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Organic aquaculture in China: A review from a global perspective

Biao Xie [a,*], Jun Qin [a], Hao Yang [a], Xia Wang [b], Yan-Hua Wang [a], Ting-You Li [c]

[a] School of Geography Sciences, Nanjing Normal University, 1 Wenyuan Road, Nanjing 210046, PR China
[b] Organic Food Development Center, Ministry of Environmental Protection, 8 Jiangwangmiao Street, Nanjing 210042, PR China
[c] Lianyungang Key Laboratory of Application Biotechnology, Lianyungang Teacher's College, Lianyungang 222006, PR China

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ABSTRACT

Negative environmental impacts, safety issues for aquaculture products, increased fish consumption and increasing market share of organic foods have combined to focus attention on organic aquaculture from both researchers and industries worldwide. There is much extant research that investigates the organic aquaculture development in the world. However, little emphasis is given to China, the biggest aquaculture production country and highest growing organic market. This research aims to narrow this gap in the literature by reviewing organic aquaculture in China from a global perspective. Organic aquaculture has experienced a remarkable growth over the last decade in China. The total production from organic aquaculture increased by 1700%, from 5000 tonnes in 2003 to 85,000 tonnes in 2012, mainly of fish (62,000 tonnes), shrimps (7600 tonnes), scallop (6400 tonnes), sea cucumber (5000 tonnes), crabs (2200 tonnes), clams (500 tonnes), eel (480 tonnes), Chinese softshell turtle (370 tonnes), trumpet shell (180 tonnes), sea hedgehog etc. (270 tonnes). 174 operations have received organic aquaculture certification, with the total area of about 400,000 ha. Organic aquaculture production is concentrated mainly in 10 provinces, Zhejiang, Jiangsu, Hunan, Inter Mongolia, Xinjiang, Anhui, Liaoning, Hainan, Fujian and Shandong. The majority of organic aquaculture farms give priority to polyculture. The development of nutritionally efficient diets using organic sources of ingredients is a challenge. Practical guidelines for energy efficiency, disease control and polyculture in organic aquaculture standard should be elaborated. Major constraints regarding organic aquaculture arise from the fragmentation of certification due to the absence of an internationally recognized standard, and limited possibilities for knowledge. The future market penetration of organic aquaculture products will depend on the improvement of the coordination between production and market. This review provides some necessary background to national conventional and organic aquaculture production. Environmental impacts and food safety issues of aquaculture are discussed. It focuses briefly on the development and operating characteristics of organic aquaculture. Finally, the authors examine the important issues of the organic standards and certification and offer recommendations for stimulating future development.

1. Introduction

Aquaculture has been impressively successful at increasing production in recent years, mainly due to the increasing demand for aquaculture products and the need for new food supplies (Demirak et al., 2006), particularly due to the declining wild fishery stocks. This development generates profits and income, but it may also lead to various environment impacts (Holmer et al., 2008) and risks to food safety (Tacon and Metian, 2008a). Accordingly, self-control, animal welfare, qualitative upgrades of the products and adding value, traceability, environmentally friendly practices, eco-labeling and consumer acceptance issues came to the foreground (Perdikaris and Paschos, 2010), resulting in the emergence of organic aquaculture.

The earliest standard was established in 1994 in Austria for common carp (*Cyprinus carpio*). Standards for organic aquaculture were first developed by the Naturland association, a certification body (CB) for organic agriculture, operating internationally. The first national general standards for organic aquaculture were established by France and the United Kingdom in 2000 (Bergleiter et al., 2009). Subsequently, the guidelines for organic aquaculture production have been privately developed (for example, KRAV, 2001; NASAA, 2001; Naturland, 2002; OFDC, 2002) in order to elaborate an alternative to the means of development in conventional production. The Guide *Aquaculture Responsible Practices and Certification* has been drafted (IUCN, 2009). Regulations for organic aquaculture production have also been developed by various bodies in Europe, United States, Australia, China and Canada. To date, around 80 different organic aquaculture standards exist, of which there are 18 in the countries of the European Union (EU) (Bergleiter et al., 2009). They vary considerably from country to country, from certifier to certifier and species to species. Table 1 summarizes the organizations or countries currently carrying out certification of organic

* Corresponding author. Tel.: +86 25 85891740.
E-mail address: biaox@hotmail.com (B. Xie).

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Table 1
Organic aquaculture standards and certification programs.
Data sources: Bergleiter, 2001; Tacon and Brister, 2002; Xie, 2008a; Prein et al., 2012; modified.

Certification program	Organic certification of/ Standards for:
1. Europe	
Private organic aquaculture certifiers	
Bio Suisse (Switzerland)	Trout
Debio (Norway)	Salmon, trout
ERNTE (Austria)	Carp, trout
KRAV (Sweden)	Salmon, trout, arctic charr
Bioland, Demeter, Biokreis (Germany)	Carp
Naturland (Germany)	Carp/tench (1995), salmon (1996), trout (2000), mussel (1999), shrimp (2001)
Soil Association (UK)	Salmon, trout (1999)
TÚN (Iceland)	Salmon, trout, arctic charr, seaweed (1999)
QCI (Italy)	Trout, seabass, seabream (2001)
SGS (Netherlands)	Organic aquaculture standards
Marine Stewardship Council (London-based — environmental standard for sustainable and well-managed fisheries)	Organic aquaculture standards
National organic aquaculture standards	
France	Organic aquaculture standards (since 2000)
UK	Organic aquaculture standards (since 2000)
2. Oceania	
Private organic aquaculture certifiers	
BIOGRO (New Zealand)	Salmon (1994), crayfish, oysters, seaweed (1999)
BFA (Australia)	Organic aquaculture standards (since Oct. 2001)
NASAA (Australia)	Organic aquaculture standards (since 1999)
National organic aquaculture standards	
Australia	Organic aquaculture standards (since Sept. 2001)
3. Asia	
Private organic aquaculture certifiers	
ACT(Thailand)	Shrimp
OFDC (China)	Organic aquaculture standards (since 2002)
National organic aquaculture standards	
China	Organic aquaculture standards (since 2005)
4. North America	
Private organic aquaculture certifiers	
FOG (USA)	
FVO (USA)	
NOFA Massachusetts (USA)	
U.S. State organic aquaculture standards	
Iowa	
Indiana	Organic aquaculture standards (since 2005)
National organic aquaculture standards	
Canada	Organic aquaculture standards (since 2012)
5. International	
International organic aquaculture standards	
EU Commission of the European Communities (EC)	Organic aquaculture legislation, EU Regulations (EC) 834/2007, (EC) 889/2008, (EC) 710/2009
International Federation of Organic Agriculture Movements (IFOAM)	Draft Standards for Organic Aquaculture adopted in 2000; adopted as full standard since 2005

aquaculture products, together with the species certified and specific organic aquaculture standards employed.

Organic agriculture has been growing rapidly in terms of diversity of produce, production volumes and value. The total global production from organic aquaculture increased by 950%, from 5000 tonnes in 2000 to 53,500 tonnes in 2008, produced by 240 certified organic aquaculture operations in 29 different countries (IFOAM EU Group, 2010).

In recent years, the living standard and consequently the consciousness of health and environmental protection among the Chinese have been increasing. This has created greater demands for healthy foods and organic foods. As a result, the organic aquaculture sector is showing strong growth in China domestic markets. This paper aims to review the situation in the Chinese organic aquaculture sector. It presents an overview of the national conventional and organic aquaculture sector in China. It then concentrates on development and operating characteristics of organic aquaculture, and the important issues of the organic standards and certification from a global perspective. Finally, the paper briefly examines the key factors shaping organic aquaculture growth and provides conclusions and recommendations for future development.

2. Overview of the aquaculture sector in China

China has a long history in aquaculture back to 3000 years ago. The farming of fish in ponds is an ancient practice. The earliest known references to pond fish culture are from China, some 4000 years ago (FAO, 2000). It was presumably developed by early farmers as one of many primary production systems to stabilize food supplies. Fingerlings were caught in the Yangtze River and subsequently transferred to earthen ponds for farming. From that moment onwards, the farming of freshwater species steadily expanded throughout China (Spring, 2010). With a great variety of climates, morphological features, vegetation and fauna, China possesses an extensive coastline, measuring approximately 18,400 km. Beach and shallow sea within 10 m fathom line along the seashore cover 10 million ha (Taiwan not included), among which more than 1.3 million ha can be used for mariculture (Wang, 1993). With the establishment of research group organized by State Aquaculture Administration in 1978, technology developed in China allowed the intensification of aquaculture. This involves high stocking densities of species that are all supplied by hatcheries, the use of processed feed, frequent water exchange and the mechanization of the farm (aerators, water pumps and feeding).

Aquaculture production in China grew dramatically from less than 1.3 million tonnes in 1970 to approximately 47.8 million tonnes in 2010, accounting for 61.2% of the total global aquaculture production by weight. China is bigger than all other aquaculture countries combined in production quantity. By value, aquaculture production within China has increased over 21-fold, from US$ 2.94 billion in 1984 to US$ 61.7 billion in 2010 (representing 49.3% of the total global aquaculture production by value) (FAO, 2012). The main factors which have driven this growth in aquaculture production are the growing demand for aquaculture products mainly from developed countries, the emergence of new production technologies and production of pellet feeds, and the ever-increasing domestic market demand. As far as shrimps are concerned, China possess about 14,000 shrimp farms, of which 5% belong to the intensive type. The majority, i.e. 85%, of farms, are semi-intensively managed and about 10% of farms are extensively managed (Rosenberry, 1998). These extensive, low or no-input systems are very suitable to be converted into certified organic operations.

Aquaculture in China is a diverse industry which includes production of a variety of fish, crustaceans, shellfish and algae. The proportion between freshwater aquaculture and marine aquaculture production is almost 1:1. In 2010, freshwater aquaculture occupied 5.56 million ha and produced 23.55 million tonnes (MABF, 2011). It takes place in ponds, lakes, rivers, reservoirs and rice paddy fields, which are widely spread in almost the entire country, with grass carp (*Ctenopharyngodon idella*, 4.22 million tonnes), silver carp (*Hypophthalmichthys molitrix*, 3.61 million tonnes), bighead carp

(*Hypophthalmichthys nobilis*, 2.55 million tonnes), common carp (*C. carpio*, 2.54 million tonnes) and crucian carp (*Carassius carassius*, 2.22 million tonnes) production accounting for 64.3% of total freshwater aquaculture production (FAO, 2012). Marine aquaculture occupied 2.08 million ha (MABF, 2011), mostly operates in shallow seas, mud flats and protected bays and includes also land-based installations (Cao et al., 2007), with Japanese kelp (*Laminaria japonica*, 4.42 million tonnes), cupped oysters nei (*Crassostrea* spp., 3.64 million tonnes), Japanese carpet shell (*Ruditapes philippinarum*, 3.54 million tonnes) and aquatic plants nei (3.11 million tonnes) accounting for 62.3% of total marine aquaculture production (FAO, 2012). China plays a decisive role in promoting the development of aquaculture worldwide. In 2009, mainland China exported 2.94 million tonnes of aquatic products to Japan (19%), United States (17%), European Union (17%), South Korea (14%), Association of Southeast Asian Nations (12%), Hong Kong (4.3%), Taiwan province (2.6%), Russia (2.5%) and other regions (11.6%) (SNICC, 2010).

Geographic distribution of China's aquaculture mainly consists of the following three sectors: (a) Bohai Sea and Yellow Sea culture zone, including Liaoning, Hebei, Shandong province and Tianjin city. The major farmed species are shellfish, algae, shrimps, and river crab; (b) Southeast coastal culture zone, including Zhejiang, Fujian, Guangdong, Guangxi and Hainan province, with kelp, carp, white shrimp, eel, tilapia, large yellow croaker and shellfish as the major cultured species, and (c) Yangtze Valley culture zone, covering Jiangsu, Anhui, Jiangxi, Hubei, Hunan, Chongqing and Sichuan provinces with carp, catfish, river crab and eel as the major species. Fig. 1 presents the distribution of provinces and and their aquaculture production volumes.

3. Environmental impacts and food safety issues of aquaculture

Aquaculture practice is capable of bringing significant development in rural and urban areas by improving family income, providing employment opportunities and reducing problems of food supply and security (Akinrotimi et al., 2009). However, its dependence on natural resources and its potential for placing greater demands on these may place aquaculture in direct competition and possible conflict with production sectors and activities (NACA/FAO, 2001). A large number of literature reported the impacts of aquaculture on the environment and food safety (De Silva, 2012; Martinez-Porchas and Martinez-Cordova, 2012; Murshed-e-Jahan et al., 2010).

3.1. Destruction of mangrove forest

Mangrove forests are habitats critical to erosion prevention, flood control, coastal water quality improvement, and the reproductive success of many coastal marine organisms (Walters et al., 2008). Owing to choice aquaculture farms can bring certain economic interest, hundreds of thousands of hectares of mangroves and coastal wetlands have been converted into fish ponds and particularly especially to shrimp ponds. From 1950 to 1998, the mangrove forest area decreased from 8000 ha to 280 ha in the east coast and from 54,000 ha to

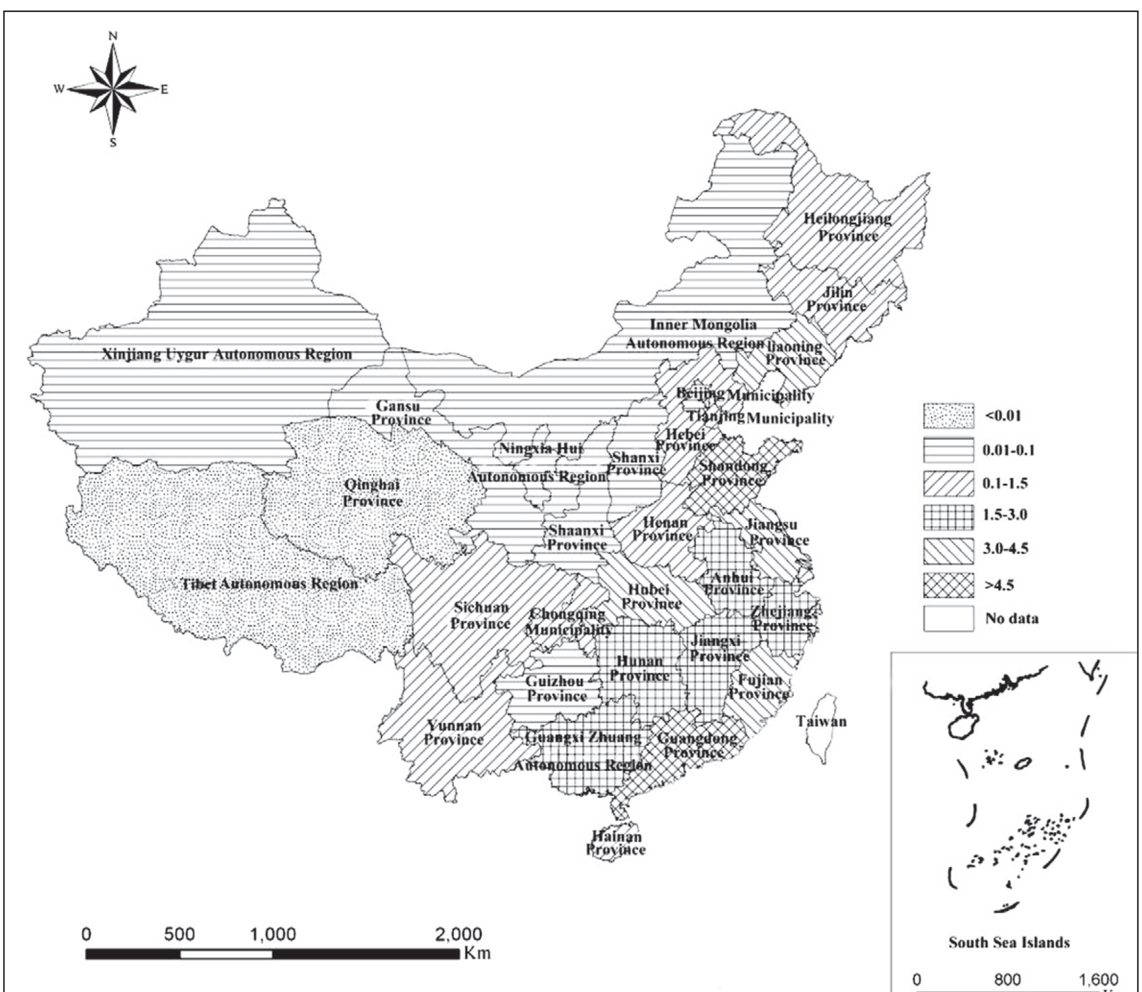

Fig. 1. The China's distribution of provinces and aquaculture production volume (million tonnes) in 2010.
Source: MABF, 2011.

14,000 ha in the west coast of Guangdong province (Chen, 2006). China's total area of mangroves declined by 73% from the early 1950s to 2002 (Liu and Diamond, 2005). The loss of mangroves is related to the reduced biomass production (Páaez-Osuna, 2001a) and increased disease outbreaks (Páaez-Osuna, 2001a, 2001b).

3.2. The drainage of nitrogen, phosphorus and other pollutants

Effluents from aquaculture ponds are typically abounding in suspended organic solids, carbon, nitrogen and phosphorus, originating primarily from uneaten feed and fecal material. Take Fujian province as an example. In 1998, the shrimp production discharged as much as 3.73 million tonnes of the shrimp sewage, including 5589 tonnes of COD, 658 tonnes of nitrogen and 307 tonnes of phosphorus (Xie and Yu, 2007). Shrimp production (79,000 tonnes) in Bohai Sea and Yellow Sea areas in 2002 indicated that more than 120,000 tonnes of uneaten feed was discharged into the sea (Cui et al., 2005). In general, some 85% of phosphorus, 52–95% of nitrogen and 80–88% of carbon input into a marine fish culture system as feed may be lost into the environment through feed wastage, fish excretion, feces production and respiration (Wu, 1995). So much sewage was drained into the surrounding waters during the production period, which can result in building-up anoxic sediments, changes in benthic communities and eutrophication of inland rivers, lakes and coastal waters (Kautsky et al., 2000; Qu and Li, 2000).

3.3. Escapes, disease transfer, use of the antibiotics and other drugs

It is widely argued that translocated species or strains may carry exotic diseases that could spread and devastate indigenous wild populations and that farmed stock escape and become established, again to the detriment of wild stocks. There is little quantitative information on the numbers of animals that escape from aquaculture operations (Cao et al., 2007). Penczak et al. (1982) estimated that about 5% of caged rainbow trout escaped each year. The results of research fishing in the Faroese ocean confirm that significant escapes of farmed salmon stocks have occurred (Youngson et al., 2001). An estimated 2 million farmed salmon escape annually into the North Atlantic (Naylor et al., 2005). Four of the Chinese carp (*C. idella*, *H. nobilis*, *H. molitrix* and *Mylopharyngodon piceus*) have become established in the wild systems in the United States largely through aquaculture escapes (Nico and Williams, 1996). Grass carp *C. idella* were originally imported from Southeast Asia to the southern United States to help aquaculture and wastewater treatment facilities keep retention ponds clean.

The escapees can result in spreading pathogens and destructing the balance of the ecosystem (Thorstad et al., 2008). A serious shrimp disease which occurred in 1993 was obviously caused by the transfer of large numbers of kuruma shrimp *Marsupenaeus japonicas* infected with viruses from southern to northern China. In the past, the introduction of new aquatic species into Guangdong from other countries or regions without risk analysis and proper quarantine has led to disease epidemics and heavy economic losses (Chen, 2006).

Overuse of the antibiotics results in too much antibiotic residues in the aquaculture products and the surrounding aquatic environment, which leads to not only the decrease in the immunity of the aquaculture products, but also the decrease in the disease resistance of consumers and the increase in the possibility of infecting the disease (Song, 1999). Most antibiotics have been prohibited to use in aquaculture in China by the government such as nitrofuran, fluoroquinolone, chloramphenicol, gentian violet, malachite green, melamine etc. (Spring, 2010). Under this circumstance, some immunopotentiators are studied to improve the anti-diseases ability of the cultured species. Currently, taurine, lactoferrine and vitamin E have been used to improve the immunity of the products and have got good effects. Bleaching powder itself has no problem of food safety, but in the oxidation of the organic substance the hypochlorite ion and other chloric preparations produce the trihalomethanes (THMs) and other hydrochloric ethers which have the potential carcinogenesis (Boyd and Massaut, 1999). Overuse of lime results in the growing and overabundance of cynobacteria and the restraining of propagation of diatom.

3.4. Food safety issues

Malpractice in aquaculture and the processing chain has a potential risk to food safety (Tacon and Metian, 2008a, 2008b). Aquaculture products can accumulate the heavy metals from diet and organic organisms used in the farming through biologic accumulation, which may lead to food safety problem. Some examples of man-made contaminants in farmed fish are: pesticides, polybrominated biphenol ethers (PBDE), and polychlorinated biphenols (PCBs) in salmon (Hayward et al., 2007; Hites et al., 2004a, 2004b; Montory and Barra, 2006), PBDE and dioxin in catfish (Minh et al., 2006), dioxin and PCBs in turbot *Psetta maxima* (Blanco et al., 2007), PCBs in sea bass *Dicentrarchus labrax* L. (Carubelli et al., 2007) and PCBs in all investigated fish (Pinto et al., 2008). Consumption of these fish can raise cancer risk (Dewailly et al., 2007; Foran et al., 2005; Hastein et al., 2006).

There are growing concerns over the safety of aquaculture products from China, particularly in the wake of widespread rejections by importing countries due to the presence of banned antibiotic residues in fish and shrimp, and recent findings of melamine in aquatic feed products (FDA, 2008). The European Union prohibited the import of shrimps from the mainland of China after finding that the prohibited chloramphenicol remained in the imported shrimps. The FDA recently banned the importation of 5 species of farmed fish from China in June 2007 following determination that 15% were contaminated with nitrofuran, malachite green, gentian violet, and/or fluoroquinolone antibiotics (FDA, 2007).

4. Development and prospects for organic aquaculture in China

Contemporary organic aquaculture is rooted in the organic agriculture movement. Chinese organic agriculture emerged in the late 1980s, which was mostly induced by reform policies and economic benefits. The year 1990 witnessed the birth of China's fledgling certified organic industry. Green tea, certified by the Dutch certifier SKAL, and shipped to the Netherlands, was China's first certified organic export (Paull, 2007; Zong, 2002). In October 1994, the Organic Food Development Centre (OFDC) of the State Environmental Protection Administration (SEPA, now changed to Ministry of Environmental Protection) was founded to take charge of national certification and labeling of organic products and promote organic farming in China. OFDC abides by the Codex Alimentarius and the basic standards established by International Federation of Organic Agriculture Movements (IFOAM). In 1999, the first private organic aquaculture standard was issued by OFDC. However, there are other standards and regulations in use step by step in China, including *Organic Food Labelling Management Regulation* and *Organic Food Production and Processing Technical Norm* in 1995 formulated by SEPA, the Organic Certification Standards developed by OFDC in 1999 and issued by SEPA in 2001, *Organic Production and Processing Certification Norm* issued by the China National Accreditation Service for Conformity Assessment (CNAS) in 2003.

By April 2005, the China's National Standard of Organic Products came into force, covering crops, mushrooms, wild plants, livestock and poultry, aquaculture products, beekeeping products and their unprocessed products among others. And *Rules for Implementing the Certification of Organic Products* was introduced. After 20 years of development, the scope, the normative standard, the certification procedure, the requirements for certification bodies, the use of organic product certification seal, the labeling as well as the importation of organic food products to China were defined. Currently, China's organic standard consists of 4 sub standards (Part 1— Production GB/T19630.1-2011, Part 2— Processing GB/T19630.2-2011, Part 3— Labeling and marketing GB/T19630.3-2011 and Part 4— Management system GB/T19630.4-2011). The four parts can be used as a whole system and also separately for different activities. These standards were developed based on the principles and requirements of IFOAM basic standards for organic production and processing. Besides that, points from the Codex Alimentarius, EU regulation, US government's National Organic Program (NOP), Japan's Japanese Agricultural Standard (JAS) etc., were also considered. China national organic standards are compatible to these standards, for the purposes of harmonization and promotion of global organic trade.

The first organic aquaculture certificate was issued by OFDC to the Organic Fishery of Development Co., Ltd of Hangzhou Qiandaohu in 1999, for grass carp *C. idella*, common carp *C. carpio*, crucian carp *C. carassius*, chub *Couesius plumbeus*, yellowfin tuna *Thunnus albacares* etc. The past decade has seen a rise in the development for organic aquaculture products in China. According to authors' statistics based on database of China agricultural products certification (http://ffip.cnca.cn/ffip/publicquery/certSearch.jsp, accessed 5 January 2013), it is estimated that in 2012, total certified organic aquaculture production was around 85,000 tonnes, with over 60 species, mainly of fish (62,000 tonnes), shrimps (7600 tonnes), scallop (6400 tonnes), sea cucumber (5000 tonnes), crabs (2200 tonnes), clams (500 tonnes), eel (480 tonnes), Chinese softshell turtle (370 tonnes), trumpet shell (180 tonnes), sea hedgehog etc. (270 tonnes) (Table 2), with an area of about 400,000 ha in China and 174 certified organic aquaculture operations. The total production from organic aquaculture increased by 1700%, from 5000 tonnes in 2003 to 85,000 tonnes in 2012 (Fig. 2). The number of species from organic aquaculture has increased from thirteen species in 2003 to around 60 species in 2012. Organic aquaculture is concentrated mainly in 10 provinces, Zhejiang, Jiangsu, Hunan, Inter Mongolia, Xinjiang, Anhui, Liaoning, Hainan, Fujian and Shandong (Xie and Ren, 2009).

The market for organic aquaculture products has been growing, but is still very much in its infancy. Due to the absence of an internationally recognized standard, at present, virtually all the organic aquaculture products are destined for the China domestic market. Retail prices are significantly higher than conventionally raised fish (Table 2). This is mainly because of the increased cost of specialized fish feeds and the cost of certification.

Globally, certified organic aquaculture production is expected to increase 60-fold, from 5000 tonnes in 2000 to 1.2 million tonnes by 2030 — equivalent to 0.6% of the total estimated aquaculture production (Tacon and Brister, 2002). China will stand head and shoulder above the rest. In recent years, prices in aquaculture generally have been declining, and aquaculture farmers have had difficulty in covering production costs. But organic aquaculture product price premiums currently paid are still attractive (30–200% over conventional) (Xie and Ren, 2009). The interest in organic aquaculture development is increasing — first, because of the food safety ensuring and high price (particularly for export) and second, due to technical issues such as protection of the environment and biodiversity.

5. Operating characteristics

5.1. General requirements

One of the main requirements for the enclosed aquaculture system is the requirement of the conversion period of at least 12 months. All introduced aquatic organisms to be eligible for certification under organic aquaculture standard shall be subsequently managed at least at the latter two thirds of the production life cycle. Water quality of organic aquaculture shall meet the requirements of national Water Quality Standard for Fisheries (GB11607-89) and be monitored if necessary. Discharge from enclosed water bodies shall be authorized by the local environmental protection agency. Contamination of water body shall be avoided or reduced in open waters where aquaculture is conducted. Aquaculture practices suitable for physiological needs of the organisms and local geographical conditions shall be adopted (GAQSIQ, 2012). Production measures shall ensure the health of the organisms and meet their basic demands. Continuously aeration for oxygen supplementing is prohibited. At present, there are no detailed regulations on the required energy efficiency (e.g. the maximum kWh/kg of product from the farming process).

The maintenance of biodiversity on the aquaculture site is a key aspect of the organic aquaculture standard. Non-destruction, or even replanting, of mangroves in brackishwater coastal locations are a key element of system design and management. The recommended system for organic aquaculture is polyculture, using complementary species, organic fertilizing of the waters and supplementary feeding. Polyculture of Chinese fish species rests on three basic principles, namely 1) the complete use of the fish pond, both in depth, from the surface to the benthic zone and over its entire surface area; 2) complete use of all types of natural food present in the pond, including phyto- and zoo-plankton, benthos, aufwuchs, detritus, aquatic plants, and 3) taking advantage of mutual benefits while avoiding competition for food, the rearing of different fish species within the same fattening pond with complementary feeding habits (Tacon and De Silva, 1997). Polyculture systems have a long history in China and are probably the best examples of successful organic aquaculture. The most common species of organic aquaculture products is common carp production in polyculture, i.e. in combination with crabs, shrimps or other local species (IFOAM EU Group, 2010). The polyculture of shrimp with mussels, and clams plus crabs is becoming a popular practice. Combinations of Chinese carps (bighead, silver, grass carp etc.) and the common carp are most common. Polyculture has practiced from mere fish species (4–7 cultivated species) to fish/turtle, fish mollusks to multiple aquatic species (fish, shrimps, mollusks and algae). The stocking density of cultured species is limited (e.g. by limiting the number of individuals per unit area or per volume of water) in order to approximate conditions as they would occur in the wild and to avoid stress as well as the tendency towards intensification. The density of organism shall not affect the health of aquatic organisms and cause abnormal activities and it shall be regularly monitored.

5.2. Broodstock, fry production and management

Where available, the brought-in aquatic organisms shall preferably come from organic origins. Organic standards generally require organically managed seedstock. Breeding system should also be based on broodstock that can breed successfully under natural conditions without human intervention. Moreover, triploid, asexual reproduction and genetic engineering are prohibited. The induction of polyploidy in the reproduction process as well as the use of polyploid animals in organic aquaculture is not permitted (GAQSIQ, 2012).

Larvae needed in Chinese farms are most produced on hatcheries wholly artificially managed. Breeding fry do not systematically endure artificial selection or inheritable improvement. Heat breeding and use of antibiotic are very common. At present, organic juveniles are mostly not commercially available. In agreement with the national standard, conventionally reared aquatic organisms may be allowed to be introduced; breeds suitable for local conditions and with strong disease resistance shall be chosen as much as possible. When non-local organisms are introduced, permanent damages to the local ecosystem caused by the organisms shall be avoided. Shrimp is currently one of the important organic aquaculture species in China. For the two OFDC certified organic shrimp producer, juvenile *Penaeus chinensis* were bought from the neighbor Sea Institute of Shandong province. Since one principle of organic aquaculture is the strict limitation of stocking density, *P. chinensis* were stocked in the organic systems at a density of 7.2 individuals/m^2, which is within the standard stocking density range of normal Chinese commercial shrimp farming practice. The stocking density can at all times permit natural behavior for species

Table 2
Marketed organic aquaculture products in China.
Data source: Xie, 2008b; Xie and Ren, 2009 (modified).

Aquaculture product variety	Production (t)	Production characteristics	Average farm gate price (US$ per kg)/price premium (%)
Fish (carp, trout, grass carp, yellow-fin tuna, crucian, chub etc.)	62,000	Totaling about 20 species; mostly cultured in reservoirs and lakes; mostly located in Zhejiang, Anhui and Jiangqu provinces.	1.7–8.5/75–117
Shrimp	7600	Totaling about 5 species; mostly located around the China coastal areas where the water quality is excellent; or collected directly from the open reservoirs and lakes; mostly located in Jiangsu, Zhejiang, Inner Mongolia and Xinjiang Provinces.	7.8–21/50–87
Scallop	6400	Normally polycultured with other organic aquaculture species; mostly located in Liaoning provinces.	1.8–7.8/40–95
Sea cucumber	5000	Normally cultured in ponds in the coastal areas; mostly located in Shandong and Liaoning provinces.	33–56/18–66
Crabs	2200	Totaling about 5 species; growing in ponds or caught from the organic paddy fields; mostly located in Jiangsu and Inner Mongolia provinces.	2.8–13.9/40–200
Clams	500	Normally caught from open waters and polycultured with other organic aquaculture species; mostly located in Liaoning province, Jiangsu and Zhejiang provinces.	1.8–3.9/80–105
Eel	480	Mostly caught domestically in marginal quantities from the open water areas; located in Zhejiang province.	4.9–10.3/30–54
Chinese softshell turtle	370	Cultured in the ponds; mostly located in Jiangsu and Inner Mongolia provinces.	10.8–21.2/63–159
Trumpet shell	180	Mostly caught from the shallow coastal waters; located in Liaoning province.	1.5–8.6/25–45
Sea hedgehog etc.	270	Sea hedgehog mostly cultured in cage or raft systems in the coastal areas; located in Liaoning province.	5.6–9.8/33–92
Total	85,000		

and seedstock are good enough in disease resistance, growth speed and quality (Xie et al., 2011b).

Most organic aquaculture standards in the world place a major emphasis on criteria for hatchery operations. The aim is to achieve a closed cycle and to avoid the collection of seed from the wild (Prein et al., 2012). According to most private and public organic aquaculture standards (EU, 2009; Naturland, 2009), the collection of seed from the wild is prohibited, whereas the 2011 China Regulation is less stringent in this regard. At present, there is no formal requirement of the prohibition of catching larvae for stocking from the wild in China organic aquaculture standard. The additional sourcing of juveniles from conventional hatcheries is permitted under certain conditions. For operations having to rely on such bought-in juveniles, a minimum of two-thirds of an animal's life span should have been under conditions certified as organic by the time of harvest.

5.3. Diseases

Diseases are the most outstanding issue, which impact the aquaculture industry. They are harmful to aquaculture species in all the growing stages during breeding, mature and wintering. Chinese governments of all levels and the administrator pay much attention to this problem. Although researches are undertaken, no effective resolution has been found thus far. According to incomplete statistics, 15–20% of shrimp farming acreage suffers from white spot and yellow head diseases (Xie and Yu, 2007).

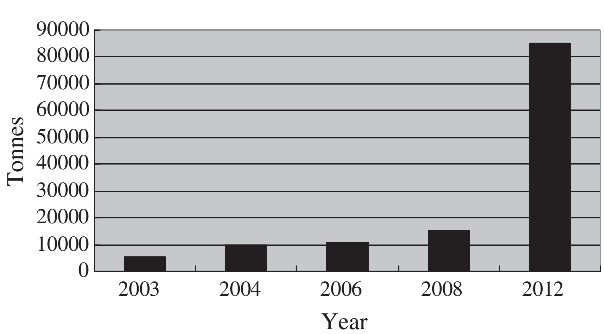

Fig. 2. Organic aquaculture production in China during 2003-2012.
Data sources: 2003 (Xie and Li, 2005); 2004 (Xie et al., 2005); 2006 (Lu et al., 2009); 2008 (Prein et al., 2012); 2012 (http://ffip.cnca.cn/ffip/publicquery/certSearch.jsp, accessed 5 January 2013).

Organic aquaculture principles aim at reduced instances of disease. Likewise, if disease does occur, the costs for treatment are expected to be reduced due to the extensive nature of the operations and the expected hardiness of the less-stressed fish (Prein et al., 2012). Suitable living conditions, feed rations, breed selection and sanitation practices can contribute to pest and disease resistance. According to organic standards, health of the cultivated organisms shall be mainly guaranteed through preventive measures (i.e. optimizing management, feed and diet). The majority of organic aquaculture farms in China give priority to polyculture. The use of lime, bleaching powder, tea seed cakes, and potassium permanganate may be allowed to disinfect culture waters and silts in ponds so as to prevent the occurrence of diseases among aquatic organisms. The use of antibiotics, chemically synthesized medicine and hormones is prohibited in daily preventive treatments. Priority shall be given to natural therapy to treat the sick aquatic organisms (GAQSIQ, 2012). For example, one of the greatest threats to organic shrimp farming is infectious hypodermal and hematopoietic necrosis virus (IHHNV). Successful strategies are likely to involve siting and polyculture management of farms, and the use of Chinese herbal medicine (Xie et al., 2011b). Whereas the 2009 EU regulation is less stringent in this regard. The use of antibiotics is not prohibited in fish, but after use the treated fish cannot be sold with a label as organically certified (Prein et al., 2012).

In agreement with the national organic aquaculture standard, the use of conventional medicinal products shall only be used if the preventative measures and natural medicinal therapy are not effective. During the treatment by the conventional method, sick aquatic organisms shall be isolated. Aquatic organisms receiving conventional medicine treatment may be sold as organic products only after the withdraw period of the used medicines has been doubled as required by manufacturer of the medicine concerned or the government. The health of aquatic seedlings shall be regularly inspected. Vaccinations are permitted if there is the risk of certain disease and the diseases cannot be controlled by other management techniques known to exist in the region. Vaccinations are also permitted if they are mandatory under applicable legislation. Genetically engineered vaccines are prohibited. For disease control, effective measures shall be taken to prevent the aquatic organisms from other aquaculture systems from entering organic sites and capturing organically cultivated aquatic organisms. In the meantime, adequate measures shall be taken to prevent the escape of cultivated species living in the enclosures which may enter other culture systems (GAQSIQ, 2012). But there are no detailed practical guidelines for the predator and unwanted fish fry control.

5.4. Feed and feeding

Much of the success in modern aquaculture has been due to advances in the development of fish feeds. These diets, however, compromise organic standards. The most salient issue in organic aquaculture production is the existing bottleneck in supply of certified organic feed (Prein et al., 2012). According to China organic aquaculture standards, feeds used in organic aquaculture shall be organically produced, natural or authorized by the CB. When the quantities or qualities of organically produced or wild feeds are not adequate, conventional feeds, that is no more than 5% of the total feed quantity (by dry weight) may be used. Under some unpredictable circumstances, the maximum percentage of conventional feeds could be 20% (by dry weight) on the premise of the authorization of the CB. In addition, feeds must be balanced according to the nutritional requirements of the organisms, promote animal's growth and health, ensure high quality of the final edible product and cause low environmental impact (GAQSIQ, 2012). Synthetic growth promoters and stimulants, synthetic appetizers, synthetic antioxidants and preservatives, synthetic coloring agents, non-protein nitrogen (e.g. urea), materials from the same family as the one being fed, feedstuff subject to solvent extraction, pure chemically extracted amino acid and genetically modified organisms (GMOs) and products produced from or by GMOs, growth-enhancing substances are not allowed as feed ingredients or additives. Hormones and hormone derivatives in the feed is incompatible with the concept of organic production. Feeding shall be performed in a way that allows natural food intake and ensure that the developmental, physiological and behavioral needs of animals are met.

Organic feeds may consist of feed ingredients coming from sustainable use of fisheries and of plant feed ingredients originated from organic production. In the case of herbivorous and omnivorous species, complete organic feeds can be formulated by plant feed ingredients. Plant feed ingredients, and generally all feed ingredients, should be certified and traceable to organic standards, except where a feed material is not available on the market in organic form but has been authorized for use in organic aquaculture. In the case of carnivorous species, organic feeds shall consist of fishmeal and fish oil to maintain animal's health, satisfy their nutritional requirements for specific amino acids and fatty acids and to suit to their carnivorous feeding habits (Mente et al., 2011). The use of fishmeal and fish oil contradicts the organic principle of sustainability owing to the decline of fisheries and overexploitation of wild stocks (Prein et al., 2012). Accordingly, alternate proteins are needed to replace fishmeal and fish oil, especially for diets of carnivorous species.

Regulation on organic aquaculture certification permits fishmeal and fish oil from certified sustainable fishery areas or from by-products and trimmings from food-processing fishery or from certified organic aquaculture, but of a different species or from by-catches from food fisheries (GAQSIQ, 2012). There are a limited number of studies investigating partial replacement of fishmeal with organic diets (M.H. Li et al., 2006; Lunger et al., 2006) and fish oil with plant alternatives (Sales and Glencross, 2011; Turchini et al., 2009). But the development of nutritionally efficient diets using organic sources of ingredients in organic aquaculture diets is a challenge. Research is still needed to evaluate the biophysical and biochemical characteristics of new alternative sustainable proteins and lipids as replacements for fishmeal and fish oil, to determine their nutrient availability, to assess their efficiency for various life stages of organic aquaculture species, to reduce their environmental impacts and to supply them with low cost (Prein et al., 2012).

Extensive fish producers (in the lakes, rivers or reservoirs) in China have little difficulties to satisfy their modest requirements for supplementary feed, which should be provided by natural foods, such as aquatic plants, algae, plankton, small invertebrates and detritus that are naturally available in the culture media. Natural foods are highly nutritious but quantitatively limited, which can support extensive production systems with low yields per unit area. The natural food productivity of the cultivated water can be enhanced by external inputs in the form of fertilizers, both of inorganic and of organic nature, such as livestock manures, plant material and inorganic phosphate, nitrogen and potassium products (Mente et al., 2011). The use of natural mineral additives, vitamins, and trace elements in organic aquaculture production is allowed in China organic regulations (GAQSIQ, 2012). Fertilizers, as external inputs, can be used only if they are sourced from certified organic farming operations, and are natural or naturally derived substances (EU, 2007; GAQSIQ, 2012; Naturland, 2009; Soil Association, 2009). In agreement with the principles of China organic aquaculture production, the use of human excrements is prohibited. The use of animal excrements which are not treated is also prohibited. Livestock manures and any organic material used for ecosystem's fertility should be coming from organic livestock production or its own organic farm and should be preferably composted (GAQSIQ, 2012). But its necessity for sustained production, the specific conditions for use and application rates has not yet been fully elaborated. However, the use of animal excreta in aquaculture systems may lead to potential concerns regarding human health, product quality and food safety issues and should be further looked into (Mente et al., 2011).

Organic semi-intensive and intensive aquafarms are facing a drastic challenge for approaching organic feed, particularly if organic feed ingredients (e.g. soy, cereals) have to be sourced from global markets. European feeding companies are pioneers in the research and development of organic fish feeds (Mente et al., 2011; Prein et al., 2012). In China, the initiation of organic agriculture feed projects and the establishment of the local organic aquaculture feed mill is a challenging process. There are no promising projects of this kind to be developed yet. Existing feed mill operators hesitate to undertake the part-time production of relatively low amounts of feed due to the stringent requirements in preparing machines between runs of organic and non-organic feed to avoid contamination. Currently, the certified organic aquaculture operators in China made the feed themselves with the organic ingredients bought from the local market or produced by their own organic farm. For example, in the certified organic shrimp farms located in Lianyungang City, Jiangsu Province of China, a formulation (organic feed) consisting of wild artemia from local salt pans, organic soybean from OFDC certified farms, and natural clam was fed to the organic shrimps (Xie et al., 2011b).

The soil of the pond bottom is the primary nutrient source of the pond ecosystem and as such plays a vital role in the maintenance of pond productivity. Therefore, a common practice in pond farming is the pond drying and liming with quicklime (CaO) or limestone ($CaCO_3$) in order to alkalify the water environment (Mente et al., 2011). In agreement with China organic aquaculture standard, the use of lime, bleaching powder, tea seed cakes, and potassium permanganate may be allowed to disinfect culture waters and silts in ponds. Another practice is the use of polyculture technique. Polyculture can fully exploit the space of the culture media, can lead to more effective utilization of available natural food and can create additional income. Polyculture of shrimp with *Meretrix meretrix* L., *Sinonovacula constricta*, or *Ruditapes philippinesis* etc. has been explored with successful results on growth rates, pollution impact or disease prevention (Chang et al., 1994; Xie et al., 2005, 2011b; Yu et al., 1996; Zhou, 2000). China should attempt to elaborate standards for polyculture in future organic aquaculture regulations.

The main concerns arising from feeds and feeding in organic aquaculture are the nutrition of aquatic animals. In aquaculture, the nutrition highly determines the economic viability and sustainability of the business (Mente et al., 2011). The growing attention paid by consumers to food safety has contributed to the spread of organic farming systems over the last few years (Zaccone et al., 2010). Quality differences have been the subject of many recent comparisons between conventional and organic food (Giannenas et al., 2009; Kelly and Alison, 2010; Xie et al., 2003). In organically cultured fish, differences in feeds and nutrition compared to conventional systems are likely to result in differences in the quality of the flesh, and this is a significant factor in consumer choice (Mente et al., 2011). Examples of nutritional quality studies have been conducted for organic shrimp *P. chinensis* (Xie et al., 2011b) and the larvae of Chinese mitten crab *Eriocheir sinensis* (T.Y. Li et al., 2006). The results clearly underline that the organic aquaculture production system has comparable growth and a nutritional quality benefit, and could allow for the reduction of heavy metal concentrations in organic shrimp and crab larvae samples when compared to those raised in the conventional systems.

5.5. Production costs and benefits

Costs of production are higher where feed costs are higher and the volume of production is relatively small and the area of the operation is larger due to the more extensive nature of the organic farming system (Prein et al., 2012). The economic benefits of the conventional and organic shrimp farming systems were assessed by calculating net profit. It was found that the organic shrimp farming system was more profitable than the conventional. The higher production costs for the organic system were largely due to differences in feed application, labor, housing, electricity, operation, and so forth. However, the cumulative gross receipt can vary depending on several factors, such as shrimp body length, price premium, yields, taste, and quality. The harvested organic shrimp had a mean body length of 11.8 cm, a mean fresh body weight of 15.7 g, and a mean dry body weight of 5.7 g, which are higher than the values for conventional shrimp (mean body length of 10.2 cm, a mean fresh body weight of 12.7 g, and a mean dry weight of 4.6 g) (Xie et al., 2011b). Xie et al. (2005) assessed the environmental benefits of the two production systems by comparing the total discharged nitrogen and phosphorus quantity. It was shown that the total discharged water quantity during the culture period was lower for the organic system than for the conventional system. The conventional system discharged 34.27 kg of nitrogen and 0.3747 kg phosphorus; some 14.89 kg and 0.3418 kg more than that for the organic system respectively. This indicates that the organic system performed better in terms of nutrient load on the environment (Xie et al., 2005).

5.6. Governmental management and farmer's knowhow

Comparing with conventional aquaculture, governmental management seems stricter for the organic sub-sector. The organic aquatic species need to be supervised by provincial governments at regular intervals. The provincial governments have also issued some standards and laws to limit farmers' practices which result in negative impacts on the environment and food safety. They also encourage producers to strengthen international cooperation. Chinese governments should provide farmers with financial and technical assistance. Research, education and provision of information are important instruments of the governments' policies.

Organic aquaculture market in China has a huge development potential and it can bring more opportunities and higher income for farmers. Many farmers have a tendency of choosing this business. Organic aquaculture has strict requirements and, farmers need to be more open to organic principles, relevant knowledge about organic farm management practices, organic processing, packaging, labeling, marketing and master basic technological skills which are about organic farming. Basic obstacles for the general development are the limited possibilities for knowledge exchange through networking and the absence of basic technical equipment.

6. Important features of the organic certification standards and labels, focusing on organic aquaculture

6.1. Global perspective

Standards refer to criteria, or specifications, that define how things are to be done. In the twenty-first century agriculture, standards are increasingly used to define new food products, such as organic food (Cranfield et al., 2009). Certified 'organic' products stand for a complete or 'holistic' concept, covering all aspects of production from the origin of stock, feed and fertilizers to the selection site, design of holding units, stocking densities, energy consumption and processing (Bergleiter, 2001). Certification is essentially aimed at regulating and facilitating the sale of organic products to consumers, providing consumer confidence that organic production ensures food integrity from seed through sell (FAO, 2007). For products to be labeled "organic" requires them to have been produced according to specifically defined organic standards (Giovannucci, 2006). Operators seeking to sell organic products usually have to hire an organic CB to make an inspection annually and confirm that they adhere to the standards established by trading partners.

Organic aquaculture standards and certification system have been common place in the world (Table 1). Regional differences in standards and certification for organic aquaculture production and processing are often justifiable and even desirable due to diverse geography agronomic conditions, culture and stage of development throughout the world. But on the other hand, variations in standards cause difficulties for CBs to recognize and accept organic products certified in other systems or programs, and therefore also for organic producers to get certified organic products accepted in different markets (FAO/IFOAM/UNCTAD, 2008).

Globally, the three major sets of organic standards are the Council Regulation (EC) (No. 834/2007, 710/2009), NOP and JAS. These regions are the largest share of organic products marketed in the world (Sahota, 2008) and offer excellent marketing opportunities to exporting countries, and developing countries in particular (Cronier, 2008; Sheng et al., 2009). Demand for organic foods is also being concentrated in countries where combined purchasing power across all people is high like China etc. The past decade has seen a rise in demand for organic aquaculture products, notably in Europe, North America and Japan. A large proportion of organically certified aquaculture products are produced in developing countries and processed and shipped to these markets (Prein et al., 2012). Agricultural products imported from other countries can only be marketed as organic if their production, processing, documentation, inspection and certification systems are considered as "equivalent" or "compliant". International trade of organic products is working on a basic level. Many exporters have found a mechanism to gain import authorizations in a destination country. Certification bodies are increasingly cooperating to help move organic products in the trade channels (UNCTAD/FAO/IFOAM, 2012).

The EU regulation on organic aquaculture animal (fish, molluscs, crustaceans) and seaweed production entered into force on 1 July 2010 (EU, 2009). The EU organic farming standard has been in place for plants since 1991 (EU, 1991) and for livestock since 1999 (EU, 2007, 2008). Its revision was a major challenge, and expanded its scope to include aquaculture. Certification in the Member States is used to be based on private standards or national specifications, but the new Regulation imposes minimum criteria to be used in all countries of the European Union. The new EU logo for organic products, the 'Euro-leaf' was compulsory from 1 July 2012 onwards and must be affixed to pre-packaged organic aquaculture products produced in the EU. Member States used to be able to draw up their own specifications through national regulations or rely on private standards. The 'Euro-leaf' will continue to remain optional for non-packed and imported organic products. Under a series of bilateral deals signed with third countries, non-EU organic products may be recognized if produced "under the same or equivalent conditions as EU producers". However, their labels must clearly state the source of the product (http://www.organiccentre wales.org.uk/news-item.php?id=371, accessed 26 December 2012). In the United States, discussions on organic aquaculture standards started in 1998 within the National Organic Standards Board. Until today, it is still unclear when the US Department of Agriculture will introduce the first regulation for organic aquaculture as part of the National Organic Program of the United States (Szeremeta et al., 2010). Currently, there are organic standards for aquaculture for EU, Canada, New Zealand, Australia, France, China etc. Canadian Organic Aquaculture Standard was released on May 10, 2012. But the new national organic aquaculture standard does not currently fall under the scope of Canada's Organic Products Regulations or Canada's trade equivalencies for organic products with the United States or European Union (http://www.organicnewsroom.com/2012/05/new_organic_standards_released.html, accessed 12 December 2012). While organic aquaculture was not clearly defined in the NOP and JAS, the lack of organic aquaculture guidelines has hampered the growth of a domestic organic aquaculture industry in the United States and Japan.

The enforced organic aquaculture standards are non-equivalent and quite separate. The main problem is that they do not recognize each other. On the global scale, there is a global shortage of organic products and producers from one country should be able to sell their products in another country and vice versa. And as a growing number of countries start to introduce national organic standards based on EU, NOP or JAS standards, this division among the three major trading blocks is increasing (Heller, 2006). Therefore, the growth of regulations in the organic sector has resulted in CBs offering certification against EU, NOP and JAS Standards as well as offering certification against its own standard. It is hard for local CBs to compete with international CBs in export certification. Local CBs however offer advantages as a service partner to international CBs due to local presence, familiarity of inspectors with local production methods and growing conditions, fluency of staff in local language, and political support for a local business. International CBs have the possibility of extending their service at competitive rates in the region where they work through collaboration with local CBs. And local CBs can link themselves as part of a service network to offer a one-stop certification service for exports to local operators (Bhat, 2009).

A few unilateral or multilateral equivalency arrangements have been reached between governments or regions. The EU has already reached mutual recognition and reciprocity in the area of organic food products with the USA, Canada, Switzerland and Japan (http://ec.europa.eu/agriculture/newsroom/82_en.htm, accessed 12 December 2012). But, generally these agreements lack transparency. Bilateral mechanisms are not an efficient means to achieve true international harmonization. A more efficient model of multilateral international equivalence is still not realized.

In a word, the importance of organic certification is increasing gradually as organic agriculture is getting attention in the world. The demanding nature of regulatory requirements makes certification more difficult as well as expensive, especially in developing markets and for export certification.

6.2. How China and the world affect each other

Inspection and certification in China shall be carried out by any one of CNAS accredited organic CBs. These CBs may operate by their own standards that go beyond the minimum national standards. During 1994–2002, there were only two CBs in China — the OFDC and China Organic Tea Research and Development Centre (OTRDC). As of 2011, there were 23 domestic organic certifiers approved by CNCA and accredited by CNAS. Apart from local certifiers, several foreign certifiers such as ECOCERT (ECOCERT SA, France), IMO (The Institute for Marketecology, Switzerland), the Soil Association (UK), JONA (Japan Organic and Natural Food Association) etc. are also active in China. Since the implementation of the Regulations of the People's Republic of China on Certification and Accreditation (Decree No. 390 of China's State Council) issued in 2003, most foreign certifiers are adopting different cooperation methods with their Chinese partners so as to get approval from CNCA. Some work with subcontract methods, while others have established joint venture companies with Chinese partners.

It is illegal in China to sell as organic any product that has not been properly certified. In order to be marketed in China as organic, goods that are imported from other countries must meet Chinese national standards, as well as specific import rules for conventional goods. But both for international and domestic operators, who want their products to be sold as organic in China market, the general principles applied are that of equivalence. Many articles in national organic product standard are related to import of organic products. Organic production, processing, documentation, inspection and certification are required to be of equivalent standard and regulations. All organic produce marketed in China must bear the words “organic” or “conversion to organic”. The national organic logo and the logo name of the control body must be clearly indicated on the product. Imported organic products must also carry the label as well (GAQSIQ, 2012). In mid September 2010, CNCA issued a draft of “Rules on Importing of Organic Products from Other Countries and Regions”. Recently, the procedure of verification at China Customs regarding imported organic products is stricter. If the exporters cannot provide documents required by the China National Standard, “organic” cannot be labeled on the products (ITC, 2011).

Developed regions or countries, such as Europe, North America and Japan, have been a main importer of organic products coming from China for years and these imports are developing (Xie et al., 2011a). However, different organic-certification legislation has resulted in important access barriers for China. Up to now, it has been very difficult for Chinese CBs to gain access to the EU, USA, Japan or other organic markets. The vast majority of imports are certified by CBs from the destination countries or regions. The certification process itself is complex and involves the connected, yet legally separated, processes of certification and annual re-inspection. Once production units have an organic certificate they must be inspected annually in order to keep the certificate. The two processes are thus highly interlinked and both are necessary in order to enter the international organic trade chain. However, when wishing to get their produce certified/inspected as organic, producers in developing counties face many obstacles. These include the cost and applicability of certification, as well as knowledge concerning the choices available to them in terms of which certifier they decide to choose (Barrett et al., 2002). For facilitating organic exporting, producers in China must pay for international inspection and CBs that have been recognized by the EU, USA or Japan etc., such as IMO (Switzerland), to undertake the audit. The use of international inspection bodies could result in additional transaction costs due to higher inspection fees. Also, producers may not be able to choose the cheapest CB, as importers may insist on the use of a particular certifier because of the problems of approval and the demands of the customer. As a result, one product may be accepted in one country but rejected in another (Xie et al., 2011a). Regulation is seen as a tool for assisting organic producers access export markets through credible inspection and certification, but the real situation is not like this. The key to export market access seems to lie in competent and qualified certification agencies of the importing country (UNCTAD/FAO/IFOAM, 2008). Until now, only some developing countries importing organic produce from China use indigenous inspection and certification (e.g. South Korea, Thailand, Malaysia etc.). An example of the successful development of local CB is OFDC, who got IFOAM accreditation in early 2003. It is the only indigenous bodies that have demonstrated equivalence in IFOAM basic standards, laws and policies (Xie et al., 2011a). And there are now thirty certification programs worldwide that are accepted for working in equivalence with the EU Regulation for organic production (Grolink, 2011), OFDC is on the list (http://www.ofdc.org.cn/en/article_info.asp?n_id=1295, accessed 16 December 2012). OFDC will soon provide qualified services for clients who plan to export their organic products to EU.

The Chinese domestic market of organic products is now developing fast, with significant perspectives ahead. For example, EU exports of organic products to China increased significantly in 2011, with promising perspectives in the years to come (http://ec.europa.eu/agriculture/newsroom/82_en.htm, accessed 16 December 2012). The European Commissioner for Agriculture and Rural Development, and the Chinese Minister for Administration of Quality, Supervision, Inspection and Quarantine (AQSIQ), agreed on 12 June 2012 to open negotiations on a mutual recognition agreement in the field of organic food products. China and EU will examine their respective legislations. Standards and controls applied to organic production will be assessed in order to seek an agreement which facilitates trade in the field of organic products and builds longer term cooperation in this area (Kreuzer, 2012).

For the future, to facilitate trade of organic products as a response to difficulties faced by organic exporters and importers due to the dozens of different organic regulations, standards and labels worldwide, the mechanism of mutual recognition or equivalence and harmonization would be the choice.

7. Conclusions

The rapid expansion of conventional aquaculture has generated serious environmental as well as socio-economic impacts. On the other hand, both the organic aquaculture production sector and the relevant markets are still in their infancy, despite the recent rapid development particularly in China. Converting conventional aquaculture to organic is a complex multidimensional operation. The development of nutritionally efficient diets using organic sources of ingredients is a challenge. Practical guidelines for energy efficiency, disease control and polyculture in organic aquaculture standard should be elaborated. Major constraints regarding organic aquaculture arise from the fragmentation of certification due to the absence of an internationally recognized standard and limited possibilities for knowledge. Uniformity in regulations translates into a lack of supply, as fish farmers are not willing to risk higher production costs if their final product will not to be recognized as organic in the market of destination. The future market penetration of organic aquaculture products will therefore depend on the harmonization of production standards and on the ability to communicate the advantages of organic aquaculture products to consumers.

China dominates global aquaculture production development. There is a future in China for organically certified aquaculture, but the following requirements should be enforced in a flexible manner: to meet the increased demand for research in organic aquaculture, especially on organic nutrition and aquafeeds; to enhance organic aquaculture publicity, while steering organic aquaculture products, production and consumption and actively penetrating domestic markets for organic products; to encourage investments with incorporated environmental criteria; and finally to draft preferential policies for organic aquaculture development.

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References

Akinrotimi, O.A., Abu, O.M.G., Ibemere, I.F., Opara, C.A., 2009. Economic viability and marketing strategies of periwinkle *Tympanotonus fuscatus* in Rivers State, Nigeria. Int. J. Trop. Agri. Food Syst. 3 (3), 238–244.
Barrett, H.R., Browne, A.W., Harris, P.J.C., Cadoret, K., 2002. Organic certification and the UK market: organic imports from developing countries. Food Policy 27 (4), 301–318.
Bergleiter, S., 2001. Organic shrimp production. Ecol. Farm. 27, 22–23 (May, 22–23).
Bergleiter, S., Berner, N., Censkowsky, U., Julià-Camprodon, G., 2009. Organic Aquaculture 2009 — Production and Markets. Organic Services GmbH and Graefelfing, Naturland e.V, Munich.
Bhat, B.R., 2009. Opportunity and challenge of organic certification in Nepal. J. Food Agric. Environ. 10, 124–128.
Blanco, S.L., Sobrado, C., Quintela, C., Cabaleiro, S., Gonzalez, J.C., Vietites, J.M., 2007. Dietary uptake of dioxin (PCDD/PCDFs) and dioxin-like PCBs in Spanish aquacultured turbot (*Psetta maxima*). Food Addit. Contam. 24, 421–428.
Boyd, C.E., Massaut, L., 1999. Risks associated with the use of chemicals in pond aquaculture. Aquacult. Eng. 20, 113–132.
Cao, L., Wang, W.M., Yang, Y., Yang, C.T., Yuan, Z.H., Xiong, S.B., James, D., 2007. Environmental impact of aquaculture and countermeasures to aquaculture pollution in China. Environ. Sci. Pollut. Res. 14 (7), 452–462.
Carubelli, G., Fanelli, R., Mariani, G., Nichetti, S., Crosa, G., Calamari, D., Fattore, E., 2007. PCB contamination in farmed and wild sea bass (*Dicentrarchus labrax* L.) from a coastal wetland area in central Italy. Chemosphere 68, 1630–1635.
Chang, J., Zhang, Y., Yu, Y., Shun, K., Chang, N., Cao, X., Shun, S., 1994. On technique for sowing the bottom of the pond with the seeds of the ark shell. Shandong Fish. 11 (6), 5–8 (in Chinese).
Chen, W., 2006. Challenges for sustainability in aquaculture for China's Guangdong Province. Aquacult. Asia Pac. Mag. (May/June, 24–25).
Cranfield, J., Deaton, B.J., Shellikeri, S., 2009. Evaluating consumer preferences for organic food production standards. Can. J. Agr. Econ. 57, 99–117.
Cronier, C.C., 2008. Marketing of Canadian organic agricultural products: regulatory impediments and success drivers. http://www.ota.com/pics/documents/MarketingCanadianOrganic.pdf (accessed 26 December 2012).
Cui, Y., Chen, B.J., Chen, J.F., 2005. Evaluation on self-pollution of marine aquaculture in Bohai Sea and Yellow Sea, China. J. Appl. Ecol. 16, 180–185 (in Chinese).
De Silva, S.S., 2012. Aquaculture: a newly emergent food production sector-and perspectives of its impacts on biodiversity and conservation. Biodivers. Conserv. 21 (12), 3187–3220.
Demirak, A., Ahmet, B., Mehmet, T., 2006. Environmental impact of the marine aquaculture in Güllük Bay, Turkey. Environ. Monit. Assess. 123 (1–3), 1–12.
Dewailly, E., Ayotte, P., Lucas, M., Blanchet, C., 2007. Risk and benefits from consuming salmon and trout: a Canadian perspective. Food Chem. Toxicol. 45, 1345–1349.
EU, 1991. Council Regulation (EC) No. 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. O. J. EU L 198, 111.
EU, 2007. Council Regulation (EC) No. 834/07 of 28 June 2007 on organic production and labeling of organic products and repealing Regulation (EEC) No. 2092/91. O. J. EU L 189, 23.
EU, 2008. Council Regulation (EC) No. 889/08 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No. 834/2007 on organic production and labeling of organic products with regard to organic production, labeling and control. O. J. EU L 250, 84.
EU, 2009. Council Regulation (EC) No.710/09 of 5 August 2009 amending Regulation (EC) No 889/2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007, as regards laying down detailed rules on organic aquaculture animal and seaweed production. O. J. EU L 204, 15–34.
FAO, 2000. Small Ponds Make a Big Difference: Integrating Fish with Crop and Livestock. FAO, Rome.
FAO, 2007. Certification costs and managerial skills under different organic certification schemes — selected case studies. In: Santacoloma, P. (Ed.), Agricultural Management, Marketing and Finance Service. Rural Infrastructure and Agro-Industries Division, FAO, Rome.
FAO, 2012. FAO Fishstat Plus database, Fisheries and Aquaculture Information and Statistics Service.
FAO/IFOAM/UNCTAD, 2008. Guide for assessing equivalence of organic standards and technical regulations. http://r0.unctad.org/trade_env/itf-organic/meetings/itf8/ITF_EquiTool_finaldraft_080915db2.pdf (accessed 26 October 2012).
FDA, 2007. Transcripts of FDA press conference on seafood imported from China. FTS-HHS-FDA Moderator: Michael Herndon, June 28, 2007, 1:00pm. CT. http://www.fda.gov/downloads/NewsEvents/Newsroom/MediaTranscripts/UCM169541.pdf (accessed 18 December 2012).
FDA, 2008. Import refusal reports by OASIS. http://www.fda.gov/ora/oasis/ora_ref_prod.html (accessed 26 October 2012).
Foran, J.A., Carpenter, D.O., Hamilton, M.C., Knuth, B.A., Schwager, S.J., 2005. Risk-based consumption advice for farmed atlantic and wild pacific salmon contaminated with dioxins and dioxin-like compounds. Environ. Health Perspect. 113, 552–555.
GAQSIQ (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China), 2012. Organic Products, National Standard of the People's Republic of China, GB/T 19630.1 ~ 19630.4-2011.
Giannenas, I., Nisianakis, P., Gavriil, A., Kontopidis, G., Kyriazakis, I., 2009. Trace mineral content of conventional, organic and courtyard eggs analysed by inductively coupled plasma mass spectrometry (ICP-MS). Food Chem. 114, 706–711.
Giovannucci, D., 2006. Salient trends in organic standards: opportunities and challenges for developing countries, prepared for the World Bank/USAID Trade and Standards E-learning Course, January-March.
Grolink, 2011. Congratulations to thirty CBs. Org. Stand. 127, 1–3.
Hastein, T., Hjeltnes, B., Lillehaug, A., Utne Skare, J., Berntssen, M., Lundebye, A.K., 2006. Food safety hazards that occur during the production stage: challenges for fish farming and the fishing industry. Rev. Sci. Technol. 25 (2), 607–625.
Hayward, D., Wong, J., Krynitsky, A.J., 2007. Polybrominated diphenyl ethers and polychlorinated biphenyls in commercially wild caught and farm-raised fish fillets in the United States. Environ. Res. 103, 46–54.
Heller, L., 2006. Differing organic standards impede international trade. http://www.meatprocess.com/Industry-markets/Differing-organic-standards-impede-internationaltrade-report (accessed 26 November 2012).
Hites, R.A., Foran, J.A., Carpenter, D.O., Hamilton, M.C., Knuth, B.A., Schwager, S.J., 2004a. Global assessment of organic contaminants in farmed salmon. Science 303, 226–229.
Hites, R.A., Foran, J.A., Schwager, S.J., Knuth, B.A., Hamilton, M.C., Carpenter, D.O., 2004b. Global assessment of polybrominated diphenyl ethers in farmed and wild salmon. Environ. Sci. Technol. 38, 4945–4949.
Holmer, M., Argyrou, M., Dalsgaard, T., Danovaro, R., Diaz-Almela, E., Duarte, C.M., Frederiksen, M., Grau, A., Karakassis, I., Marbà, N., Mirto, S., Pèrez, M., Pusceddu, A., Tsapakis, M., 2008. Effects of fish farm waste on *Posidonia oceanica* meadows: synthesis and pro-vision of monitoring and management tools. Mar. Pollut. Bull. 56, 1618–1629.
IFOAM EU Group, 2010. Organic Aquaculture EU Regulations (EC) 834/2007, (EC) 889/2008, (EC) 710/2009: Background, Assessment, Interpretation. Brussels.
ITC (International Trade Centre), 2011. Organic Food Products in China: Market Overview (Technical paper) (Doc. No. SC-11-196.E. Geneva).

IUCN, 2009. Guide for the Sustainable Development of Mediterranean Aquaculture 3. Aquaculture Responsible Practices and Certification.IUCN, Gland, Switzerland and Malaga, Spain (VI+70 pp.).

Kautsky, N., Ronnback, P., Tedengren, M., Troell, M., 2000. Ecosystem perspectives on management of disease in shrimp pond farming. Aquaculture 191, 145–161.

Kelly, S.D., Alison, S.B., 2010. Comparison of mineral concentrations in commercially grown organic and conventional crops—tomatoes (*Lycopersicon esculentum*) and lettuces (*Lactuca sativa*). Food Chem. 119, 738–745.

KRAV, 2001. Standards. Idetryck Grafisk Uppsala, Sweden. 60–69.

Kreuzer, K., 2012. Mutual recognition process between EU and China started. http://oneco.biofach.de/en/news/mutual-recognition-process-between-eu-and-china-started–focus–10fcd132-8a89-4015-b3a1-7cce23d59379/ (accessed 16 December 2012).

Li, M.H., Robinson, E.H., Mischke, C.C., Eugene, L., Torrans, E.L., Bosworth, B.J., 2006a. Effects of organic fertilization and organic diets on production of channel catfish in earthen ponds. N. Am. J. Aquac. 68, 53–62.

Li, T.Y., Xie, B., Yan, B.L., Lan, Y.Z., Tian, Y.X., 2006b. A study on the quality of larval crab under organic and conventional cultivation. Trans. Oceanol. Limnol. 2, 82–88 (in Chinese).

Liu, J.G., Diamond, J., 2005. China's environment in a globalizing world. Nature 435, 1179–1186.

Lu, D., You, W.P., Xiao, X.J., Zhang, A.G., Zhou, Z.J., 2009. The status quo and prospect of organic aquaculture in china. Symposioun for Sino–US Forum on Aquaculture, Water Environmental Protection and Food Safety, Nanjing.

Lunger, A.N., Craig, S., McLean, E., 2006. Replacement of fishmeal in cobia (*Rachycentron canadum*) diets using an organically certified protein. Aquaculture 257, 393–399.

MABF (Ministry of Agriculture Bureau of Fisheries), 2011. China Fisheries Yearbook. China Agriculture Publishing Company, Beijing.

Martinez-Porchas, M., Martinez-Cordova, L.R., 2012. World aquaculture: environmental impacts and troubleshooting alternatives. Sci World J. 2012, 1–9.

Mente, E., Karalazos, V., Karapanagiotidis, I.T., Pita, C., 2011. Nutrition in organic aquaculture: an inquiry and a discourse. Aquacult. Nutr. 17 (4), 798–817.

Minh, N.H., Minh, T.B., Kajiwara, N., Kunisue, T., Iwata, H., Viet, P.H., Tu, N.P., Tuyen, B.C., Tanabe, S., 2006. Contamination by poylbrominated diphenyl ethers and persistent organochlorides in cathish and feed from Mekong River Delta, Vietnam. Environ. Toxicol. Chem. 25, 2700–2708.

Montory, M., Barra, R., 2006. Preliminary data on polybrominated dephenyl ethers (PBDE) in farmed fish tissues (*Salmo salar*) and fish feed in Southern Chile. Chemosphere 63, 1252–1260.

Murshed-e-Jahan, K., Ahmed, M., Belton, B., 2010. The impacts of aquaculture development on food security: lessons from Bangladesh. Aquac. Res. 41 (4), 481–495.

NACA/FAO, 2001. Aquaculture in the third millennium. In: Subasinghe, R.P., Bueno, P., Phillips, M.J., Hough, C., McGladday, S.E. (Eds.), Technical Proceedings of Conference on Aquaculture in the third Millennium. Bangkok Thailand, pp. 20–25.

NASAA, 2001. The Standards for Organic Agricultural Production. Stirling. S.A 5152, Australia, pp. 37–38.

Naturland, 2002. Naturland Standards for Organic Aquaculture. Kleinhaderner Weg 1, 82166 Grafelfing, Germany.

Naturland, 2009. Naturland Standards for Organic Aquaculture. http://www.naturland.de/standards.html (accessed 16 December 2012).

Naylor, R., Hindar, K., Fleming, I.A., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D., Mangel, M., 2005. Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. Bioscience 55 (5), 427–437.

Nico, L.G., Williams, J.D., 1996. Risk Assessment on Black Carp (*Pisces Cyprinidae*). Final Report to the Risk Assessment and Management Committee of the Aquatic Nuisance Species Task Force. U.S. Geological Survey, Biological Resources Division, Gainesville, Florida.

OFDC (Organic Food Development Center of State Environmental Protection Administration), 2002. Organic Certification Standards. Nanjing, China, pp. 30–32.

Páaez-Osuna, F., 2001a. The environmental impact of shrimp aquaculture: causes, effects, and mitigating alternatives. Environ. Manage. 28 (1), 131–140.

Páaez-Osuna, F., 2001b. The environmental impact of shrimp aquaculture: a global perspective. Environ. Pollut. 112, 229–231.

Paull, J., 2007. China's organic revolution. J. Org. Syst. 2 (1), 1–11.

Penczak, T., Galicka, W., Molinshi, M., Kusto, E., Zalewski, M., 1982. The enrichment of a mesotrophic lake by carbon, phosphorus and nitrogen from the cage aquaculture of rainbow trout (*Salmo gairdert*). J. Appl. Ecol. 371–393.

Perdikaris, C., Paschos, I., 2010. Organic aquaculture in Greece: a brief review. Rev. Aquacult. 2, 102–105.

Pinto, B., Garritano, S.L., Cristofani, R., Ortaggi, G., Giuliano, A., Amodio-Cocchierri, R., Cirillo, R., DeGiusti, M., Boccia, A., Reali, D., 2008. Monitoring of polychlorinated biphenyl contamination and estrogenic activity in water, commercial feed and farmed seafood. Environ. Monit. Assess. 144, 445–453.

Prein, M., Bergleiter, S., Ballauf, M., Brister, D., Halwart, M., Hongrat, K., Kahle, J., Lasner, T., Lem, A., Lev, O., Morrison, C., Shehadeh, Z., Stamer, A., Wainberg, A.A., 2012. Organic aquaculture: the future of expanding niche markets. In: Subasinghe, R.P., Arthur, J.R., Bartley, D.M., De Silva, S.S., Halwart, M., Hishamunda, N., Mohan, C.V., Sorgeloos, P. (Eds.), Farming the Waters for People and Food. Proceedings of the Global Conference on Aquaculture 2010. FAO, Rome and NACA, Bangkok, pp. 549–567.

Qu, K.M., Li, B.S., 2000. A review on ecological environment of shrimp culture. Mar. Fish. Res. 21 (3), 67–71.

Rosenberry, B., 1998. World Shrimp Farming 1998. Shrimp News International, San Diego, CA, USA.

Sahota, A., 2008. The Global Market for Organic Food & Drink, Paper Presented at BioFach Congress 2008, Nurnberg, Germany.

Sales, J., Glencross, B., 2011. A meta-analysis of the effects of dietary marine oil replacement with vegetable oils on growth, feed conversion and muscle fatty acid composition of fish species. Aquacult. Nutr. 17, 271–287.

Sheng, J.P., Lin, S., Qiao, Y.H., Yu, M.M., Fan, B., 2009. Market trends and accreditation systems for organic food in China. Trends Food Sci. Technol. 20 (9), 396–401.

SNICC (Seafood Network Information Center of China), 2010. Import and export trade of aquatic products of China in 2009. http://www.seafoodchina.com/new_view.asp?id=9034 (accessed 15 December 2012).

Soil Association, 2009. Organic market report 2009. http://www.soilassociation.org/LinkClick.aspx?fileticket=GPynfoJoPh0%3D&tabid=116 (accessed 16 December 2012).

Song, S.X., 1999. *Penaeus monodon* Farming. Marine Publishing House.

Spring, 2010. An overview of China's aquaculture. http://china.nlambassade.org/binaries/content/assets/postenweb/c/china/zaken-doen-in-china/import/kansen_en_sectoren/agrofood/rapporten_over_agro_food/an-overview-of-chinas-aquaculture (accessed 16 November 2012).

Szeremeta, A., Winkler, L., Blake, F., Lembo, P. (Eds.), 2010. Organic Aquaculture EU Regulations (EC) 834/2007, (EC) 889/2008, (EC) 710/2009. Background, Assessment, Interpretation. International Federation of Organic Agriculture Movements EU Group and Valenzno, Bari, CIHEAM/IAMB, Brussels.

Tacon, A.G.J., Brister, D.J., 2002. Organic agriculture, environment and food security. In: Scialbba, N.E.H., Hattam, C. (Eds.), Organic Aquaculture: Current Standards and Future Prospects. Environment and Natural Resources Series, 4. Food and Agriculture Organization (FAO) of the United Nations, Rome.

Tacon, A.G.J., De Silva, S.S., 1997. Feed preparation and feed management strategies within semi-intensive fish farming systems in the tropics. Aquaculture 151, 379–404.

Tacon, A.G.J., Metian, M., 2008a. Aquaculture feed and food safety: the role of the Food and Agriculture Organization and the Codex Alimentarius. Ann. NY. Acad. Sci. 1140, 50–59.

Tacon, A.G.J., Metian, M., 2008b. Global overview on the use of fishmeal and fish oil in industrially compounded aquafeeds: trends and future prospects. Aquaculture 285, 146–158.

Thorstad, E.B., Fleming, I.A., McGinnity, P., Soto, D., Wennevik, V., Whoriskey, F., 2008. Incidence and impacts of escaped farmed Atlantic salmon *Salmo salarin* in nature. NINA Special Report, 36.

Turchini, G.M., Torstensen, B.E., Ng, W.K., 2009. Fish oil replacement in finfish nutrition. Rev. Aquac. 1, 10–57.

UNCTAD/FAO/IFOAM, 2008. Harmonization and Equivalence in Organic Agriculture, vol. 4 (UNCTAD/DITC/TED/2007/14).

UNCTAD/FAO/IFOAM, 2012. Proceedings of the Global Organic Market Access Conference (ISBN-13: 978-3-940946-98-0).

Walters, B.B., Rönnbäck, P., Kovacs, J.M., 2008. Ethnobiology, socio-economics and management of mangrove forests: a review. Aquat. Bot. 89 (2), 220–236.

Wang, X., 1993. Coastal development and environmental protection. UNEP Ind. Environ. 15 (1–2), 7–10.

Wu, R.S.S., 1995. The environmental impact of marine fish culture: towards a sustainable future. Mar. Pollut. Bull. 31, 159–166.

Xie, B., 2008a. The development of and prospects for organic aquaculture worldwide. Outlook Agr. 37 (4), 255–260.

Xie, B., 2008b. Market survey for organic fishery products in China. Project report.INFOFISH, Nanjing (supported by).

Xie, B., Li, T.Y., 2005. Organic aquaculture and its facing challenges. Freshw. Fish z1, 23–26 (in Chinese).

Xie, B., Ren, M., 2009. Best practices of organic aquaculture in China. 2009 International Organic Aquaculture Symposium, organized by Uljin County and KFSA, 28 July 2009, South Korea.

Xie, B., Yu, K.J., 2007. Shrimp farming in china: operating characteristics, environmental impact and perspectives. Ocean Coast. Manag. 50, 538–550.

Xie, B., Wang, X.R., Ding, Z.H., Yang, Y.P., 2003. Critical impact assessment of organic agriculture. J. Agric. Environ. Ethics 16, 297–311.

Xie, B., Li, J.H., Wang, X.R., 2005. Assessing the consequences of converting to organic shrimp farming. Aquacult. Asia Mag. 10 (3), 11–17 (July–September, 11–17).

Xie, B., Li, T.Y., Qian, Y., 2011a. Organic certification and the market: organic exports from and imports to China. Br. Food J. 113 (10), 1200–1216.

Xie, B., Zhang, M.L., Yang, H., Jiang, W., 2011b. Effects of conventional versus organic production systems on amino acid profiles and heavy metal concentrations in the Chinese shrimp *Penaeus chinensis*. Fish. Sci. 77 (5), 839–845.

Youngson, A.F., Dosdat, A., Saroglia, M., Jordan, W.C., 2001. Genetic interactions between marine finfish species in European aquaculture and wild conspecifics. J. Appl. Ichthyol. 17, 153–162.

Yu, Z., Yao, G., Song, X., 1996. Polyculture of shrimp with *Meretrix meretrix Linnaeus* and its related factors. J. Aquacult. 4, 14–16 (in Chinese).

Zaccone, C., Caterina, R.D., Rotunno, T., Quinto, M., 2010. Soil—farming system—food—health: effect of conventional and organic fertilizers on heavy metal (Cd, Cr, Cu, Ni, Pb, Zn) content in semolina samples. Soil Tillage Res. 107, 97–105.

Zhou, C., 2000. Polyculture of shrimp with *Ruditapes philippinesis*. Inform. Sci. Technol. Aquacult. 27 (4), 147–148.

Zong, H., 2002. The role of agriculture and rural development in China. Symposium for Organic Agriculture and Rural Poverty Alleviation: Potential and Best Practices in Asia. United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), Bangkok.