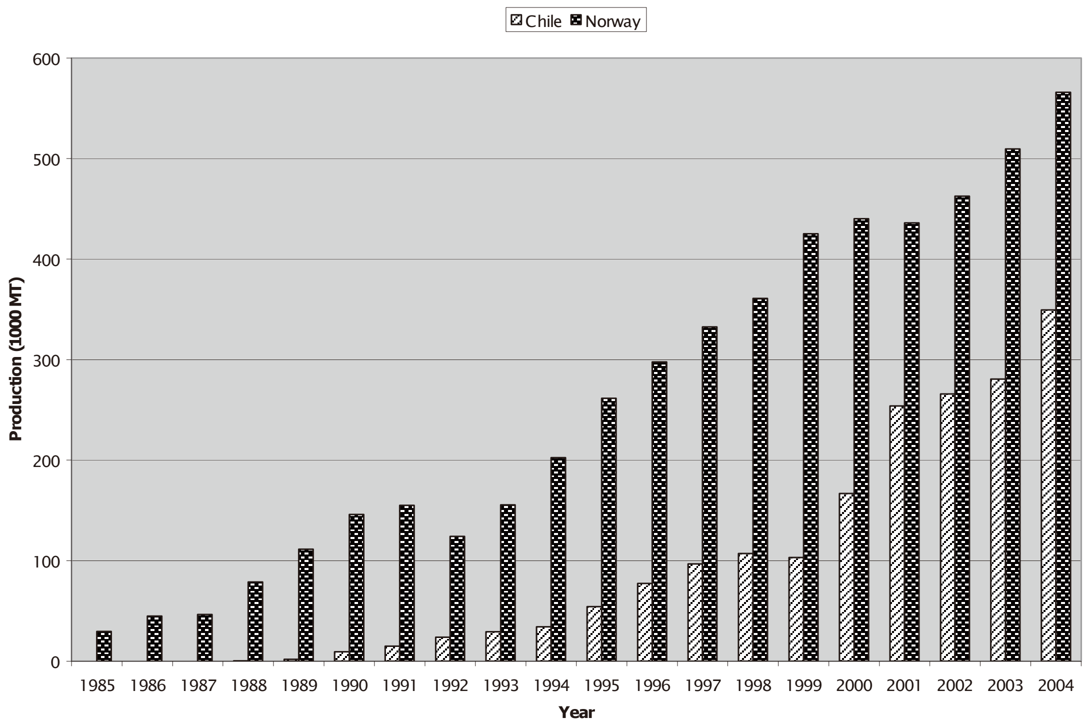

Fig. 3. Atlantic salmon production in Chile and Norway

production of Atlantic salmon worldwide.

3. Rainbow trout (*Oncorhynchus mykiss*) was native to western North America from Mexico to the Bering Sea, Siberia (Laird and Needham, 1990). Since 1874, it has been introduced to all continents except Antarctica for aquaculture and recreation purposes (FAO 2007). By 2002, 64 countries were reporting rainbow trout farming production. The primary trout-farming countries were in Europe, North

America, Chile, Japan, and Australia. According to statistics from FAO, total production in Europe accounted for 57.31% of the total global production of 504,876 mt in 2004 (Fig. 4). In contrast, production in the U.S. was less than 30 thousands MT in 2004. .

4. Common carp (*Cyprinus carpio*) has been reared in China for more than 200 years and currently is cultured throughout the world, with a yield of about 5.8 million mt in 2004. More than 58% of that total production came from countries other than China and Japan, where the carp is

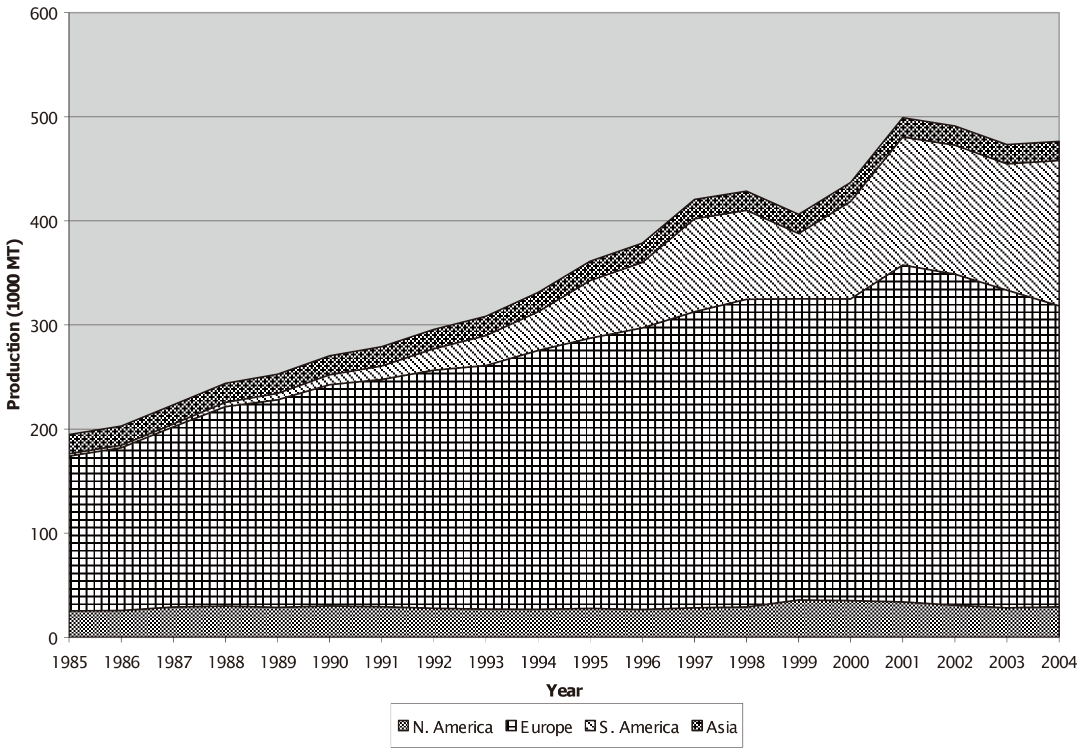

Fig. 4. Rainbow trout production in different continents.

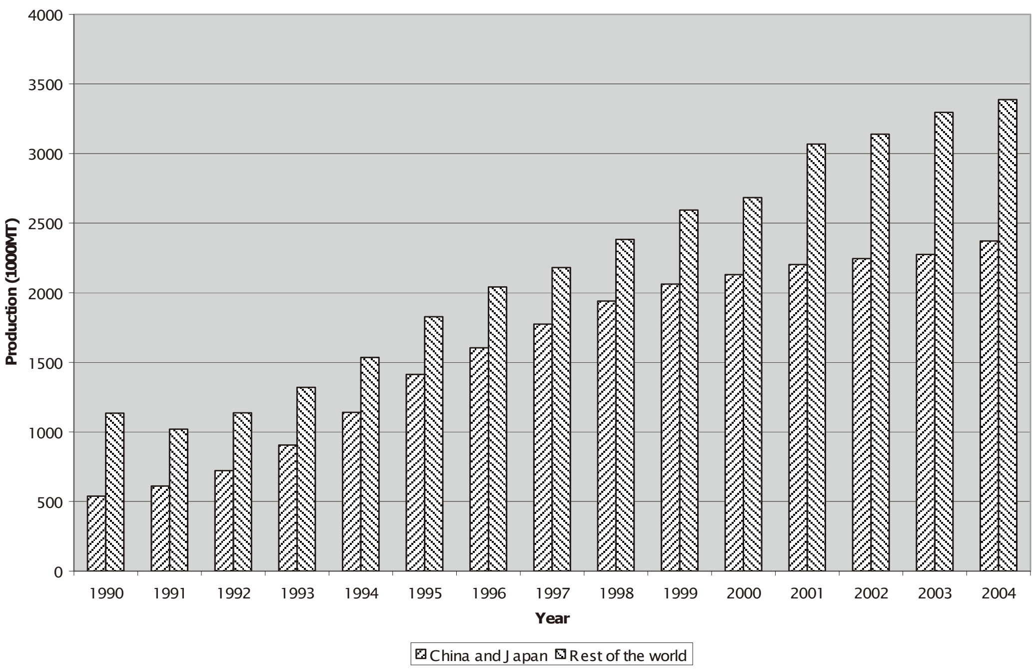

Fig. 5. Comparing common carp production in China and Japan to production in the rest of the world.

native. (Fig. 5). Domesticated carps have been produced in most of the carp producer nations. Strains can be very different from each other in performance. Although it was considered a luxury food in the middle and late Roman period (FAO 2007), it has became a traditional food fish and provided a very important animal protein source in many farming countries.

The above information clearly indicates the significance of the contribution made by the aquaculture production of introduced species, such as tilapia, Atlantic salmon, rainbow trout and common carp. Total aquaculture production from the above species would be reduced by more than half, if they were prohibited from "introduction". It is not difficult to imagine the impact on market prices from the elimination of the production contribution from introduced species. No doubt, we would all have to pay higher prices for the above species.

Species introduced to locations where they already exist

Not all introductions involve bringing species to locations where they are alien. Unlike the previously discussed species, the following species are examples of introductions to a location where the same species already exists. The rationale for this type of transfer can be either to meet a shortage of fingerling supply for farming purposes or to introduce desired traits to a local strain in order to improve its performance. The genetic structure of native strains will be altered eventually.

Milkfish (*Chanos chanos*) have a broad geographic distribution, existing virtually throughout the entire tropical Indo-Pacific Ocean and is a popular farming species in Southeast Asian countries, especially in Taiwan, the Philippines, and Indonesia (Lee, 1995). Before the establishment of hatchery technology, milkfish farmers had to rely on wild collection of fingerlings to stock fishponds. Because of shortages and fluctuations in the number of fingerlings available annually in the region, the milkfish industry had to conduct inter-country transfers of milkfish fingerlings every year to meet demand. Genetic differences among different strains have been diluted or may no longer exist.

This situation has not improved. Even after hatchery technology was established in those three countries (Lee 1995), fingerlings were still moved around the region to meet the needs of farming practice in terms of availability and cost. For example, Taiwanese milkfish farmers would stock their ponds with fingerlings from Indonesia to extend their growing season after winter.

The danger in such transfers is that microorganisms, along with the fish, can be transported from one region to another. Undesired pathogens can be unintentionally introduced to a new location and create other issues. Although no major outbreaks of diseases were reported, additional measures to prevent any negative impacts should always be taken. After all, the intra- and inter-regional transfers of shrimp stocks were one of the causes for the collapse of shrimp farming industries in several countries in Asia and other regions (Lin 1989).

Marine shrimp aquaculture expanded significantly throughout Latin America and Asia during the 1980s (Moss, 2002). Black tiger shrimp (*Penaeus mondon*) and Chinese shrimp (*Fenneropenaeus chinensis*) were the two major marine crustacean species commercially cultured in Asia and China, respectively. Pacific white shrimp (*Litopenaeus vannamei*) was the major species cultured in Central and South America.

During the peak of black tiger shrimp farming in Taiwan, wild shrimp broodstocks were not abundant to meet the demand and were imported from different locations in Southeast Asia to make up for local broodstock supply shortages. Most of the transfers were carried out without any examination of stock health conditions or gone through quarantine procedure. Pathogens could be transferred to new locations if the transported stock carried any infectious disease. Furthermore, intensification of stocking densities and deterioration of culture conditions provided favorable conditions for the outbreak of shrimp diseases.

Shrimp diseases caused by viral infection are not easily treated under current technology and have caused significant economic losses that have affected industry survival in many countries (Lightner, 2003). Shrimp viral disease outbreaks have caused billions of dollars in lost revenue for the global shrimp industry. Disease outbreaks were one of the major reasons for the collapse of the shrimp industry in Taiwan and China in the late 1980s and early 1990s (Fig. 6). Ecuador and Thailand have longer coastlines, so the effect of disease outbreaks on total production in those nations were not seen right away.

Because of the uncontrolled transfer of stock, a disease outbreak in one area could also cause unintended consequences in other parts of the world though trade. The outbreaks of Taura syndrome virus (TSV), white spot syndrome virus (WSSV), and infectious hypodermal and hematopoietic necrosis virus (IHHNV) were found in one location but were identified later in other countries (Lightner, 2003). Nunan et al.(1998) reported that frozen shrimp from an infected area could serve as a vector for exotic shrimp viruses during seafood trade. This report sent out an alarm for international trade.

The most effective way to deal with viral infection is through prevention. The concept of biosecurity has been introduced to aquaculture production systems through a variety of management strategies and by following internationally agreed upon policies and guidelines (Lightner, 2003). The key elements of biosecurity can be summarized into this short list: reliable sources of specific-pathogen-free domesticated stock, adequate diagnostic and detection methods for excludable diseases, disinfection and pathogen eradication methods, best management practices to exclude diseases, and practical and acceptable legislation. In addition to biosecurity, stock improvement can also combat the viral infection issue. Disease-free stocks are not always possible and are not the only tactic. Disease-resistant stocks should be used in any area where the exclusion of disease is difficult.

Under these disease management guidelines and with the availability of specific pathogen free (SPF) shrimp stock from Hawaii, Pacific white shrimp (*L. vannamei*) was introduced to Asia and impressive production data-particularly in China-were reached in less than four years and more than four times

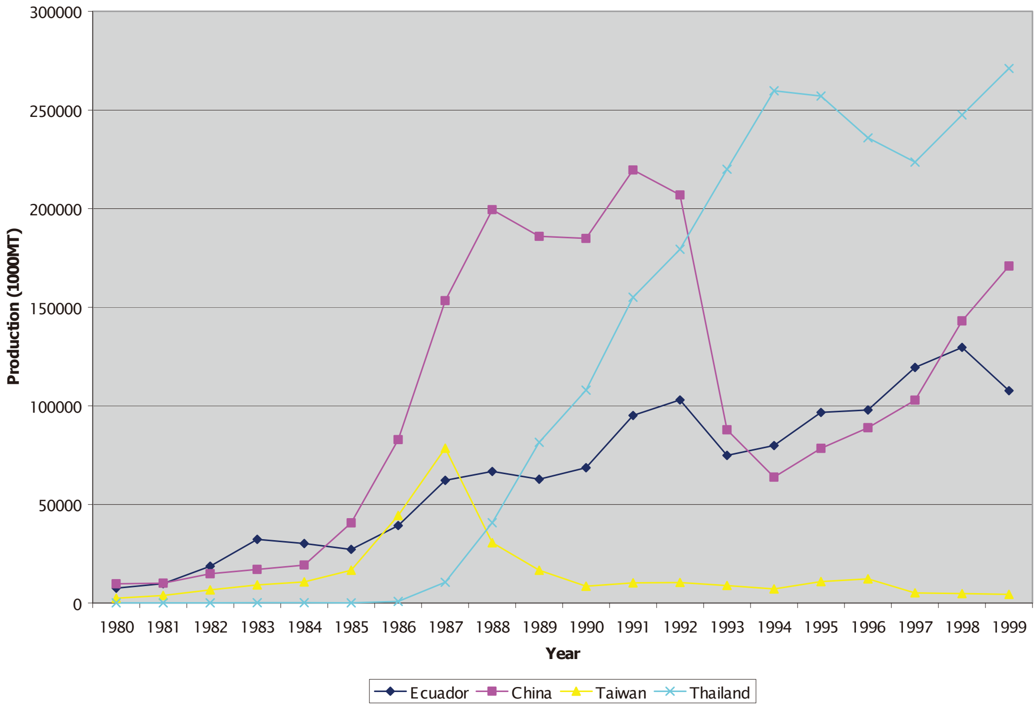

Fig. 6. Shrimp production in selected countries from 1980 to 1990.

production levels in Central and South America (Fig. 7).

Implications and conclusion

The above examples clearly indicate that the culture of introduced species was a common practice throughout the world. Exotic species will be introduced whenever and wherever an aquaculture industry sees potential for making a profit. To stop the importation of non-native species for aquaculture purpose will not only reduce total production but also affect the stability of seafood spplies and prices. Still, environmental and socio-economic damage from farming introduced species will expand if left without any controls. Introductions, for example, will alter the aquatic community structure and genetic composition of native populations, as well as reduce biodiversity (Beveridge et al., 1994; Goldburg and Triplett, 1997; Naylor et al. 2000). The current use of SPF shrimp stock and biosecurity practices in shrimp farming are positive steps toward reducing potential negative impacts of culturing foreign species. Urgently needed, however, are other means of containing introduced species from escaping farm areas and breeding with native species. Meanwhile, all introduction and transfer should follow the code developed by ICES (ICES 1995).

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Literature cited

Atz, J. M. 1954. The peregrinating Tilapia. Anim. Kindom, 57(5): 148-155.

Beveridge, M.C.M., L.G. Ross, and L.A. Kelly. 1994. Aquaculture and biodiversity. Ambio, 23: 497-502.

Bartley, D. and C. Casal. 1998. Impacts of introductions on the conservation and sustainable use of aquatic biodiversity. FAO Aquaculture Newsletter, 20: 15-19

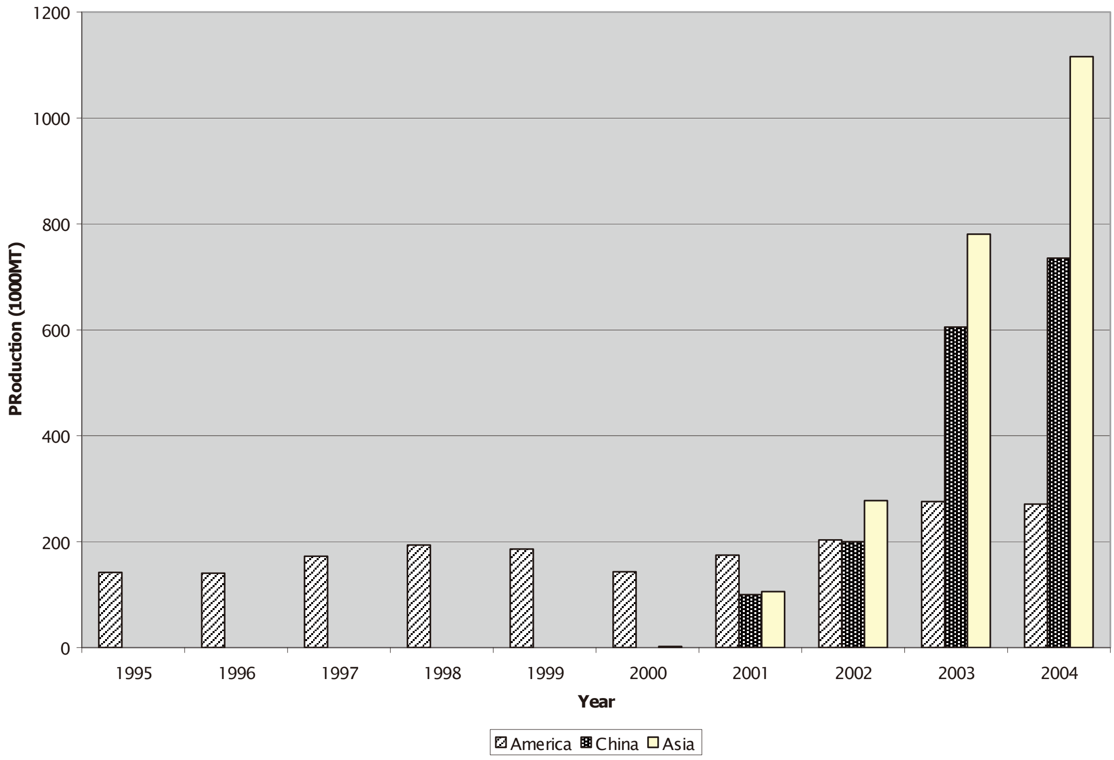

Fig. 7. Production of Pacific white shrimp in Central and South America, Asia, and China.

Copping, A.. and S. Smith. 2005. Pathways of aquatic introductions. http://www.washington.edu/outreach/mas/aquaculture/pathways.html

Jacques Cousteau. 1973. Statement cited by Justin Henry at 2006 Legislative Session: Second Session, 38th Parliament, Special Committee on Sustainable Aquaculture British Columbia.

FAO (Food and Agriculture Organization of the United Nations). 2004. The State of World Fisheries and Aquaculture 2004. Fisheries Department, Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO 2006. The state of world aquaculture 2006. FAO Fisheries Technical Paper 500, 134 p. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO 2007. Culture aquatic species fact sheets. http://fao.org/figis/cultured aquatic species.

Froese, R. and D. Pauly. 2000. FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Laguna, Philippines. 344p. published by the International Center for Living Aquatic Resources Management, Philippines.

Garibaldi, L. and D. Bartley. 1998. The database on introductions of aquatic species (DIAS): the web site. FAO Aquaculture Newsletter, **20**: 20 - 24.

Goldburg, R. and T. Triplett. 1997. Murky Waters: Environmental effects of aquaculture in the United States. The Environmental Defense Fund, EDF Publications, Washington, D.C., 196 pp.

Goldsborough, W.J. 2003. Statement cited from http://see-the-sea.org/topics/species/invasive_species.htm.

Hershberger, W. K. 2002. Aquaculture: its role in the spread of aquatic species. In: Kinnunen, R.E. (ed.) Environmental Strategies for Aquaculture Symposium Proceedings. Minneapolis, MN, 5-6 December 2000. Information Development- Expanding Awareness, Iowa State University, Ames, Iowa, USA. http://www.idea.iastate.edu/aqua/pub07.pdf.

Hites, R.A., J. A. Foran, D. O. Carpenter, M. V. Hamilton, B. A. Knuth, and S. J. Schwager. 2004. Global assessment of organic contaminants in farmed salmon. Science, **303**: 226-229.

ICES. 1995. ICES Code of Practice on the Introductions and Transfers of Marine Organisms. International Council for the Exploration of the Sea, Copenhagen, Denmark. 5p.

Laird, L.M. and E.A. Needham. 1990. Seawater culture of salmonids. P. 628-646. In: G. Barnabe. (ed.) Aquaculture (Vol. II). Ellis Horwood; Chichester, UK.

Lee, Cheng-Sheng. 1995. Aquaculture of milkfish (*Chanos chanos*). 141 pp. published by Tungkang Marine Laboratory, Taiwan and Oceanic Institute, Hawaii, USA.

Lightner, Donald V. 2003. Exclusion of species patchogens for disease prevention in a penaeid shrimp biosecurity program. Page. 81-116. In: Lee, C.-S. and O'Bryen, PJ. (ed.) Biosecurity in Aquaculture Production Systems: Exclusion of pathogens and other undesirables. The World Aquaculture Society, Baton Rouge, Louisiana, USA.

Lin, C.K. 1989. Prawn culture in Taiwan. What went wrong? World Aquaculture, **20(2)**: 19-20.

Moss, Shaun M. 2002. Marine shrimp farming in the Western hemisphere: past problems, present solutions, and future visions. Review in Fisheries Science, **10(3&4)**: 601-620.

Naylor, R.L., R.J. Goldburg, J.H. Primavera, N. Kautsky, M.C.M. Beveridge, J. Clay, C. Folke, J. Lubchenco, H. Mooney, and M. Troell. 2000. Effects of aquaculture on world fish supplies. Nature, **405**: 1017-1024.

Naylor, R.L., S.L. Willams, and D.R. Strong. 2001. Aquaculture-A gateway for exotic species. Science, **294(5547)**: 1655- 1656.

Nunan, L.M., B.T. Poulos, and D.V. Lightner. 1998. The detection of white spot syndrome virus (WSSV) and yellow head virus (YHV) in imported shrimp. Aquaculture, **160**:19-30.

Riedel, D. 1965. Some remarks on the fecundity of Tilapia (*T. mossambica* Peters) and its introduction into Middle Central America (Nicaragua) together with a first contribution towards the limnology of Nicaragua. Hydrobiologia, 25: 357-388.

U.S. Congress, Office of Technology Assessment. 1993. Harmful non-indigenous species in the United States. OTA-F-565. U.S. Government Printing Office, Washington, DC. 391 pp.

Welcomme, R. L. 1988. International Introductions of Inland Aquatic Species. FAO Fisheries Technical Paper No. 294. Food and Agriculture Organization of the United Nations, Rome, Italy. 318pp

Wurmann, C. 2007. Salmon farming in Chile: history, policies, and development strategies. Paper presented at Socioeconomic Aspects of species and system selection for sustainable Aquaculture Workshop help from October 17-20, 2005 in Honolulu, Hawaii.