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Why are Prices in Wild Catch and Aquaculture Industries so Different?

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Abstract Through a comparative analysis of prices in capture fisheries and aquaculture sectors, the objectives of this paper are a) to investigate three the trends in prices of forage catches to feed the aquaculture species, b) to analyze the amount of fish species need to feed aquaculture species in order to assess the level of efficiency in resource use, and c) to examine the degree of economic concentration either in wild-catch industry and aquaculture sectors. The results show that prices of cultivated species are higher than prices of the same species when harvested from the sea. We explain this fact by the interplay of three forces. First, the amount of wild fish to feed aquaculture species continues to improve over time. Second, the pressure of fishing activities has not been reduced since catches of most forage fishes are declining, which induce higher prices of capture species that feed aquaculture production. Third, the level of seafood market concentration is significantly higher in aquaculture than in wild catches, which generates higher prices in aquaculture.

Keywords Global seafood markets · Wild fisheries · Aquaculture · Prices · Economic concentration

INTRODUCTION

Catches from wild fisheries and aquaculture (i.e., the farming of aquatic animals and plants) supplied the world with about 148 million tonnes of fish in 2010, with an estimated total value of US$ 217.5 thousand million (FAO 2012a). Wild captures amounted about to 89 million tonnes in 2010, comprising about 77.8 million tonnes from marine waters and a record 11.2 million tonnes from inland waters. The estimated economic value of wild-capture amounted to US$ 98 thousand million.

On the other hand, aquaculture is among the fastest growing food production sectors in the world and this trend is set to continue (FAO 2012a). The production of food fish from aquaculture increased at an average annual rate of 8.8 % in the period 1980–2010, while the world population grew at an average of 1.6 % per year (FAO 2012a). Given that production from aquaculture is mostly destined to human consumption, aquaculture is widely viewed as an important source in the global fight against malnutrition and poverty, particularly within developing countries (Tacon et al. 2010).

In recent years there has been a growing demand for fish consumption, although there are considerable variations between countries and regions in terms of the overall amount of fish for human consumption, which reflects large differences in eating habits, the availability of fish and other foods, prices, and socioeconomic levels (Fabinyi 2012; Oken et al. 2012). Fish and fishery products represent a very valuable source of essential micronutrients and animal protein for much of the world's population. Globally, fish provides about three thousand million people with almost 20 % of their daily intake of animal protein (FAO 2012a). Some of the benefits attributed to the incorporation of fish (fish oils) in diets are mental health (Lin and Su 2007), dementia (Lim et al. 2006), cancer (MacLean et al. 2006), asthma (Woods et al. 2002), multiple sclerosis (Farinotti et al. 2012), diabetes (Hartweg et al. 2008), and early neurologic development (Simmer et al. 2008).

In this setting, the growth of aquaculture has been considered as the production sector that could compensate for the declining wild-fish stocks and continue to supply the fish markets (FAO 2012a). Although the advance of commercial development of aquaculture involves benefits such as a greater volume of food supply (FAO 2012a) and creating new jobs (European Commission 2002), it inevitably also

causes increased risks of impacts on marine ecosystems and farming areas along the coast. Common problems associated with the growth of aquaculture are the energy requirements of wild fish (Tacon and Metian 2008), the modification of habitats where they are located causing a loss of ecosystem services (Naylor et al. 2000), the growing demand for fish for fishmeal and fish oil (Tacon and Metian 2008), the conflicting uses of the marine space, some changes in market conditions (Natale et al. 2013), the possible introduction of exotic species, and the different perceptions of consumers of aquaculture products compared to those from wild fisheries (European Commission 2002).

Moreover, within economically developed countries aquaculture focus has been on the culture of high economic value, high trophic-level carnivorous species (Deutsch et al. 2007; Naylor et al. 2009; Tacon et al. 2010), which require significant amounts of fishmeal and fish oil in their diets. At present, small pelagic forage fish species (e.g., anchovies, herring, mackerel, sardines) also represent the largest landed species group in capture fisheries (27.3 million tonnes or 29.7 % of total capture fisheries landings), and they primarily serve as farm feeds inputs (Tacon and Metian 2009).

Given that one of the necessary inputs for aquaculture production is feeding wild fish, and both types of fish (those captured at sea and those produced in aquaculture) may be considered as substitute products, an interaction arises between wild-catch and aquaculture industries. So it seems relevant to examine some of the most important variables in both industries to understand how they behave. For example, do prices for wild-fishery species and aquaculture species behave similarly over time or not? And if both prices do not behave similarly, what are the underlying reasons that may explain such differences?

Through a comparative analysis of prices in capture fisheries and aquaculture sectors, we particularly investigate three aspects: (a) the trends in prices of forage catches to feed the aquaculture species, (b) the amount of fish species need to feed 1 kg of aquaculture production in order to assess the level of efficiency in resource use, and (c) the degree of economic concentration either in wild-catch industry or aquaculture sector. We believe this is an important issue because, depending on which of the two sources of fish total supply (wild catches or aquaculture) will be dominant in the future, we can assess the behavior of the seafood industry or, at least, some of its main variables.

Market Interactions Between Wild Fisheries and Aquaculture

The relevance of the interactions between the two sectors is becoming more evident as the process of transition from wild fishing to farming production has reached a pivotal point, with almost 50 % of the fish food supply now coming from aquaculture (Natale et al. 2013). Clearly, in a more global perspective the understanding of interactions between fishery catches and aquaculture production needs to evaluate the respective contributions to food security goals and the implications in terms of environmental sustainability and resource use efficiency (Deutsch et al. 2007; Alder et al. 2008; Naylor et al. 2009; Natale et al. 2013).

Interactions between capture fisheries and aquaculture production include various dimensions, ranging from their relationship in seafood markets, the response of actors to market signals or competitive pressure to ecological aspects. Both wild populations and farmed species are biologically linked via disease transfer, escaped fish, or the ingestion of contaminated waste by wild fish (Heggberget et al. 1993).

In the field of economics, Kleih et al. (2013) recently investigated the role of financial sources to support the development of fishing and aquaculture activities. In particular, Omar and Bechardas (2012) examined the role of credits, lack of financial support, capacity building as well as the increasing demand from international markets on the level of development of rural aquaculture in Mozambique, and how price levels ultimately act as local and global drivers for small producers.

New approaches and methodologies from the scientific community have emerged during recent years to better understand the implications from the interactions between wild fisheries and aquaculture at global level. For example, Tveterås et al. (2012) used a Fish Price Index to track the evolution of fish prices and they found that prices of traded species from capture fisheries are greater than the prices of aquaculture production because of the scarcity of fishery resources. Villasante et al. (2012) also conducted the first effort to investigate the synergies and trade-offs between marine ecosystems, seafood markets, poverty alleviation, food security, and governance by creating the Global Seafood Market Performance Index. Recently, Halpern et al. (2012) also developed and implemented a systematic approach for measuring overall condition of marine ecosystems that treats nature and people as integrated parts of a healthy system.

In general, wild and farmed fish have some degree of substitution[1] for consumers (Asche et al. 2005; Natale et al. 2013). For example, while Hanesson (2003) found that the overfishing problem in wild fisheries (of all species) was not significantly reduced by the development of aquaculture, Valderraman and Anderson (2010) showed that the introduction of salmon aquaculture may contribute to the fail of prices, the decline of profit margins and the decrease of fishing effort in the Bristol Bay sockeye salmon. Nevertheless, Asche and Tveterås (2005) and Rodríguez et al. (2013)

[1] Two products are said to be substitutes if an increase (decrease) in the price of one leads to an increase (decrease) in the quantity consumed of the other.

have shown that the diversity of the results reported and the low number of studies in the literature indicates that these findings should only be generalized with caution and based on the specific ecological, economic, and institutional characteristics of each species studied.

MATERIALS AND METHODS

Data Collection and Compilation

In this paper we use the following official databases: FAO database FishStatJ,[2] which provides information of catches by species and countries (in volume and value) (1950–2011); FAO Global Aquaculture Production database,[3] which allows us to gather information of the aquaculture production (both in volume and value) (1950–2011); and FAO Fishery Global Commodities Production and Trade (1976–2011) database,[4] which reports the volume and value of imports and exports of all countries by species. We consider that the FAO databases provide a robust support information for the purposes of this study. However, it is also important to highlight that none of these databases report the total volume extracted from the sea (Froese and Pauly 2013) since data do not include the volume of discards neither the catches from illegal, unreported, and unregulated activities (Agnew et al. 2009).

We focus our attention on the evolution of prices of major species from aquaculture production in order to compare them with those reported for the same species when they are harvested from wild fisheries. To perform this analysis, we have selected the following groups for which FAO reported the highest production (in volume) in the 2000–2010 period: (a) Carps, barbels, and other cyprinids; (b) Miscellaneous freshwater fishes; (c) Clams, cockles, and arkshells; (d) Oysters; (e) Shrimps and prawns; (f) Tilapias and other cichlids; (g) Salmons, trouts, and smelts; (h) Mussels; (i) Scallops and pectens; and (j) Freshwater crustaceans (FAO 2012b).

Fish-In and Fish-Out

In this section we calculate the fish conversion ratio (FCR)[5] in the use of pelagic species as food for the breeding and culture of species in aquaculture production. Since fishmeal and fish oil are key inputs for aquaculture production, we aim to identify the degree of efficiency in the use of these resources by the aquaculture industry. This may help to partially explain the price evolution of aquaculture species. To this end, we have selected the forage fish species selected by Tacon and Metian (2009) and Meyer (2011) as feed for aquaculture production. The catch data for non-human uses to calculate the fish-in fish-out ratio come from the FishStatJ and FAO Global Aquaculture Production Databases (FAO 2013a, b).

The Concentration Degree of Seafood Markets

As well known a concentration ratio is a measure of the total output produced in a given industry by a certain number of firms in such industry. One of the most common concentration ratios is the so-called four-firm concentration ratio (CR_4) that measures the market share of the four largest firms in the industry. Formally:

$$CR_4 = \sum_{i=1}^{4} s_i, \qquad (1)$$

where s_i denotes the percentage market share of firm i. The values of this concentration rate (and others such as the CR_8) range from 0 % (meaning a perfectly competitive market) to 100 % (denoting the maximum level of concentration). In general, it is assumed that a level for CR_4 between 0 and 50 % reveals low concentration and covers the cases from perfect competition to oligopoly, a level from 50 to 80 % indicates medium concentration (an industry in this range is likely an oligopoly) and a level from 80 to 100 % denotes high market concentration (from oligopoly to monopoly).

However, it is worth to note that what the CR_4 provides is only a sign of the competitive or oligopolistic nature of a given industry. It neither uses the shares of all the firms in the industry nor takes into account the distribution of firm size. To overcome these limitations we can use a second tool (also based on market shares) as the Herfindahl index (also called the Herfindahl–Hirschman index), which provides a more complete picture of industry competitiveness than does the concentration ratio (Hirschman 1964). The Herfindahl index is a measure of firms' size in relation to the industry and an indicator of the competition level among them. It is defined as the sum of the square of market shares of the 50 largest firms within the industry (or all the firms if there are fewer than 50), that is,

$$H = \sum_{i=1}^{50} s_i^2 \qquad (2)$$

This index ranges from 0 to 10 000, moving from a huge number of very small firms in the industry to a single

[2] See http://www.fao.org/fishery/statistics/software/fishstatj/en.

[3] See http://www.fao.org/fishery/statistics/global-aquaculture-production/en.

[4] See http://www.fao.org/fishery/statistics/global-commodities-production/en.

[5] The FCR is defined as the coefficient between capture from fisheries to feed aquaculture species. It particularly measures how many kilograms of wild fish does it take to produce 1 kg of farmed fish.

monopolist.[6] Particularly, a value below 100 denotes a very low industry concentration, a value between 100 and 1500 indicates an un-concentrated market, an index between 1500 and 2500 reveals moderate concentration, and an index above 2500 reflects high concentration.[7]

Indices stated in (1) and (2) are well-known concepts that were widely applied in law competition, antitrust, and technology management (Liston-Hayes and Pilkington 2004). They were also empirically used to test the level of concentration of different economic sectors such as the electric sector (Hellmer and Warrel 2009), tourism (Costa et al. 2010), banking (Alegria and Schaek 2009), and gas transportation (Doane et al. 2008), among others.

It is important to note that the seafood market probably is one of the most globalized markets in the world, with a high level of interconnected feedbacks between States and fishing companies, harvested species, and final destination of seafood products (Villasante et al. 2012). The fishing and aquaculture sectors are also highly internationalized due to (i) the diversified consumer preferences and (ii) the economic supply strategies based on the objective of obtaining increasing revenues by exporting or by satisfying local needs of fish intake (FAO 2012b). Thus, we may consider countries as firms both in the wild-catch industry (with the wild captures harvested by their fleets) and the aquaculture industry (with their aquaculture production) and, consequently, we can compute the values of the indices stated in (1) and (2) for such industries at global level. This allows us to elucidate the concentration level existing both in the wild-fishery catches and aquaculture markets in the 1950–2010 period. Ultimately, the objective is to try to elucidate whether or not some type of common patterns of economic concentration are observed over time.

For the application of the four-country concentration ratio and the Herfindahl index we consider data of wild-fishery catches and aquaculture production from FAO. To calculate the four-country concentration ratio we consider those countries who were between the largest four producers in world in each year of the 1950–2010 period, whereas the Herfindahl index is obtained by taking into account the largest 50 producers in each year.

Finally, and in order to explore the possible consequences of the concentration of fish commercialization, we use the case study of the Spanish seafood market as one of the largest in the world. We use prices of origin and destination for different groups of species including pelagic species (anchovies, mackerel, and sardines) for human consumption as well as aquaculture species (salmon and trout). We also analyse the evolution of the prices of origin and destination in different fish distribution channels: supermarkets, hypermarkets, and traditional markets and fishmongers. The data for the Spanish market analysis come from the Database "Datos de Consumo de Hogar del Panel de Consumo Alimentario" for the 2004–2012 period (MAGRAM 2013).

[6] The major advantage of the Herfindahl index over the concentration rate is that the former, but not the latter, gives more weight to larger firms.

[7] See http://www.justice.gov/atr/public/guidelines/hmg-2010.html.

RESULTS

Prices from Wild-Fishery species and Aquaculture: How Do They Behave?

Figure 1 shows that prices for aquaculture species showed a growing trend from 1984 to the end of the 1990s, then the prices dropped until 2002 to show a steady increase again up until 2010. This reveals the increasing degree of shortages in terms of fish and is in agreement with the upward trend shown by the price of other goods such as meat, grain, or other commodities (FAO 2012a; Tveterås et al. 2012).

Figure 1 also shows the price for the same species than farmed species, but when they are harvested from the sea. Comparison of both series of prices indicates that the prices of cultivated species were always higher than those of capture fisheries in the 2000–2010 period. Specifically, aquaculture prices have oscillated around US$ 1500–2000 per tonne depending on whether the data source was provided by the FAO Yearbook-Fisheries and Aquaculture Statistics (2012) or by FAO FishStatJ Database. That is, although prices from capture fisheries and aquaculture have both increased in recent years, the growth rate of price from capture fisheries has been lower than that of aquaculture production. We conjecture that the higher prices observed in aquaculture species is probably due to the increasing trend (and high volatility) of prices from wild pelagic species and, most probably, due to the high concentration of the aquaculture sector as compared to that of wild captures.

Our results differ from those provided by Tveterås et al. (2012). Their study concluded that prices of traded species from capture fisheries are greater than the prices of aquaculture production. The differences in the results can be explained at least by three different reasons. First, our results included prices of capture fisheries and prices of international trade of fishery products, while Tveterås et al. (2012) only used prices of international fish trade. Thus, we include the production of all capture and aquaculture species destined for both human consumption and for the production of fishmeal and fish oil. Second, prices in origin are used here (FAO data do not include taxes) and, most importantly, prices do not include added value in the whole process of marketing of fish products. Third, our price for

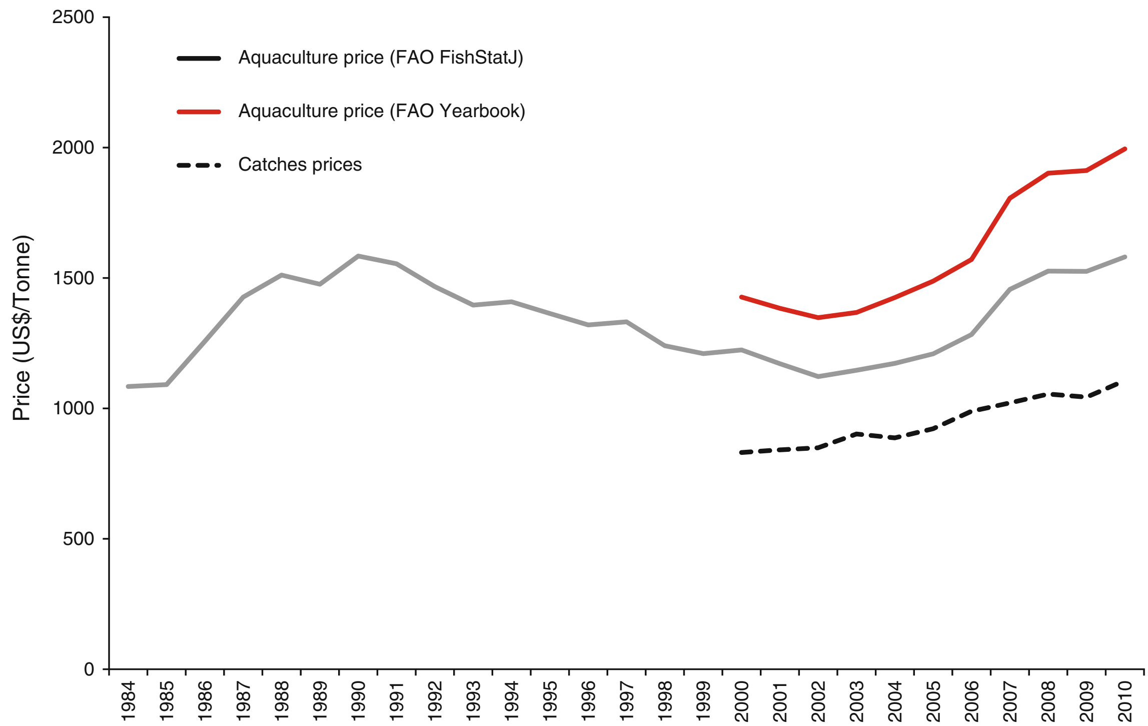

Fig. 1 Evolution of prices for wild-catches species and aquaculture production in the 1984–2010 period. *Source* own elaboration from FAO (2012a, b, 2013a, b)

captured species also includes the production of fish reduction, which is a very important part of seafood production. Production for fish reduction represents about 20 % of global seafood production, which has a very low value, making catches pull the price down.

Figure 2 offers a more detailed picture by showing the evolution of prices for both capture fisheries and aquaculture of the 10 groups of selected species. In general terms, the prices of aquaculture species are higher than those of the same species from wild capture fisheries. In addition, the prices for capture fish have followed a stable trajectory all over the 2000–2010 period, except for the group of salmon and scallops that have shown an increasing trend from 2002 onwards. On the other hand, aquaculture species present an increasing price trend, apart from the group of clams, oysters and shrimps and prawns. The prices for these groups of aquaculture species have decreased over 50 % between 2000 and 2004, after which the prices seem to stabilize. Several points are worth noting from the results provided in Fig. 2. First, the prices of aquaculture species are almost always higher than the prices of the same species when they are harvested from wild fisheries (except in the cases of the group of carps, oysters and clams and others for some years of the studied period). Second, the prices of wild-fishery catches remain constant during the 2000–2010 period. The groups of salmons, trouts and smelts, oysters and scallops show an increasing trend between 2002 and 2010. However, in the case of the aquaculture, most of species show an increasing trend in their prices, except clams, cockles and arkshells, and shrimps and prawns which decreased over 50 % between 2000 and 2004 and then show a slight increase from 2004 to 2010 (Fig. 3). Third, it should be noted that aquaculture species show a prominent increase in prices in the 2005–2010 period. This may in part be due to the price increase of the necessary inputs for aquaculture production or because of the added value incorporated through the value chain, in the group of species such as salmons, trouts and smelts and carps, tilapia and others. In fact, the prices of fishmeal and fish oil increased significantly between 1997 and 2013, from US$ 490 per tonne to US$ 2100 per tonne, respectively, which means that the prices for such inputs have increased by a factor of 4.2 (Fig. 3). Fourth, when comparing prices for both types of species we observe that prices from aquaculture products are higher than prices from capture species. We argue that at least three mutually reinforced factors may explain such different pattern, namely (i) the fact that the FCR is decreasing over time, (ii) the increase of prices over time of wild pelagic species, and (iii) the higher level of market concentration in the aquaculture industry than in the wild-catch sector throughout this period. The combined effect of these factors on the price of aquaculture production may lead in fact such price to behave quite differently than the price of captured species. These factors will be explained in detail in the following subsections.

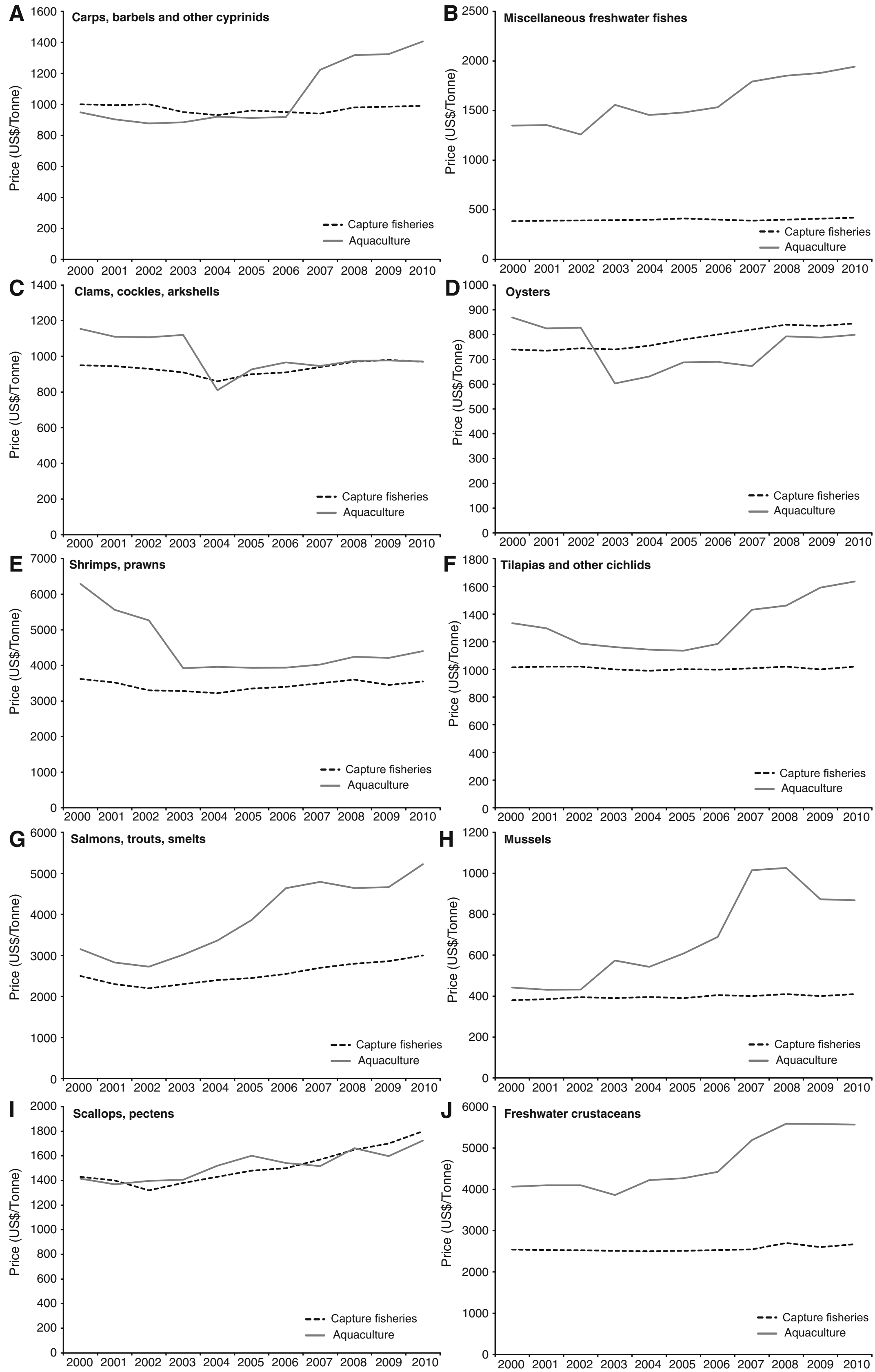

Fig. 2 Evolution of prices for selected commercial species from wild-catches and aquaculture production. *Source* own elaboration from FAO (2012a, b)

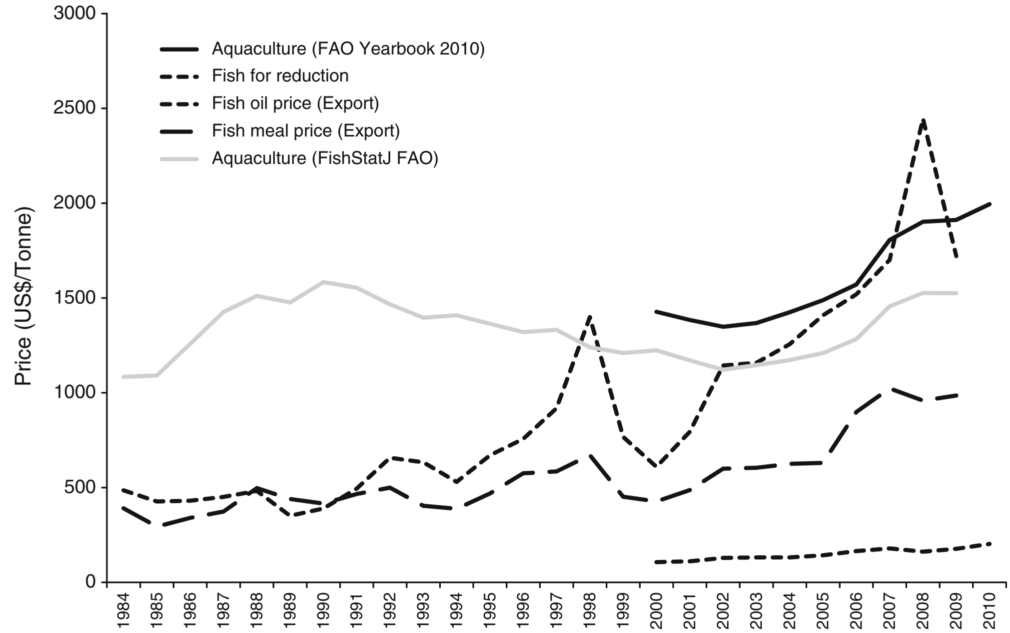

Fig. 3 Evolution of prices for species of aquaculture production, species for reduction (non-human consumption), and oil-meal seafood trade. *Source* own elaboration from FAO (2012a, b, 2013a, b)

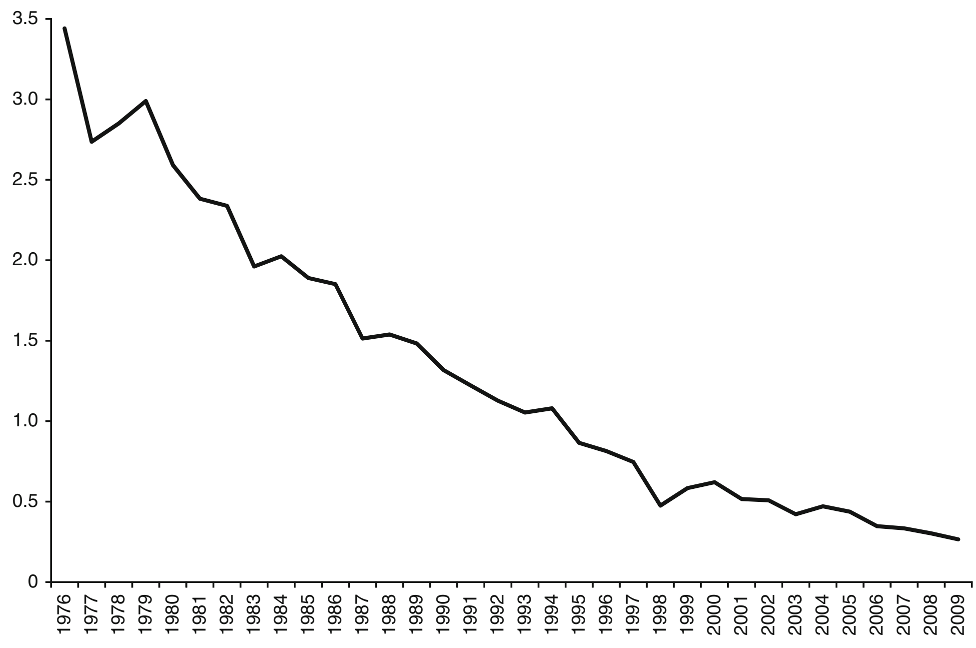

Fig. 4 Fish conversion rate of catches into aquaculture production. *Source* own elaboration from FAO (2013a, b)

Improvements in the Fish Conversion Rate: Fish-In and Fish-Out

Figure 4 shows that the fish conversion rate (FCR)[8] of wild species to feed aquaculture production has declined significantly all over the 1976–2010 period. While in 1976 the FCR was estimated at 3.44 kg of wild species to produce 1 kg of aquaculture species, in 2009 it has been reduced drastically to 0.26.

In their country-level analysis Tacon and Metian (2009) showed that FCRs for aquaculture species were significantly reduced in the 1995–2006 period due to the technological changes and improvements in the production process of the aquaculture industry. Here, we further extended these estimates of the FCRs over time until 2011. As illustrated in Fig. 4, the FCR effectively continued to decline since 2006,

[8] Recall that the FCR refers how much of fish harvested from wild fisheries it takes to produce 1 kg of farmed fish (see Footnote 5).

as Tacon and Metian (2009) already predicted. It is also important to note that the process of efficient use of resources is not a recent phenomenon. Rather, it is a process that started in the early 1970s and, except for the period 1977–1979, the improvement of FCR in the aquaculture sector has occurred continuously as depicted in Fig. 4.

The improvement of the FCRs is due to several factors that are worth highlighting. First, the stagnation of pelagic species catches due to the overexploitation problem observed in most of these stocks (Alder et al. 2008) has made the availability of pelagic species more limited. However, Merino et al. (2013) also pointed out that regional stocks can recover from climate-driven fluctuations unless these act simultaneously to an expansion in international market demand. Second, and as shown in the previous section, the price of small pelagic forage fish species in the short and long term is increasing because of the increase of production costs (mainly energy, water consumption, salaries and taxes) and the increasing costs of forage fish for direct human consumption and/or feeding (marine) species (Tacon and Metian 2009). Third, the forage fish are being used more strategically, more efficiently, and they are being increasingly substituted with vegetable protein and oil ingredients (IFFO 2013). Fourth, a greater awareness of civil society and the aquaculture industry towards sustainability of aquaculture (Naylor et al. 2009) as well as the necessity to follow the objectives of international fishing regulations are also increasing (Coll et al. 2013).

All the reasons explained above have seemed to act as a stimulus for innovation and, as a consequence, the improvements in the FCRs have been remarkable. In turn, the costs for animal and fish feed have increased. These results have considerable and important implications for the management and health of pelagic fisheries (Kristofersson and Anderson 2006). It is also important to note that if prices of fish meal and fish oil are compared with those of soybean oil—one the most traded commodities globally—they followed a similar trend and with even higher prices than those reported for soybean oil, in particular since June 2006 (Fig. 5). In fact, the export prices of fishmeal and fish oils tripled from US$ 461 per tonne to US$ 1157 per tonne between 2000 and 2010, while prices of aquaculture species only increased 24.6 %, from US$ 1224 per tonne to US$ 1525 per tonne in 2000 and 2010, respectively. Likewise, the price of fish for reduction to be used in the fishmeal and oil industry oscillated between US$ 107 per tonne and US$ 203 per tonne in the same period.

The Concentration of Wild-Fishery Catches and Aquaculture Production

Figure 6 summarizes the results for the application of the four-country concentration ratio (CR_4) and the Herfindahl index to wild-fishery catches and aquaculture production. It can be observed that the value of the CR_4 for wild catches lies below 50 at the beginning of the 1950–2010 period and falls below 40 at the end, which denotes that the degree of economic concentration in the global market of wild-fishery catches is low during the entire 1950–2010 period, and its trend is even slightly decreasing over time. The four countries that held the largest market share in 1950 were Japan (1.55 %), USA (1.36 %), USSR (0.88 %), and Norway (0.66 %). Together, these countries represented a low portion of the market. However, even though the market share of the top 10 countries has remained stable until 2010, there have been significant changes in the key players contributing to the reduced concentration degree of catches from wild fisheries. In 2010 the four countries which held 4.3 % of the global market catches were China (1.16 %), Peru (0.87 %), Indonesia (0.60 %), and USA (0.54 %).

This highlights some considerations that should be emphasized. First, the seafood markets for wild-fisheries catches are (and have been) very diversified in terms of number of countries (or, equivalently, fishing fleets). Second, developing countries (and in particular China) are having an increasing weight in seafood markets of wild catches, and only the USA continue to have an important role in the already low concentration of such markets. The rest of the developed countries represented only one-third of the market share in the 1950s. These two features abovementioned have been also observed during the 2006–2010 period.

The aquaculture industry departed from a concentration level in 1950 similar to the industry of wild-fisheries catches. However, aquaculture presents a very different pattern compared to that observed for seafood markets of wild species as can be observed in Fig. 6. In fact, the aquaculture production presents a CR_4 value of 50 in 1950 and a CR_4 value of 80 in 2010, which indicates that its concentration is higher than that observed in the capture fisheries. Thus, we can conclude that the global market for aquaculture species is behaving as an oligopoly concentrated in the following four countries (all from the developing world): China, India, Indonesia and Vietnam. Similar results are obtained when using the Herfindahl index. In this case, the value of the index for capture fisheries decreased from 4500 in 1950 to 4000 in 2010, while the index for aquaculture production significantly increased from 5000 in 1950 to 8000 in 2010.

Logically, the two cited indices only provide an overview of the market concentration in both industries that should be complemented with data for each of the value chain phases. In this respect, there are clear examples of processes of concentration in the fish distribution sector that are generating an increase in prices. Seafood retail is

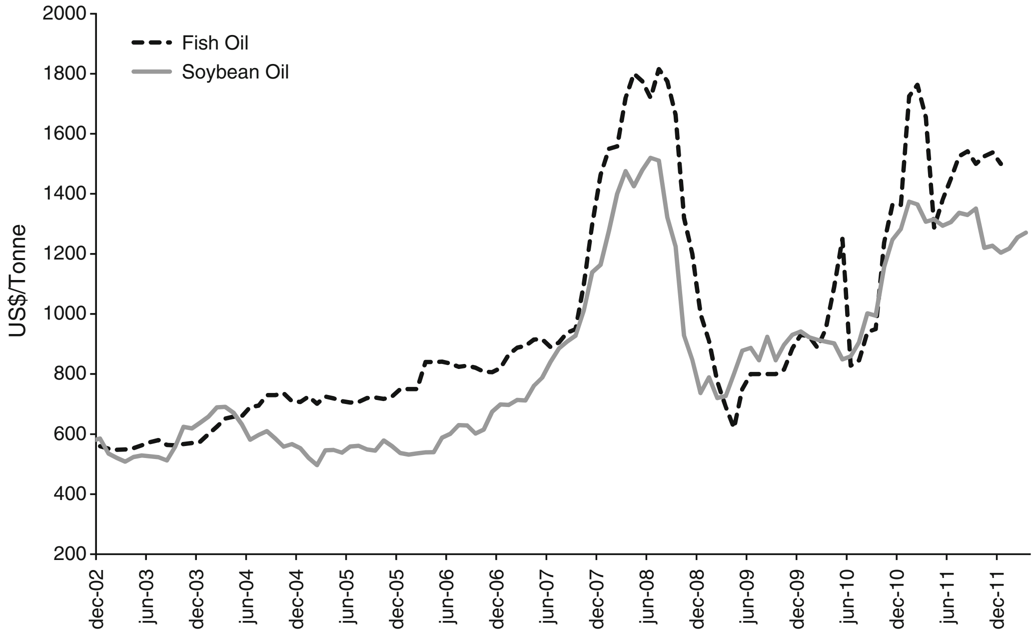

Fig. 5 Prices for fish oil and soybeal oil. *Source* own elaboration from data provided by Helga Josupeit (pers. comm.)

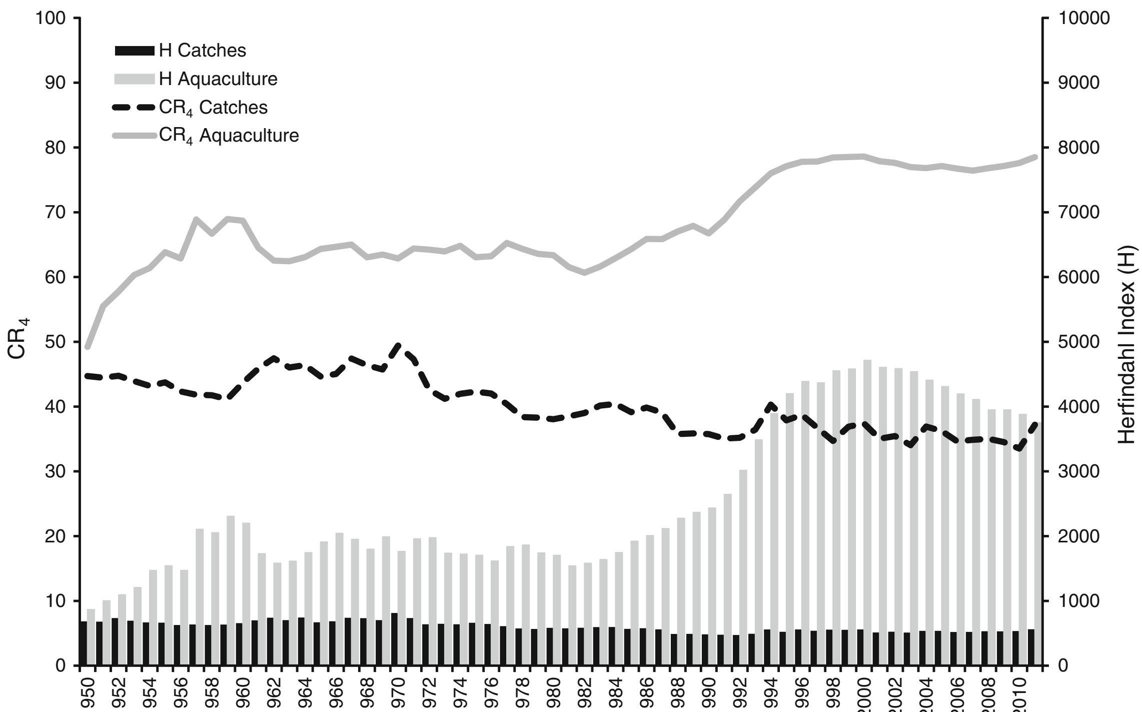

Fig. 6 The concentration degree of wild catches and aquaculture measured by the four-country concentration ratio (CR_4) and the Herfindahl–Hirschman index. *Source* own elaboration from FAO (FAO 2013a, b)

facing a process of concentration that leads to an increasing power of retailers in a few number of supermarkets and large shopping areas, even in the most traditional coastal communities (Fernández-Polanco et al. 2012, 2013). In addition, it seems that aquaculture species with large volumes of production such as salmon, bass and bream are mainly priced by supermarkets (Fernández-Polanco et al. 2013).

For example, the Spanish fish market—considered to be the biggest EU fish market and one of the most important in the world (Villasante et al. 2012)—is experiencing a process of concentration in the fish distribution sector. In fact,

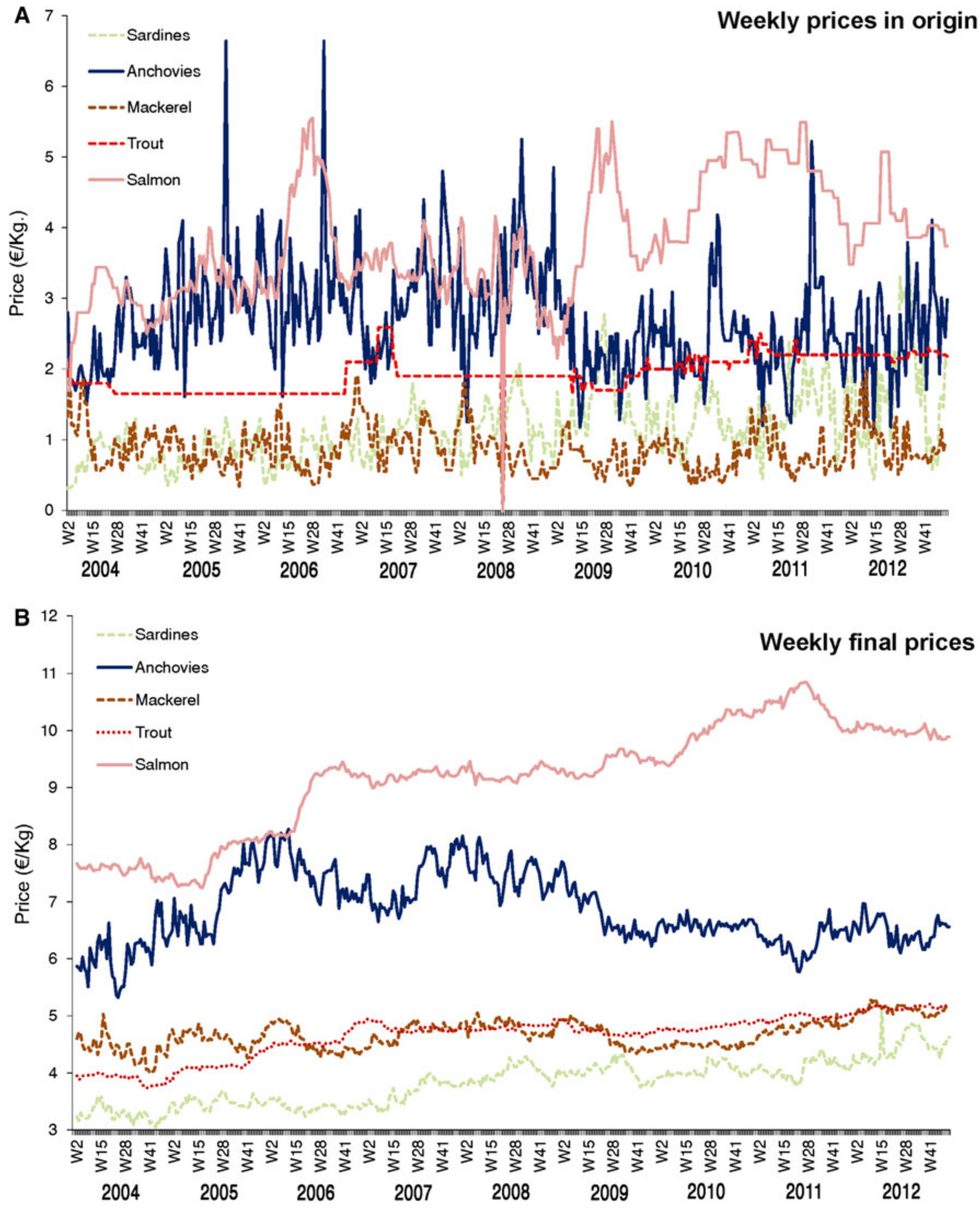

Fig. 7 Weekly prices of selected wild and aquaculture species in the Spanish seafood market (2004–2013). *Source* own elaboration from Panel Consumo Alimentario (MAGRAM 2013)

the fish distribution is mainly in the hands of the supermarkets and large shopping areas, which have increased from 62.6 % in 2004 to 71.8 % in 2011 of market share (Fernández-Polanco et al. 2013).

It is also important to analyse the prices at origin and destination of some of the main pelagic species (anchovies, mackerel and sardines) used not only for human consumption but also for aquaculture (salmon and trout) in Spain, to test the above-mentioned findings in a particular market. If we perform such analysis for the Spanish fish market in the period 2004–2013, we obtain three main features that are summarized in Fig. 7A. First, all species

undergo, to a greater or lesser extent, an increase in prices at origin. Second, on average, the prices of aquaculture species are slightly higher than those of captured species. Third, the prices of aquaculture and captured species are both surprisingly volatile over time. These findings are then confirmed in the Spanish seafood market.

When comparing Fig. 7B with prices at destination, several considerations should be noted. First, there is a clear trend of price increase of aquaculture species that is not necessarily the case for capture species. Some species such as anchovies even show a downward trend. Second, the level of volatility in prices of both type of species are lower than prices at origin. Third, the observed differences between the prices at the beginning and at the end of the 2004–2013 period are higher in cultured than in wild species. Fourth, prices at destination for aquaculture species are increasing at a faster rate than prices for capture species. These results highlight that the fish distribution centers (particularly supermarkets and hypermarkets) are clearly having a positive impact on the increase of fish price, possibly due to the higher concentration of the aquaculture market.

Furthermore, it is interesting to observe the evolution of average prices of these species in the different fish sale channels (supermarkets, hypermarkets and markets/fishmongers). Table 1 shows that prices for pelagic and aquaculture species in Spain are increasing over time. Second, the average price of pelagic species sold in markets/fishmongers increased by 22 % between 2004 and 2012, while the price of aquaculture species increased by 30 % in the same period. At the same time, the average price for aquaculture species in supermarkets were 37.7 % higher in 2012 than in 2004, whereas that for capture species only 7 % higher. Third, there is a positive relation between the size of the area to sell the seafood products and the price difference. This pattern is particularly relevant in pelagic species for which prices may even increase up to 40 % between the observed price in small markets/fishmongers and supermarkets. However, the prices of aquaculture species do not follow a similar tendency as observed in wild species (see Table 1).

Table 1 Average prices (in € per kg) for selected wild pelagic and aquaculture species in the Spanish seafood market

	Supermarkets		Hypermarkets		Traditional			
					Small markets		Fish shop	
	2004	2012	2004	2012	2004	2012	2004	2012
Wild pelagic species	8.24	8.81	9.51	10.1	6.49	7.96	5.13	6.30
Anchovies	18.10	18.20	21.20	21.9	11.9	14.2	7.71	9.03
Horse mackerel	3.57	3.61	3.82	3.87	3.99	4.56	3.94	4.63
Sardines	3.04	4.63	3.50	4.60	3.58	5.13	3.75	5.25
Cultivated species	3.23	4.43	3.28	4.07	3.53	4.39	3.53	4.61
Salmon	5.96	7.69	5.81	7.11	6.50	8.12	6.47	8.23
Trout	3.74	5.59	4.02	5.09	4.08	5.05	4.12	5.59

Source own elaboration from Panel Consumo Alimentario (MAGRAM 2013)

DISCUSSION

Management Implications for Forage Fish

There has been great concern that the increasing demand for fishmeal will place stress on the world's pelagic fisheries and may undermine the sustainability of aquaculture systems (Naylor et al. 2000; Alder et al. 2008). However, progress has been made in the development of new technologies and improvements in the resource use, which has led to important changes (Tacon and Metian 2009; FAO 2012a). For example, improvements have been made regarding the FCR rate from wild species that are used as feed for cultivated species. In addition, there have been changes in the use of both fishmeal and fish oil, while 98 % of fishmeal was used in pig and chicken diets in 1960, by 2010 that had shrunk to 25 %, and 73 % of fishmeal was being used in aquaculture feed (IFFO 2013).

The main reasons for the price increase of forage fish are probably a combination of very high demand and reduced fishing quotas (Globefish 2013a). While some management efforts have led to improvements in reducing exploitation rates, some forage fish stocks are still under high exploitation rates and environmental changes of marine social-ecological systems (Merino et al. 2013). As a consequence, fish oil could become limiting as the consumption of forage fish continues to increase as well as the demand for human consumption, pending availability of new sources. Increasing demand for fish oil for direct human consumption would also contribute to increasing fish oil prices and lower inclusion rates in feeds for farmed seafood.

Although there has been a significant reduction of the FCR in the 1976–2010 period, the pressure on forage fish stocks has not been reduced, not only for feeding aquaculture production but also for human consumption. The catches of pelagic species declined from 24 to 20 million tonnes between 2002 and 2012 (FAO 2013a), and the prices for most pelagic species have increased over time.[9]

[9] To take an example, the growth of the monthly average price of the main small pelagic species (Globefish 2011a, b, 2013a, b) was as follows: (a) world imports of canned sardines: US$ 0.43 per kg in 1999 to US$ 0.86 per kg in 2009, (b) world imports of fresh and frozen herring: US$ 0.48 per kg in 1999 to US$ 0.76 per kg in 2009, (c) whole herring prices (in Norway, origin Norway): US$ 0.40 per kg

The Combined Effect of FCR, Input Costs, and Economic Concentration on Prices of Aquaculture Species

Our results indicate that the concentration of the aquaculture industry is greater than that for wild catches. Indeed, an increasingly smaller number of operators (countries) is concentrating weight (particularly China) in the aquaculture industry. This process is appearing in most major world fish markets, and is particularly evident in the distribution channels where the number of intermediaries tends to decrease and to concentrate even more in large supermarkets. Obviously, this has repercussions on the ability of the supply side to set prices. This process of concentration is causing not only a higher price for aquaculture production than for wild catches, but also a greater increase margin of prices over time. Furthermore, the prices for pelagic species for human consumption are substantially higher in supermarkets, that is, as the size of seafood retailers increases; the bargaining power of large operators is also increasing in relation to the capacity of negotiation of producers.

Evidently, there are other factors that cause an impact on prices of aquaculture species making these prices to behave quite differently than prices of wild-catch species. On one hand, the technological improvement in the production processes and a better scientific knowledge of how to reduce potential diseases in the cultivated species lead to a decrease on prices of aquaculture species. On the other hand, the trend of increasing prices on fishmeal and fish oil causes an increase in the prices of aquaculture species.

In sum, the fact that in the 1995–2010 period the prices of aquaculture species were higher than those of the same species when harvested in wild fisheries can be explained by the interplay of these three factors: namely the (decreasing) rate of wild-fish transformation, the (increasing and volatile) prices of wild species used to feed farmed species, and the higher level of economic concentration in aquaculture production than in wild-catch industry.

Finally, we would like to address some of the limitations in this study. First, the interactions between wild and cultivated species are beyond a price analysis (and the underlying forces contributing to price formation) as performed here. Other cultural, social, and economic factors also have an impact on the consumption (and prices) of different seafood products. Second, in the analysis of the behavior of fishing markets, production and consuming strategies of different seafood operators may considerably vary at national, regional, or local levels. Third, the analyses of fisheries market concentration and its relation to the price evolution are more accurate and robust if one adopts case study approach, that is, species by species. These and other related questions are left for further analysis in future research.

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Footnote 9 continued
in 1999 to US$ 1.35 in 2009, (d) world imports of fresh and frozen mackerel: US$ 0.66 per kg in 1999 to US$ 1.04 in 2009, (e) fresh herring (Sardinella eba): US$ 0.77 per kg in mid 2005 to US$ 1.77 per kg in mid 2011, (f) fresh horse mackerel: US$ 0.42 per kg in 1999 to US$ 1.17 per kg in 2009, (g) canned sardines in oil skinless/boneless: US$ 40 per kg in 1999 to US$ 52 per tonne in 2013.

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