J Parasit Dis (Oct-Dec 2017) 41(4):913–918
DOI 10.1007/s12639-017-0938-y

REVIEW ARTICLE

An overall estimation of losses caused by diseases in the Brazilian fish farms

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Received: 24 March 2017 / Accepted: 3 July 2017 / Published online: 7 July 2017

Abstract Parasitic and infectious diseases are common in finfish, but are difficult to accurately estimate the economic impacts on the production in a country with large dimensions like Brazil. The aim of this study was to estimate the costs caused by economic losses of finfish due to mortality by diseases in Brazil. A model for estimating the costs related to parasitic and bacterial diseases in farmed fish and an estimative of these economic impacts are presented. We used official data of production and mortality of finfish for rough estimation of economic losses. The losses herein presented are related to direct and indirect economic costs for freshwater farmed fish, which were estimated in US$ 84 million per year. Finally, it was possible to establish by the first time an estimative of overall losses in finfish production in Brazil using data available from production. Therefore, this current estimative must help researchers and policy makers to approximate the economic costs of diseases for fish farming industry, as well as for developing of public policies on the control measures of diseases and priority research lines.

Keywords Aquaculture · Diseases · Economic losses · Fish production

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Introduction

The world fisheries production has levelled off and most of the main fishing areas have reached their maximum potential. In contrast, the global human population is increasing; thus, the demand for aquatic food products also increase (FAO 2014; Bueno et al. 2015; Kato and Freitas 2015). Sustaining fish supplies from capture fisheries will not be able to meet the growing global demand for aquatic food. In contrast, the aquaculture is a great opportunity to supply the demand by aquatic food in most regions of the world; thereby it presents the fastest growing food-producing sector in the world (Subasinghe et al. 2009; Bueno et al. 2015), due to increasing of food requirement of healthful protein origin (Kato and Freitas 2015).

Global aquaculture production attained 90.4 million tons in 2012, generating an incomes US$ 144.4 billion, and the production of food fish was 66.6 million tons (FAO 2014; Sosa-Villalobos et al. 2016). Aquaculture is at a global level the most dynamic food sector, experiencing an annual average growth rate of 8.8% over the past three decades. This activity has also increased in terms of social and economic impact due to food production contribution to livelihoods and income generation (Sosa-Villalobos et al. 2016) for population of various region around the world. However, one of the major concerns faced by the aquaculture production is related to parasites and diseases outbreaks (Mustafa et al. 2001; Martins et al. 2008; Sahoo et al. 2013; Bagum et al. 2013; Monir et al. 2015). A variety of environmental and biological factors, husbandry and management practices may influence the abundance and impacts of diseases in farmed fish (Mustafa et al. 2001; Tavares-Dias 2011; Bagum et al. 2013). Information on impacts of the economic losses may help to develop management strategies against diseases in fish farms and to reduce the magnitude of the parasitism.

The parasitism and disease outbreaks have negative impacts on fish production, but economic losses as a result of these problems are difficult to adequately assess. Estimating the disease's economic impact is handicapped by the lack or inadequate information on the morbidity, mortality and other costs in finfish production. Diseases can reduce reproductive performance and have a negative impact on feed conversion efficiency leading to reduced growth and overall performance of cultured fish. Economic losses caused by certain diseases have been estimated for some regions with significant costs. Diseases caused serious economic losses to finfish aquaculture in around the world (Mustafa et al. 2001; Johnson et al. 2004; Sahoo et al. 2013; Monir et al. 2015), globally estimated in US$ 1.05 to US$ 9.58 billion/year (Shinn et al. 2015a). The disease outbreaks are increasingly recognized as a significant constraint to production of finfish, and some estimation are available on economic losses for some countries or regions (Mustafa et al. 2001; Johnson et al. 2004; Sahoo et al. 2013; Saad et al. 2014; Monir et al. 2015). Models have been used considering the costs and marginal benefits to measure a specific disease control (Mustafa et al. 2001; Costello 2009; Sahoo et al. 2013; Saad et al. 2014). Indirect and direct losses due to sea lice species in salmonid aquaculture have been globally estimated to be greater than US$ 100 million annually (Johnson et al. 2004). To date, pancreas disease in farmed Atlantic salmon (*Salmo salar*) was estimated in 55.4 million Norwegian kroner (Pettersen et al. 2015).

In Brazil, more than 70% of fish production comes from intensive fish farming. This is one of the South America's leading fish producing countries and its total production of native and non-native species shows an increased trend in total production greater than 1.4 million tons in 2014 (IBGE 2014). However, this produced volume is not enough to supply the domestic market, still very dependent on imports. The per capita mean consumption of fish per year is of about 9 kg per year, but the consumption in the North region (Brazilian Amazon) is higher, 24.6 kg per year (Kato and Freitas 2015), and tends to increase along the country. In fish farming activity, there are great number of people direct and indirectly involved, which depend for its economic and financial survival. Economic activity is the most dynamic food sector, experiencing an annual average growth rate of 13.4%. Fish farming is practiced at various scales of production in virtually in all regions of country. In that sense the small-scale enterprises with limited resources or the named "homely fish farm" is the most practiced for thousands of families (MPA 2013).

In the Brazilian territory few reports of farmed fish mortality have been recorded, as for example those caused by bacterial (Kubitza 2005; Martins et al. 2008; Figueiredo et al. 2012; Silva et al. 2012; Pádua et al. 2014) and parasitic diseases (Martins et al. 2000, 2001; SantÁna et al. 2012; Silva et al. 2012; Moreira et al. 2013; Pádua et al. 2013, 2015; Valladão et al. 2013, 2014; Videira et al. 2016). Large-scale mortality is rarely registered despite of their non-diagnosed occurrence in the country. However, the economic impacts of diseases on Brazilian freshwater finfish remains unknown. The economic impacts caused by diseases on fish growth, epizooties, cost of production and prophylactic treatments, and loss of product value need to be estimated. Due to the importance of these impacts caused in production, this study was designed to estimate the costs related to economic losses caused by diseases in farmed fish in Brazil.

Estimation of economic losses caused by diseases

In period of August to November 2016, official data of the Brazilian Federal Government on the account of the fish farm in Brazil were herein used to estimate the economic costs. There are about 16,100 fish farms, but the majority (about 15,000) are small fish farms (until 499 hectares each), 1000 are medium fish farms (>500 hectare) and 100 are large fish farms (5000 hectare) (MPA 2013). From these data, it can be estimated that the country uses a total area of culture of approximately 2 billion hectares to produce 10 billion fish per year at a mean stocking density of 5 fish/m^2. We also used estimative from Kubitza et al. (2013) who reported that about 15% of losses due to mortality caused by diseases in fish of net-cages and ponds can occur. In addition, labor cost considered two permanent staff members, being a field manager and a helper, was estimated in monthly cost of US$ 874.88 and US$ 473.89, respectively (Kubitza et al. 2013); yet, there are day laborers hired during ponds preparation and harvesting at a daily cost of US$ 14.78, which was based in data of Costa et al. (2016). The losses as a result of infectious and parasitic diseases were calculated considering therefore fish mortality with expected loss of 15% of total production (i.e. costs with fingerlings purchase and equipment, feed, feed additives, labor, mortality, feed conversion rate, and growth loss), and overall costs of this production per fish was estimated in US$ 0.28 per fish. However, expenditure towards drugs and chemicals applied for prevention and treatment of diseases, as well as conservation of the equipment and ponds were not considered.

The Brazilian fish farming is gaining great importance in food production and with this expansion of intensive culture, problems and disease-related losses have become increasingly frequent. In some extreme cases, these losses on fish production come even to derail the continuity of small fish farming (Silva et al. 2012; Kubitza et al. 2013). Although diseases are common in farmed fish in Brazil few studies recorded mortalities of fish, making difficult to estimate the economic costs caused by losses in total production from country. Table 1 shows an estimative of direct losses due to parasitic and bacterial diseases and do not account the secondary losses resultant of the productivity and use of inputs in production (ration, chemicals products or drugs for controlling or treating parasitic diseases, and other variable costs). However, feed conversion rate, productivity and growth loss were not estimated (Table 1), contrarily to that estimated in other countries (Mustafa et al. 2001; Johnson et al. 2004; Costello 2009; Sahoo et al. 2013; Bagum et al. 2013; Monir et al. 2015). Calculated values in US$ 5.05 million are sub estimated for the overall economic costs in Brazil, because the production costs were not considered. In addition, there are yet a lack of reliable disease data for economic analyses, with inadequate data to allow marginal analyses of disease control in Brazilian fish farm. Data on the efficacy of disease control methods are also lacking.

A precise dataset on mortality outbreaks of freshwater farmed fish species could be reported using surveys on the occurrences, but unfortunately these data are scarce and have been not made for any disease in Brazil. A combination of information from the scientific research and some official data must be used in the analysis of economic costs. In Brazil, diseases account for an annual loss of about 15% of production for freshwater fish farm. Thus, we estimated a loss of about US$ 84 million, provoked direct and indirectly by diseases in farmed stocks (Table 2). Therefore, this study clearly demonstrates that parasitic and bacterial infections are an important source of economic loss in Brazil. Without a step change in management priorities and a concentrated move towards more integrated pest management strategy, it is evident that as the Brazilian fish farm industry grows and intensifies, disease outbreaks will similarly rise as will the attendant economic costs to infections. Large losses of production in regional or national scale can result in less fish for market and raising prices.

Currently, the increase annual growth rates of the global population have led to growing of aquaculture industry due to larger global demand for farmed fish for food, fishmeal and fish oil, putting thereby a strong unsustainable strain on the world's natural food resources. Nevertheless, diseases have a major impact on global finfish, having significant effects on fish farm production, sustainability and economic viability. Disease impacts are related to the pathogen and can be considered to be either unpredictable/sporadic or predictable/regular (Shinn et al. 2015b). Indirect and direct estimative of losses due to different sea lice species in salmonid aquaculture industry were greater than US$ 300 million annually (Johnson et al. 2004; Costelo 2009). For India, Sahoo et al. (2013) estimated that the loss due to argulosis disease were US$ 615.0 ha^{-1} $year^{-1}$ for carp culture and 82% for reduced growth rate, 8% for carp mortality and 10% for cost of drugs used for controlling the argulosis (*Argulus* spp.). Current studies suggest that parasites account for an annual loss of 5.8–16.5% of UK aquaculture production considered all the species in both freshwater and marine aquaculture (Shinn et al. 2015b). Diseases and aquatic environment imbalance are constant in intensive fish farming production. The management strategy to improve the fish health status must be emphasized.

Disease outbreaks in finfish are frequent due to several factors on production system that result in heavy infections leading to high fish mortality. The economic potential of fish production is highly dependent on the limiting factors, since several factors have contributed to increase the occurrence of diseases in Brazilian finfish aquaculture. Among such factors increased stocking density favors the rapid spread of pathogens, nutritional deficiency; inadequate husbandry management responsible for stress, low water quality and low temperatures can cause debilitation of finfish, favoring the pathogens infection (Martins et al. 2000, 2001, 2002; Tavares-Dias 2011; Sant́Ana et al. 2012; Kubitza et al. 2013). Disease problems constitute significant economic losses in fish production in biomass that consist mainly in mortality, decreased growth and productivity, besides costs of production. In contrast, the Brazilian population is increasing and will have a higher demand for food of protein origin, including fish.

Conclusions

The economic impacts of diseases in finfish were estimated for the industry of the Brazilian aquaculture. Such estimative of direct and indirect costs of mortality in finfish production may support decisions concerning to disease control and priority lines of research. The main social impacts in finfish culture are to create jobs and livelihood, and although disease outbreaks are increasingly recognized as a significant constraint to production of fish farming, the social impacts have been never properly quantified. Furthermore, other negative impacts on production of fish farming are perceived in decrease of number small enterprises. Nevertheless, this activity provides also an indirect livelihood for a great number of people, such as suppliers, administrators and processors. An improved growth of production and increased survival of finfish will have great impact in the Brazilian annual throughput, and not enhance this potential is an important loss for industry of fish farming. These results also indicate that improving finfish

Table 1 Some major losses of freshwater and marine finfish induced by diseases in Brazil

Hosts	Parasites	Production loss (ton)	Estimated loss (US$, million)	References
Piaractus mesopotamicus, *Colossoma macropomum*, *Cyprinus carpio*, *Leporinus macrocephalus*, *Oreochromis niloticus*, hybrid tambacu	*Ichthyophthirius multifiliis*, *Piscinoodinium pillulare*, monogeneans, *Lernaea cyprinacea*,	10,000	0.28	Martins et al. (2000)
C. macropomum	*Neoechinorhynchus buttnerae*	1.12	0.002	Malta et al. (2001)
P. mesopotamicus, *C. macropomum*, *L. macrocephalus*, *O. niloticus*, hybrid tambacu, *Procilodus lineatus*	*P. pillulare*	10,000	0.28	Martins et al. (2001)
P. mesopotamicus, *C. macropomum*, *L. macrocephalus*, *O. niloticus*, hybrid tambacu	*I. multifiliis*, trichodinids, *P. pillulare*, *Henneguya piaractus*, monogenean, *L. cyprinacea*	1.2	0.29	Martins et al. (2002)
O. niloticus	*I. multifiliis*, *P. pillulare*, monogeneans, *Epistylis* sp., trichodinids, *Aeromonas spp., Pseudomonas fluorescens, Flavobacterium columnare Streptococcus* sp.	5000	4.0	Kubitza (2005)
O. niloticus	*Aeromonas caviae*	0.56	0.013	Martins et al. (2008)
C. macropomum, hybrid tambacu	*I. multifiliis*, *P. pillulare*, monogeneans	0.55	0.012	Tavares-Dias (2011)
Oncorhynchus mykiss	*Weissella* sp.	Not-informed		Figueiredo et al. (2012)
Hybrid surubim	*Aeromonas hydrophila*	20.0	0.16	Silva et al. (2012)
P. mesopotamicus	*P. pillulare*, *Henneguya* sp.	3.3	0.009	SantÁna et al. (2012)
O. niloticus, *P. mesopotamicus*, *Gymnotus* aff. *inaequilabiatus*	*Chilodonella hexasticha*	Not-informed	–	Pádua et al. (2013)
Rachycentron canadum	*Amyloodinium ocellatum, Neobenedenia melleni*	Not-informed	–	Moreira et al. (2013)
Pseudoplatystoma reticulatum	*Citrobacter freundii*	Not-informed	–	Pádua et al. (2014)
P. lineatus	*Trichodina heterodentata*	Not-informed	–	Valladão et al. (2014)
O. niloticus	*Paratrichodina africana*	Not-informed	–	Valladão et al. (2013)
Astyanax altiparanae	*Acusicola* sp.	Not-informed	–	Pádua et al. (2015)
C. macropomum	*Myxobolus*, *Ellipsomyxa*, *Henneguya*, *Thelohanellus*	Not-informed	–	Videira et al. (2016)
Total	–	25026.3	5.05	–

Hybrid tambacu: *P. mesopotamicus* male x *C. macropomum* female. Hybrid surubim: *Pseudoplatystoma corruscans* male x *P. reticulatum female*

Percentage of fish losses and fish final production not informed in these studies

Table 2 Estimation of direct costs due to losses by diseases in finfish in Brazil

Factors	Values
Average husbandry area (hectare, billion)	2
Stocking density (fish per m^2)	5
Number of individuals cultivated (billion)	10
Mean price of production per fish (US$)	0.28
Average mortality (%)	15
Total number of dead fish per year (million)	300
Total loss in fish production per year (US$, million)	84

health and management has substantial potential to improve the economy of fish farming industry. Finally, further studies must be carried out to pinpoint how the losses by mortality are related to different diseases in finfish. Although many disease events are complicated by the complex interplay of numerous factors making it difficult to calculate the precise costs attributable to each pathogen, it must be encouraged the collection of these data.

Acknowledgements The authors thank National Council of Scientific and Technological Development for research grant to M. Tavares-Dias (CNPq, 303013/2015-0) and M. L. Martins (CNPq, 305869-2014-0).

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