UNIVERSIDADE FEDERAL DO PARANÁ
CURSO DE ZOOTECNIA

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INTERNATIONAL OPPORTUNITIES IN GENETIC IMPROVEMENT OF AQUACULTURE AND SHEEP PRODUCTION, TWO SUPPLY CHAINS OF GREAT POTENTIAL IN BRAZIL

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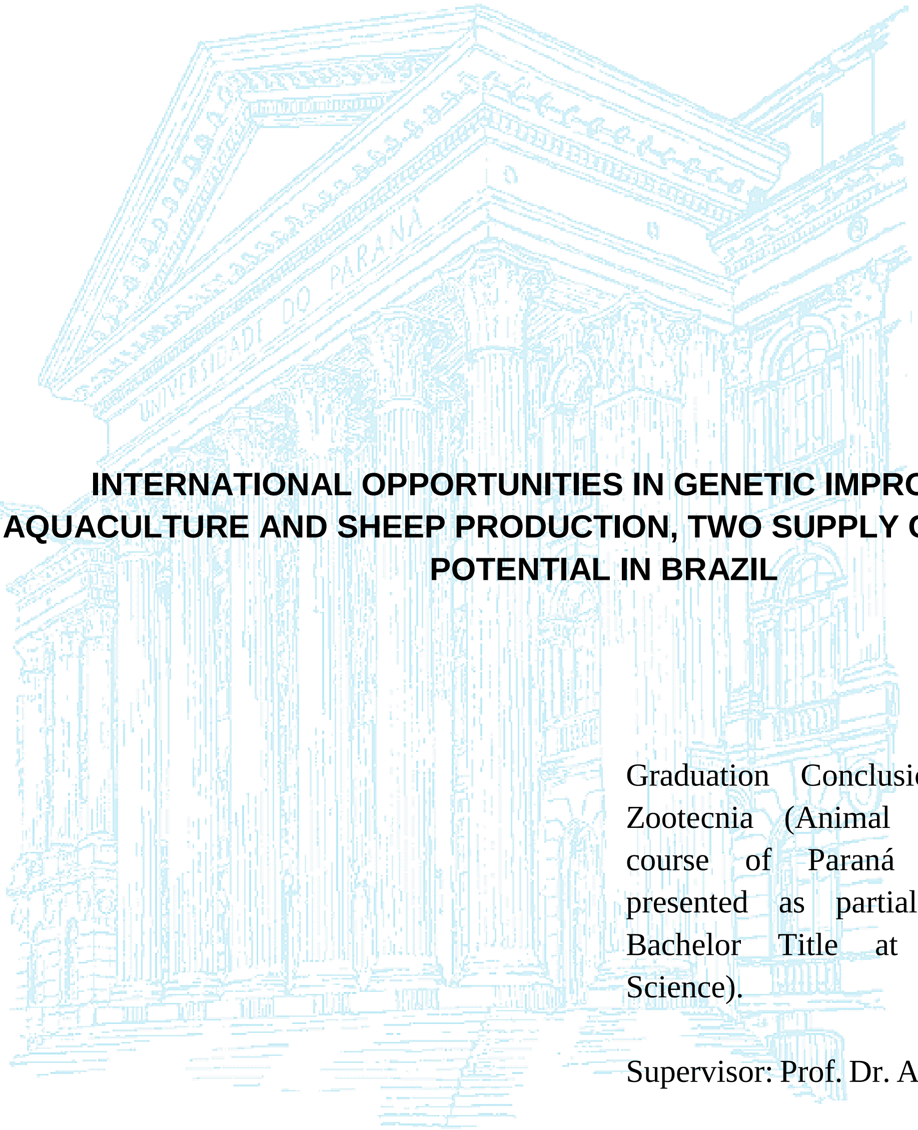

INTERNATIONAL OPPORTUNITIES IN GENETIC IMPROVEMENT OF AQUACULTURE AND SHEEP PRODUCTION, TWO SUPPLY CHAINS OF GREAT POTENTIAL IN BRAZIL

Graduation Conclusion Term Paper in Zootecnia (Animal Science) Graduation course of Paraná Federal University, presented as partial request to obtain Bachelor Title at Zootecnia (Animal Science).

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DEDICATION

To my parents, Waleska e Fabian, that even far away physically, have always been present in the best way, with all my love,

I dedicate.

ACKNOWLEDGMENTS

To everyone who direct or indirectly contributed to this work realization.

To Professor Antonio Ostrensky, that contribute to my trip to New Zealand, and was always helping and advising me, with his entire patient.

To all people from AbacusBio, Tim, Fiona, Grace, Simon Glannie, Simon Ryan, Natalie, Cheryl, Nadia, Luke, Mark, Anna, David and all that received me with care and attention and in some way, helped me. Especially to Peter Amer, who not just received me at AbacusBio, but also guide me and taught me in many moments, always with patient.

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And to all my friends, that always supported and advised me, even indirectly to persue all the way to the end: Giovana (always exited with everything, spreading her happiness), Thiago (always saving my computer), Claudio (making me think about everything on different views, helping me to get my visa), Ana Rosalia, Ana Retora, my aunt Alessandre and Mylene and all the others that have always been presents in some good way in my life.

“Works of art make rules. Rules do not make works of art.”

Claude Debussy

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SUBJECT INTRODUCTION

Genetic improvement programmes have provided substantial contribution to livestock viability around the globe. It has been used to improve quality and productivity in a rational way, which allow profitability and sustainability at the same time. There are countries that have achieved high level of development in the aquaculture and sheep industries, using breeding programmes systematically. Countries such as New Zealand and Australia developed expertise and technology to use genetic improvement to increase productivity and profitability of their animal breeding species. According to Ribeiro & Legat (2008), genetic improvement programmes present highly desirable attributes such as:

- Power to modify animal's makeup to achieve an objective or suit an specific environment.
- Productivity improvement, production confidence and consistency, since the gains are permanent.
- Increased tolerance to existing and emergent pathogens and to environmental challenges.
- Increased rates of positive return on the investment.
- Reducing the distance between offer and demand, without environmental negative impacts.
- Tool for controlling the level of inbreeding in the production system.

All of these attributes can directly help on the establishment of viable livestock production. Especially when production systems are supported by technology that combines well-structured breeding programmes and genetic resources management. In developed countries, where animal breeding is largely applied on improvement of production, rates of genetic gain through selection vary on average from 1 to 2% annually (Pereira, 2008).

On the other side, improved livestock production in emerging countries, such as Brazil, generally happens based on horizontal expansion, and frequently with non-optimal economic efficiency. The poultry sector is an exception, once the vertical integration in this industry denotes good establishment and organization of the entire sector. According to Silva (2009), the first attempts of genetic improvement of poultry in Brazil took place at the 50s, aiming commercial laying hens. However, in both aquaculture and sheep sectors, which also have potential in Brazil, the model adopted for expansion remains the horizontal expansion model. This model does not allow progress based on development and structure that matches the natural and structural potentialities available in the country.

Genetic improvement in Brazilian aquaculture

The development of aquaculture value chains underlined by genetic improvement programmes is still relatively limited in Brazil. Only two species present well-structured breeding programmes based on genetic improvement and selection. Coincidentally, these two species together lead aquaculture production in the country. Nile Tilapia (Oreochromis niloticus) and the white shrimp *Litopenaeus vannamei* are well adapted to the country's environment and cultivation systems. Aquaculture production of these species corresponds to more than 60 percent of the total harvest aquaculture volume in the country (Nunes & Rocha, 2015), placing Brazil among one of the main producers of *L. vannamei* in the world (FAO, 2015b). However this amount represents less than 1% of Brazil's total international trade, which total amount was approximately US$225 billion of exportation and US$229 billion of importation in 2014 (MDIC, 2014). Besides, both tilapia and *L. vannamei* are exotic species, and genetic progress for these species has been generated overseas. In Brazil, projects encouraging genetic improvement programmes of native species with potential to be farmed are sparse and depend largely on public research and governmental resources. Currently, breeding objectives and selection indexes are non-existent for native species suitable for aquaculture in Brazil .

Genetic improvement programmes for sheep in Brazil

The development of the Brazilian sheep industry is not unlike to that of aquaculture. Because of the wool crisis in the beginning of 90's, many sheep flocks in the main production areas of South Brazil gave up on the activity, resulting in a dramatic decrease in the number of wool flocks. This scenario, associated with an increase of the demand for ovine meat created conditions for the sheep meat industry to strengthen (Ono, 2011). Over the years, the Brazilian sheep industry has pursued to establish a structure that allows increase in productivity and profitability of sheep farming. However, the development process has not been exploited efficiently to ensure profitability across the value chain. One of the reasons is that there is a lack of genetic improvement underlying the breeding structure of the industry and limiting achievement of significant progress, both genetically and phenotypically. According to Pereira (2008), despite some attempts to implement sheep breeding programs in Brazil, there is lack of organization and enlightenment of the farmers and breed associations, which overestimate the appearance and breed profile of the animals, leading to believe that select this kind of animals is genetic improvement. This kind of misleading decisions cause damage to the development of the national sheep production. Currently, sheep meat market in Brazil, even with low domestic consumption comparing to the other meat sources, presents over demand, determining need for imports of the product (Viana, Moraes, & Dorneles, 2015).

Aquaculture and sheep genetic improvement around the world

Countries like New Zealand and Australia, with developed sheep industries, rely largely on genetic improvement programmes, which focus in economically important traits to ensure profitability of their value chains (Garrick, Blair, & Clarke, 2000; Brown et al., 2007). Genetic improvement programmes in sheep are present in many places of the world with the intent to improve productivity, e.g. South Africa (Schoeman, Cloete, & Olivier, 2010), US (Notter, 1998), Europe (Croston et al., 1980) and Norway (Eikje, Ådnøy, & Klemetsdal, 2008). New Zealand sheep breeders have a good track record in applying cost effective technologies to assist with the genetic improvement of their stock, with current annual rates of genetic gain in the New Zealand sheep industry likely to be between 0.1 and 0.2 genetic standard deviations (Blair & Garrick, 2007).

Genetic improvement programmes in aquaculture exist to enhance farmer profits in the short, medium and long term by maximising genetic gain per year while preserving the potential for future genetic gain (Camara & Symonds, 2014). The gains with genetic improvement at aquaculture chain around the globe are mainly observed at salmon, tilapia and shrimp industry. According to Gjedrem (2015), the Norwegian Salmon industry now produces more than 1.3 million tons per annum and, through use of genetically improved stocks, saves in the range of 120.000 tons of feed annually (amounting to ~US$700-800 million in reduce annual feed costs[1]). The production output doubled and helps to save in labor cost as reduced mortality due to shorter production cycle with improved genetic material.

Investment in effective breeding programmes can give high economic returns in future generations because genetic improvement is cumulative over generations and also permanent and sustainable (Gjedrem, Robinson, & Rye, 2012). Because of that, genetic improvement programmes can be a key to organized and focused development of any animal breeding supply chain with potential to be improved such as aquaculture and sheep industry at Brazil. It has been proven that economic returns are possible in both cases. Nevertheless, it is important for the country to be supported by an experienced country to develop and implement genetic improvement programmes for these industries, allowing to solve problems that have been preventing progress.

There is opportunity for Brazil to count with abroad technology to build up and improve its economy through aquaculture and sheep supply chains, in an efficient and well-structured manner, adding value and productivity, consequently, profitability without damage to the social element and environmental sustainability. For other countries, such as New Zealand, there is opportunity to explore new markets and establish a strong relationship between countries to explore future business opportunities within Brazil and abroad.

This study was developed with the intention to help to better understand market opportunities between Brazil and New Zealand. The opportunities are focused on genetic improvement programmes to aquatic species and sheep as a tool and product to be used by Brazil with New Zealand support through genetic improvement initiatives.

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[1] US$ exchange referent to June 2015.

OBJECTIVES

1. General

To present arguments to emphasize the importance of knowledge shared between New Zealand and Brazil to contribute to social, economic and environmental sustainability of the aquaculture and ovine supply chain development, two emerging productive chains in Brazil.

2. Specific

a) Identify opportunities to implement genetic breeding programs on aquaculture supply chain in Brazil based on New Zealand support and expertise, promoting approach and relationship between these countries.

b) Present results from sheep genetic improvement programme used on Brazilian flocks developed and supported by a New Zealand consulting company.

CHAPTER 1 – Case study: Genetic improvement opportunities in aquaculture.

General Objective of the case study: Present arguments to emphasize the importance of knowledge exchange between New Zealand and Brazil to build market opportunities that are able to contribute to the social, economic and environmental sustainability of aquaculture, an emerging supply chain in Brazil.

Table 1: Structure of the case study development.

Specific objective	Action	Evaluation question	Quantitative indicator	Qualitative indicator
a) Show how genetic improvement can be a valuable tool for development of the aquaculture supply chain in Brazil.	Report gains through utilization of genetic improvement from breeding programmes around the globe.	How can genetic improvement programmes improve the development of the aquaculture supply chain?	Outcomes from genetic improvement programmes around the globe.	Show how improved and differentiated products can lead to highly competitive markets.
	Present benefits from investing in genetic improvement	How has New Zealand progressed and realized economic returns from genetic improvement of fish?	Results obtained in New Zealand fish species (King Salmon, Hapuku and King Fish): how much profit has been realized in NZ businesses as a result of selection in fish.	Brand strategy example: Ōra King Salmon and its value in the market.
b) To understand the role of genetic improvement in the Brazilian aquaculture supply chain.	Research and report on the current status of Brazilian aquaculture with emphasis on genetic improvement.	What is happening in genetic improvement in aquaculture species in Brazil?	General production, exports and imports.	The genetic improvement potential of aquaculture species in Brazil.
			General domestic consumption.	Development programmes, companies and research institutes involved in, or with potential to be involved in, genetic improvement of aquaculture species.
			General market prices.	
c) Description of a cooperation between Brazil and New Zealand to improve the aquaculture value chain through genetic improvement.	Description of the approach between a Brazilian and new Zealand companies	How should a successful international business interaction in the aquaculture industry be developed between Brazil and New Zealand?		Develop a procedure with appropriate steps.
	Present the feedback from the Brazilian company	What will the next steps be?		Positive or negative feedback.
				Summary of the next steps based on the feedback.

1. Context

Brazil is one of the most important global suppliers of primary products from agriculture, with available land and environmental conditions to produce several species of plants and animals commercially. Despite significant advances in various areas of the livestock sector, the country is still unsuccessful in aquaculture, even with the possession of vast water resources and thousands of kilometers of suitable coastline available. The main issue is the lack of institutional security, which results in the absence of stability in aquaculture, which deters private investments. Without investors, there’s underuse of the country’s natural resources for aquaculture.

Conversely, there are examples of countries, with much smaller areas and natural resources, using a wide range of available technology to increase productivity and efficiency at different levels of the supply chain. This implies more productivity per area, in a sustainable way. New Zealand is an example of a developed country with advanced production in sectors such as sheep, beef, dairy and aquaculture.

For instance, in the New Zealander aquaculture sector, the average conversion rate in Salmon production is 1.4 kg of salmon protein for every kilogram of fish protein used in the salmon diet. From this, one of the businesses is able to generate revenue of $115m from 5 ha of water surface (Greenfish Bluefish, 2013). Like dairy and sheep farming, salmon aquaculture in New Zealand is strongly supported by genetic improvement programmes. Breeding and genetics tools are used to optimize production in given environments, while leveraging the natural conditions to add value to naturally high quality products. This strategy is an example of a technology used in New Zealand which provides the basis for primary production linked to marketing and value adding.

The exchange of this kind of knowledge, in the direct form of business to business, could help Brazilian businesses to explore well-structured aquaculture systems and markets. This sort of sharing could establish a strong relationship between leading aquaculture companies within both countries and enable future business opportunities within Brazil and abroad.

The sections below describe the objectives outlined in the Table 1.

2. Genetic improvement as a valuable tool for development of an aquaculture supply chain

2.1. Outcomes from genetic improvement programmes around the globe.

2.1.1. Estimates of potential gains

There are successful genetic improvement programmes in aquaculture around the world, applied to several species of salmon, Nile Tilapia, and to shrimp *Litopenaeus vannamei*. One of these programmes has been implemented in Norway and started in 1975 as a family-based (Norwegian model) breeding programme for Atlantic Salmon (*Salmon salar*). It has produced great results for the industry through genetic gain (Table 2). According to Gjedrem (2015), the Norwegian Salmon industry now produces more than 1.3 million tons per annum and, through use of genetically improved stock, saves in the range of 120,000 tons of feed annually (saving up to US$700-800 million in annual feed costs[2]), produces twice as much output compared to 1975 and helps to save labor costs. There is reduced mortality due to a shorter production cycle with improved genetic material. Gjerde and Olsen (1990) in Gjedrem et al, (2012) estimated a profit, based on genetic gain to Atlantic Salmon in Norway, of US$0.13 and US$0.08 per kilogram of fish produced from growth rate and sexual maturity respectively; a total gain of US$0.21 per kilogram of fish over a generation.

Table 2: Genetic gains in the Norwegian genetic breeding program model.

Species	***Generations***	***Trait***	***Cumulated genetic gain***	***Genetic gain per generation***
Atlantic Salmon	1		15%	
Atlantic Salmon	5		Performance compared with wild salmon	
Atlantic Salmon	11	Growth rate	113%	13%
Atlantic Salmon	11	Retention of protein	9%	
Atlantic Salmon	11	Retention of energy	14%	
Atlantic Salmon	11	Improvement in FCR	23%	
Nile Tilapia	5	Growth rate	85%	13%
Rohu carp (common carp)	4	Growth rate	-	29.6%

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[2] US$ exchange referent to June 2015.

Species	***Generations***	***Trait***	***Cumulated genetic gain***	***Genetic gain per generation***
General fish species	-	Several diseases	14%	
L. vannamei (shrimp)	1	TSV survival	12.4%	
L. vannamei (shrimp)	1	Harvest body weight	4.4%	

Source: (Gjedrem, 2015) (Gjedrem, 2012)

With the growth of global aquaculture estimated at 7.7% per year by FAO during the period of 1998-2007, Gjedrem (2012) simulated, at 12.5% genetic gain per generation, a huge increase in the fish and shellfish production (Figure 1).

Gjedrem (2015) stated that only approximately 10 percent of aquaculture in the world is based on genetic material improved through selective breeding, which means that the majority of aquaculture production is based on wild stocks and stocks where individuals at best are selected for growth rate but without consideration of pedigree relationship (i.e. phenotypic or mass selection). Inevitably, this leads to inbreeding and loss of genetic variation in the target stocks and subsequent loss of fitness and production performance, after many generations. An example of inbreeding caused by random reproduction is seen in the shrimp *Litopenaeus vannamei* (or *Panaeus vannamei*). Reproduction with no genetic control happened during several generations and resulted in high levels of inbreeding with associated reduced performance. During the 90’s, tests and genetic improvement programmes started to be developed for *Litopenaeus vannamei* shrimp. The Brazilian company Aquatec was involved in the development of these programmes. Currently, Brazil is one of the main producers of *L.vannamei* in the world (FAO, 2015b). According to Gjedrem (2012), *L. vannamei* has increased in production from 13% to 45% of world’s shrimp production between 1993 and 2008.

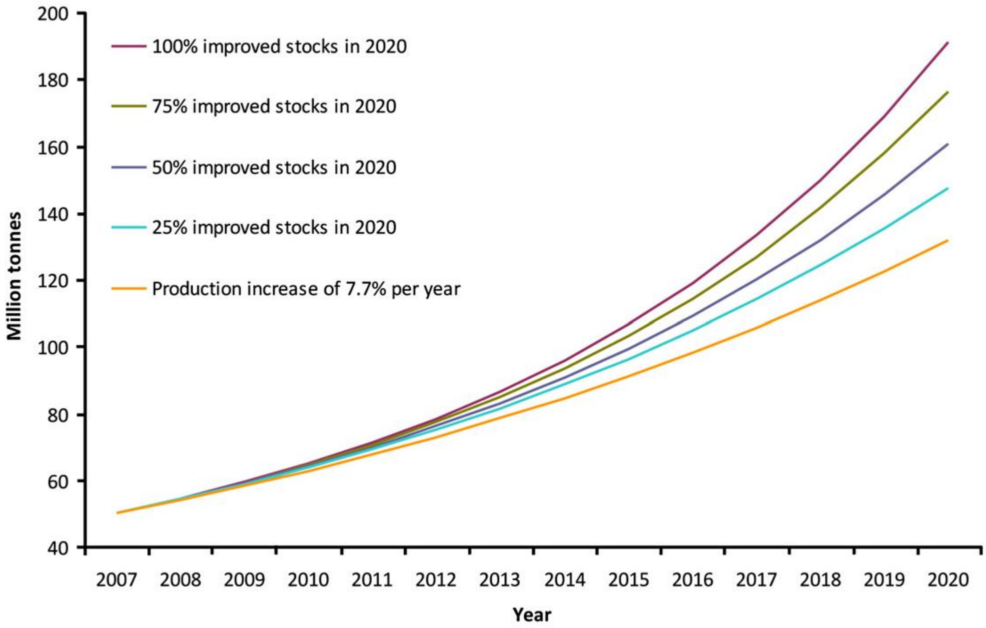


Figure 1: Expected future aquaculture production of fish and shellfish with 7.7% increase per year and adding genetic gain of 12.5% per generation of selection considering a generation interval of 2.3 years with varying increase frequency of improved stocks. Source: (Gjedrem, 2012)

Not only salmon and shrimp has seen improvements in production due to genetic improvement. Nile Tilapia is a good example of a tropical aquatic species involved in a genetic improvement programme. With very good results from selection for growth traits (Table 2) it was possible to demonstrate the idea that selection works for cold water species like salmonids and trout and also for tropical species.

Genetic improvement programmes in Nile Tilapia started around the 90’s and because of such good results in growth rate, production of this species is expanding fast. World production of Nile Tilapia increased from 1.67 to 3.44 million tons in the 2006-2013 period (Figure 2) (FAO, 2014). Ponzoni et al. (2007) estimated benefit/cost ratios of genetic improvement programmes in Nile Tilapia of 8.5:1 in the 10th year.

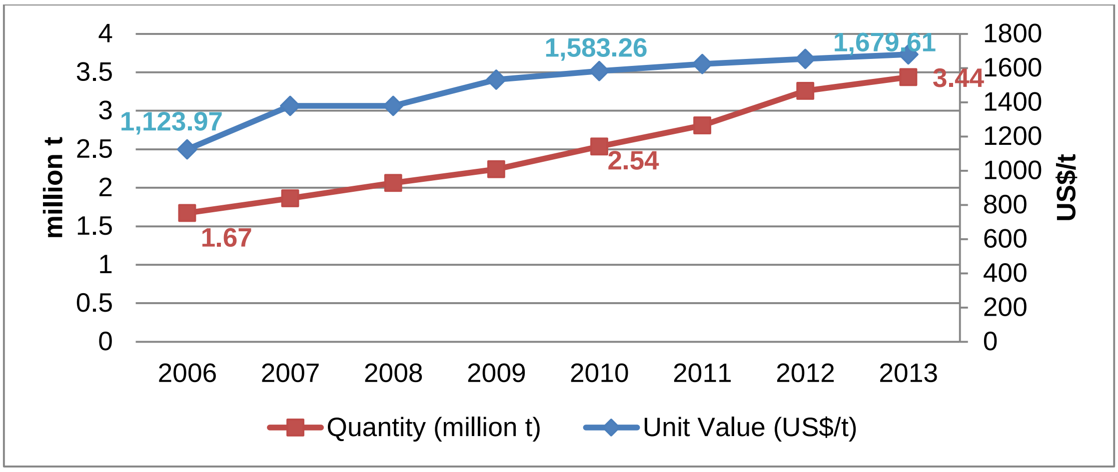


Figure 2: Nile Tilapia world production increase in the period between 2006 and 2013. Source: (FAO, 2014).

Another example of a tropical fish species that has achieved production gains because of selective breeding programmes is the Rohu Carp (also called by common carp). The species shows high response to selection, as presented in Table 2.

Investment in effective breeding programmes are highly effective because genetic improvement is cumulative over generations, permanent, and sustainable (Gjedrem et al., 2012). These are very important aspects in understanding how an investment of this nature might generate returns. An example of investment is the practice of electronic tagging in fish that allows tracking and reliable identification of brood-stock. The identification of individual fish enables the establishment of genetic relationships between individuals and associated individual trait performance, which underpins genetic evaluation. Estimates of genetic merit combined with economic values can be used to predict progress in productivity. The use of these traceability systems is expensive, but they are used in the current structure of several companies cited in this study (Appendix I: Programmes).

2.1.2. How improved and differentiated products can lead to competitive markets.

Successful companies engaged in aquaculture production generally operate a fully integrated value chain of one or more aquatic species, from the farm to the end consumer, and are able to market products with high standards of quality. The concepts of economic viability, as well as social and environmental compliance are frequently associated to the sustainable nature of genetic improvement programmes. This meets the requirements of the most demanding markets in the world. Achieving success in these markets requires a proper strategy which can overcome production issues, enable better control of the process, generate higher quality produce, and ultimately achieve higher profitability. In spite of the company’s position in the market, there may be technical factors faced by the company that influence the whole operation. Some examples of these are provided below.

a) Exploitation and management of genetic resources of native fish species, and/ or controlling levels of inbreeding and productivity.
b) Connection between available genetic resources and aspects of value to the market. There is a need to appropriately define breeding objectives which connect farming and economic principles to market expectations.
c) An association of principles of genetic improvement with the sustainability story and telling the story to the market. High quality native species, farmed in an environmentally friendly production system, supplying high-end consumers, is a story that should be underpinned by breeding tools and systems, in vertically integrated aquaculture value chains.
d) Quality of data generated from the appropriate identification of the best individuals and families. Correct and accurate data is required for generating increased farming production, which is directly connected to trait measurements and pedigree records.
e) Feed conversion is the most important trait of selection in fish, and probably the principal cost component of the production system. However, its relationship with other traits has to be balanced through the breeding programme.

These examples cited above are five factors that an aquaculture business should consider in structuring a genetic improvement programme for the production system. The structure of the programme should include important economic traits and also traits of interest, such that differentiated products can be developed for specific consumers and markets. Products with differential characteristics generally get higher prices and have stable markets. This can be used as strategy to gain and progress a competitive market advantage.

New Zealand King Salmon (NZKS, http://www.kingsalmon.co.nz/) developed a product to compete with others king salmons in the international market and with Atlantic salmon from Norway, Chile, and other world fisheries. A strategy to develop a new brand to their salmon was used to ensure that their products had enough brand stability and inherent brand value to increase the price and prevent prices being dictated by the curve for the Norwegian commodity salmon (see chapter 2.2.2). The brand strategy worked for NZKS. The new brand was exported and the sale price rose from about $US4.34 per kilogram to $US14.71 per kilogram in 10 years (Band & Johnstone, 2015). The product was not sensitive to a drop in the price of the Norwegian product (Figure 3).

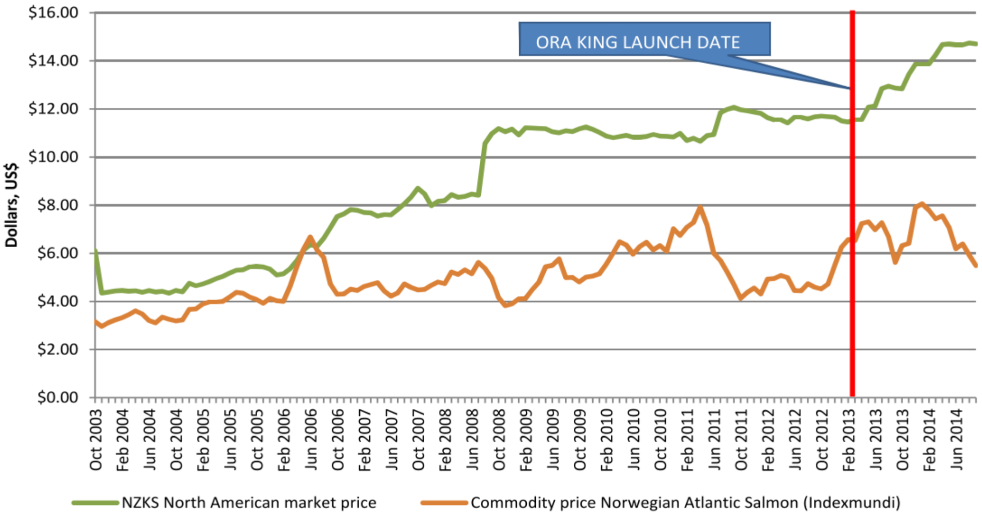


Figure 3: CIF pricing for NZKS whole salmon in North America market relative to commodity price of farmed Norwegian Atlantic salmon (USD/kg). Source: (Band & Johnstone, 2015).

Another strategy that can be used is to add-value by selecting for differentiated traits such as meat color and flavor. The development of programmes that focus on product quality as well as product quantity will be important for aquaculture businesses that can underpin the development of a differentiated premium products.

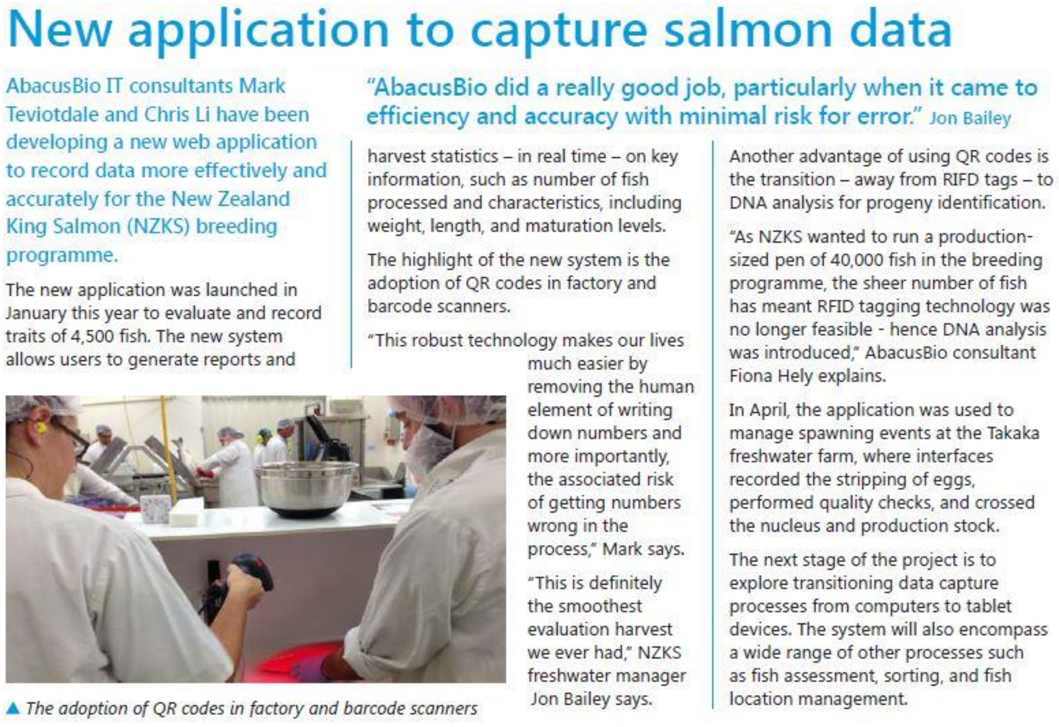
2.2. Examples of potential gains from investing in genetic improvement support in New Zealand

2.2.1. How profit has been generated for New Zealand businesses investing in genetic improvement of fish.

King (Chinook) Salmon

The King Salmon, also called Chinook salmon (*Oncorhynchus tshawytscha*) is an anadromous fish (adapted to life in both fresh and salt water) native of the northern Pacific Ocean and the only salmon species farmed in New Zealand. New Zealand King Salmon Co Ltd is the world's major supplier of King Salmon, suppling 50% of the world King Salmon. New Zealand King Salmon is exported to 30 countries and is readily available at local supermarkets and restaurants around New Zealand (Camara & Symonds, 2014).

AbacusBio has been working with the NZKS breeding programme since its inception in the late 1990's in the development, implementation and monitoring of the breeding programme. AbacusBio is a New Zealander enterprise, with international operation in agribusiness consulting, which works in partnership with companies to add value to their business through genetic improvement. To help NZKS grow it value, AbacusBio has also developed a system that allows selection of superior brood-stock through integration, at multiple levels, of real time key information on fish performance (Figure 4), pedigree (i.e. family formation) and harvest statistics.



New application to capture salmon data

AbacusBio IT consultants Mark Teviotdale and Chris Li have been developing a new web application to record data more effectively and accurately for the New Zealand King Salmon (NZKS) breeding programme.

"AbacusBio did a really good job, particularly when it came to efficiency and accuracy with minimal risk for error." Jon Bailey

The new application was launched in January this year to evaluate and record traits of 4,500 fish. The new system allows users to generate reports and harvest statistics – in real time – on key information, such as number of fish processed and characteristics, including weight, length, and maturation levels.

The highlight of the new system is the adoption of QR codes in factory and barcode scanners.

"This robust technology makes our lives much easier by removing the human element of writing down numbers and more importantly, the associated risk of getting numbers wrong in the process," Mark says.

"This is definitely the smoothest evaluation harvest we ever had," NZKS freshwater manager Jon Bailey says.

Another advantage of using QR codes is the transition – away from RIFD tags – to DNA analysis for progeny identification.

"As NZKS wanted to run a production-sized pen of 40,000 fish in the breeding programme, the sheer number of fish has meant RFID tagging technology was no longer feasible - hence DNA analysis was introduced," AbacusBio consultant Fiona Hely explains.

In April, the application was used to manage spawning events at the Takaka freshwater farm, where interfaces recorded the stripping of eggs, performed quality checks, and crossed the nucleus and production stock.

The next stage of the project is to explore transitioning data capture processes from computers to tablet devices. The system will also encompass a wide range of other processes such as fish assessment, sorting, and fish location management.

▲ *The adoption of QR codes in factory and barcode scanners*

Figure 4: AbacusBio services example to aquaculture chain, in this case New Zealand King Salmon. Source: **(AbacusBio Breeder Journal, 2015)**

A family-based selective breeding programme has been run for New Zealand King Salmon since 1998, with 90 nucleus families established per year. In 2014, the programme was in the seventh generation with the individuals tracked using electronic tags inserted into their body cavity to record several traits (e.g. weight, age of sexual maturation, body conformation) (Camara & Symonds, 2014). Pedigree recorded back to 1998 enabled the recent development of a premium quality high value brand, Ōra King salmon (see section 2.2.2). The breeding merit of each individual fish is assessed by statistical Best Linear Unbiased Prediction (BLUP) analysis based on its own records and the records of its close relatives. Total genetic merit selection indexes are computed using breeding values for each trait, and sets of economic values specific to several different production systems, and also for the nucleus (Amer, Jopson, Dodds, Symonds, & Hills, 2001). The aim of the selection is maximizing this genetic merit while constraining co-ancestry.

The selection strategy focuses on quality and performance traits, using an index based on desired gains. With appropriate selection, NZKS is able to maintain the inbreeding trend at around 0.2% per year. Furthermore, between 1998 and 2012 the average genetic merit for weight in the nucleus increased by 0.8 kilograms, while keeping the maturation proportion at 2 years old close to zero, which is desirable (Figure 5). With these results it was possible to estimate the value of a production increase of 1 percent per year. Considering 2014 production levels at 7,000 tons of King Salmon with an average price of US$17.00 per kilogram and harvest weight of 3.5 kg, a 1 percent increase in production per year due to genetic improvement, adds 1100 tons to the annual production in the 10th year. This has a value of US$18.7 million added in the 10th year revenue (Figure 6). Note that in any economic analysis (a cost benefit analysis for example) this revenue needs to be adjusted for the time value of money.

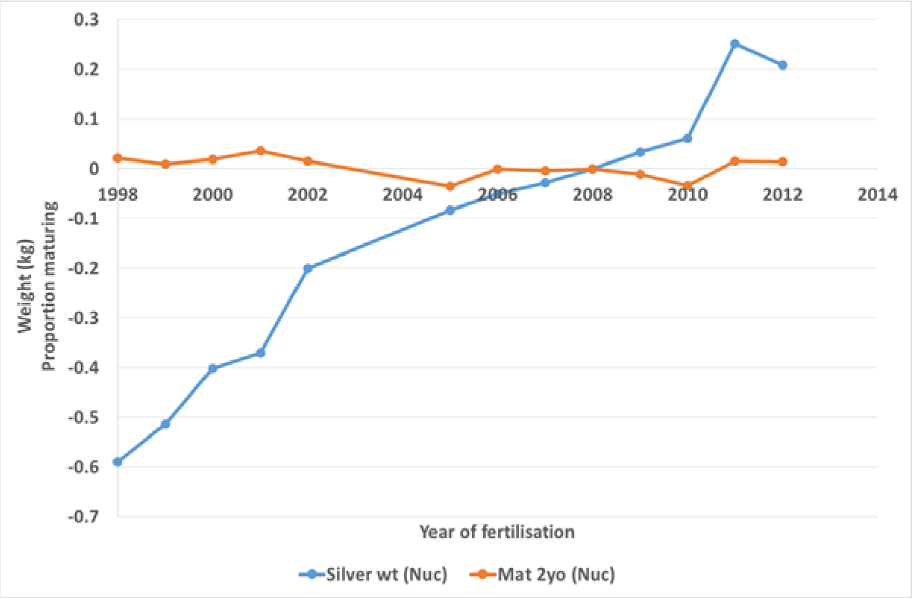


Figure 5: Genetic trends for growth and maturation of the King Salmon of NZKS. It was set a “base year” for the analysis to zero, so in this case 2008 weight (Silver wt) and maturation (Mat 2yo) was set to zero, which shifts the weight trend prior to 2008 as negative.

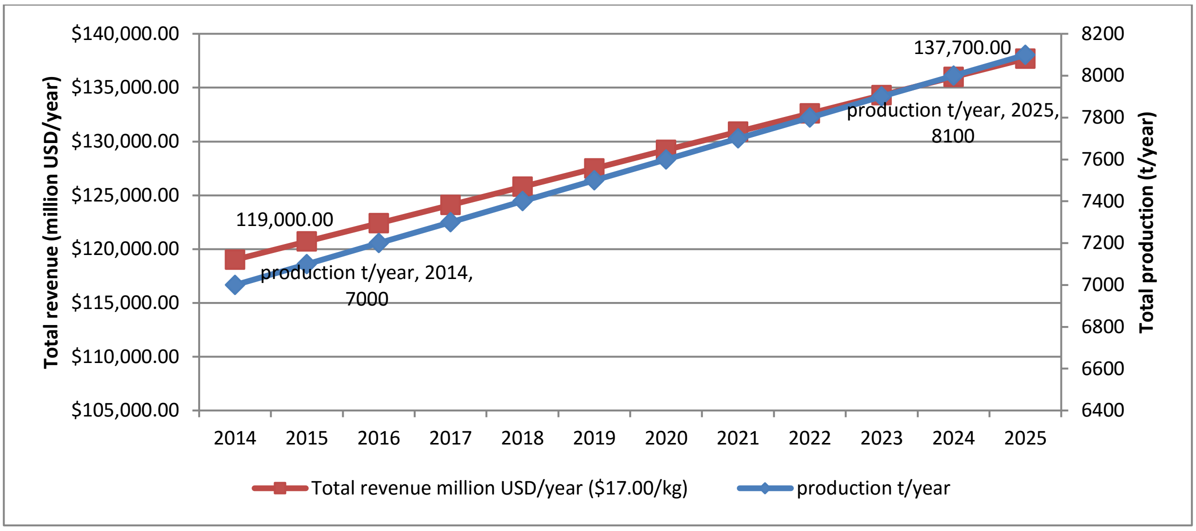


Figure 6: Potential NZKS production increase with the current genetic gain of 1% year on the 2014 production values (i.e. non-cumulative).

Other species

AbacusBio also works with other aquaculture businesses to establish well-structured breeding programmes, which enable high economic returns for vertically integrated value chains of native aquatic species in New Zealand. Hapuku and King Fish are examples of cases in which small breeding programmes support these native marine species of fin fish for domestication and efficient farming. This work is being led by the National Institute for Water and Atmospheric Research (NIWA) in New Zealand. The biggest challenge, in these cases, is to balance the trade-off between appropriate rates of genetic progress whilst maintaining genetic diversity. These fish are large at maturity, and infrastructural demands make existing programmes used for commercial breeding of smaller species such as salmon, completely unrealistic. A cornerstone of these emerging industries is their successful breeding programmes, which enhance business profitability in the short, medium and long term by properly selecting, preserving and promoting these native species.

A cost-benefit model for marine brood stock, similar to what is used and developed by NIWA and P.Amer (AbacusBio Ltd) in New Zealand, when applied to genetic improvement of King Fish in Australia estimated a 60% internal rate of return from a breeding programme selecting for growth rate with 60 families (N Robinson, Nofima, unpubl.data 2009 apud Camara & Symonds, 2014). The Hapuku and King Fish are fledgling industries in New Zealand, expected to improve returns on exports and targeted to introduce great products to high end consumers around the world.

2.2.2. Brand strategy example: Ōra King and its value in the market

Ōra King is a New Zealand example of differentiated product developed based on genetic improvement concepts to increase its value.

AbacusBio works in partnership with companies to add value to their business through genetic improvement. Ōra King is a case where this concept has proven successful. The brand (Figure 7) is owned by New Zealand King Salmon Co Ltd (NZKS). The company´s selective breeding has created a genetically distinct breed which has become its strongest proposition (i.e. Ōra King, http://orakingsalmon.co.nz/our-story/) and main vehicle connecting NZKS with premium menus around the world. The program supports the story about New Zealand in general, and its values highlight the great quality of products, the landscape where it is farmed, and the clean-and-green concept.

Around year 2000, the company realized that it needed to take more responsibility for what happened to its product in the market (Band & Johnstone, 2015). Therefore, it started a rebranding programme in NZKS. The Ōra King brand project started with a need of the company to make a move from commodity to premium food service to avoid to be affected by the salmon commodity prices at the market, when they were a small market compared with Atlantic salmon.

Figure 7: Ōra king New Zealand King Salmon (NZKS) brand. Source: http://www.kingsalmon.co.nz/

Ōra King was launched in the US market in 2012 and is considered a specific breed of salmon raised especially for the premium restaurant and chefs. The genetic improvement programme and AbacusBio technological support were fundamental tools to the development of the Ōra King brand as a base of the selected product. Grant Rosewarne, CEO of NZKS and one of the people responsible for the new brand said that AbacusBio genetic consultants agreed with him that NZKS's selective breeding created a genetically distinct separated breed, which lead them to decide that this was the strongest position and most likely to get traction on premium menus (Band & Johnstone, 2015).

Exploiting the selective eating quality traits from salmon, on what the brand was developed on, the Ōra King salmon from NZKS reaches international market and the customers started to put the brand on menus. So, the strategy works as it was planned and the brand got the meaning of, not just the high premium quality guaranteed product, but also tells its history to the consumers. Through the years, with the Ōra king salmon brand strong, NZKS conquered the United States market, Australia, China and the high picky European market, without let out New Zealand retail.

3. To understand the role of genetic improvement at Brazilian aquaculture supply chain structure

3.1. Brazil’s aquaculture in a global context

Brazil has more than 7,400 km of Atlantic Ocean coastline. It also holds 13.8 percent of the global surface of freshwater and 8.5 million hectares of public and private reservoirs (Ostrensky, Borghetti, & Soto, 2007). The majority of these resources are concentrated in the north and mid-west region, where population density is low.

According to FAO, Brazil possesses more than two million hectares of marshlands, reservoirs and estuaries suitable for aquaculture (FAO - Suplicy, 2004). This includes about 25,000 suitable rivers throughout the country

3.1.1. Production, imports and exports and domestic consumption in Brazil

In 2013, for the first time, Brazilian aquaculture industry was included in PPM (Municipal Livestock Production in English), data series annually published by IBGE (Brazilian Institute of Geography and Statistics). The data showed that aquaculture is presents in at least 2,618 counties. The total value of this production performed R$ 3.1 billion (approximately US$ 1.3 B), of which 66.1 percent comes from fish farming and 25.0 percent comes from shrimp farming. Brazil’s total aquaculture production in 2013 was 392.5 thousand tons, and except from shrimp, the marine aquaculture contribution is very small.

Also, in 2013 Brazil was included among the Top 20 FAO leaders in world aquaculture production (Table 3). However, the amount produced by Brazil which put the country in this position, represented less than one percent of its total trade, i.e. imports and exports, in the commercial balance of the country’s fisheries (Table 4).

Table 3: Leading aquaculture producers of fish, crustaceans, mollusks, etc. in 2013 (FAO)

Position	Country	Quantity =t	Value = USD 1000
1	China	43,549,738.00	70,037,313.00
2	India	4,549,607.00	10,355,807.00
3	Indonesia	3,819,732.00	8,779,298.00
4	Viet Nam	3,207,200.00	6,198,422.00
5	Bangladesh	1,859,808.00	4,413,994.00
6	Norway	1,247,865.00	6,896,891.00
7	Egypt	1,097,544.00	2,088,867.00
8	Thailand	1,056,944.00	3,165,809.00
9	Chile	1,033,206.00	7,525,266.00
10	Myanmar	929, 180.00	1,714,771.00
11	Philippines	815,008.00	1,976,898.00
12	Japan	608,800.00	3,332,353.00
13	Brazil	473,429.00	1,310,071.00
14	USA	441,098.00	1,211,480.00

(FAO, 2013)

Table 4: Brazil IMPORTS and EXPORTS of fish, crustaceans, mollusks, etc. and their prepared in– 2014.

	US$ FOB	Aquaculture % of total Brazilian trade	kilogram	Average price US$/t
IMPORT	1,539,605,765.00	0.67%	403,091,161.00	3,819.50
EXPORT	207,219,010.00	0.09%	32,178,215.00	6,439.73

(MDIC, 2014)

The consumption of aquaculture and fisheries items (i.e. Fish Seafood (Total)) in Brazil was estimated by FAO (2013) as more than 2,177 thousand tons in the year, or 10.87 kg per capita per year. Comparing this with other meat consumed in the country (Table 5), e.g. bovine and poultry meat, this amount is smaller but still significant. The World Health Organization recommends consumption 12 kilograms of fish per capita per year (SEBRAE, 2014). The consumption in Brazil is close to the recommended amount, but there is opportunity to increase the average consumption. For example, in the Northern region of the country consumption is around 34.2 kilograms per capita per year; three times the country’s average. In general, the national consumption is still below the global consumption average, which is 18 kilograms per capita per year.

Table 5: Food Supply Quantity - BRAZIL 2013

ITEM	kg/capita/year	tons/year
Fish, Seafood (Total)	10.87	2,177,589.86
Marine Fish	0.62	124,776.57
Freshwater Fish	4.94	989,346.07
Molluscs, Other	0.19	37,687.67
Bovine meat	39.25	7,863,342.71
Poultry meat	45.00	9,016,211.44
Pig meat	12.60	2,525,057.35
Meat (Total – except Fish)	97.58	19,552,000.50

(FAO, 2015a)

3.1.2. Market prices

Average revenue per kilogram of fresh water species obtained by producers has significant variation among species (Table 6) and sometimes, within species depending on the region. Most of the species described have potential for aquaculture although the vast majority are currently wild fish harvested from rivers and lakes.

Table 6: Average value of fish species in Brazil.

	Rank	***Species(Common name)***	***Value/kg***	***State***	***Region***
Most Valued	1	Dourado (Dorado)	R$13.9	Goiás	Midwest
	2	Truta (Trout)	R$11.12	Minas Gerais	Southeast
	3	Pirarucu (Arapaima)	R$9.38	Rondônia	North
	4	Tucunaré (Peacock Bass)	R$9.08	Goiás	Midwest
	5	Pintado, Cachara, Cachapira e Pintachara, Surubin (Barred sorubin)	R$8.08	Mato Grosso	Midwest
	6	Piaus, Piapara, Piauçu, Piava (Characin)	R$6.76	Goiás	Midwest
	7	Curimatã, curimbatá (Black prochilodus)	R$6.75	Maranhão	Northest
	8	Matrinxã (Sábalo)	R$6.62	Amazonas	North
	9	Lambari (Tetra)	R$6.24	São Paulo	Southeast
	10	Jatuarana, Piabanha e Piracanjuba (Tiete tetra)	R$6.22	Rondônia	North
	11	Pirapitinga (Red-ballyed pacu)	R$5.84	Mato Grosso	Midwest
	12	Traira, Trairão (Wilf fish)	R$5.72	Paraná	South
Less Valued	13	Pacu e Patinga (Pacu)	R$5.69	Goiás	Midwest
	14	Tambaqui (black pacu or chachama)	R$5.40	Mato Grosso	Miswest
	15	Carpa (Common carp)	R$5.35	Rio Grande do Sul	South
	16	Tambacu, Tambatinga	R$4.84	Mato Grosso	Midwest
	17	Tilápia (tilapia)	R$4.53	Paraná	South

*Values from December 2014. Exchange US$ 1,00 = R$ 2,66

Adapted from (Ito & Torres, 2014)

3.1.3. The Genetic improvement potential of aquaculture species in Brazil

The two main aquaculture species farmed in Brazil are exotics, i.e. Nile Tilapia and *L. vannamei* shrimp. Both are well adapted to the country's environment and systems of cultivation and their production amounts to more than 60 percent of the total aquaculture harvest in the country (Nunes & Rocha, 2015). These two specific species are currently highly productive, and have been developed and supported by genetic improvement programmes. For shrimp, this has allowed faster production cycles and shorter intervals between crops, reduced inbreeding problems, increased diseases resistance, stress factor tolerance and faster growth. All of this together, combined with the development and enhancement of management and nutrition, has led to significant production increases. A similar process has occurred in the production of tilapia (Figure 8). Although there are many native species and hybrids with potential, there is underutilization of genetic improvement technologies and scientific expertise to effectively improve their production in Brazil (Table 7).

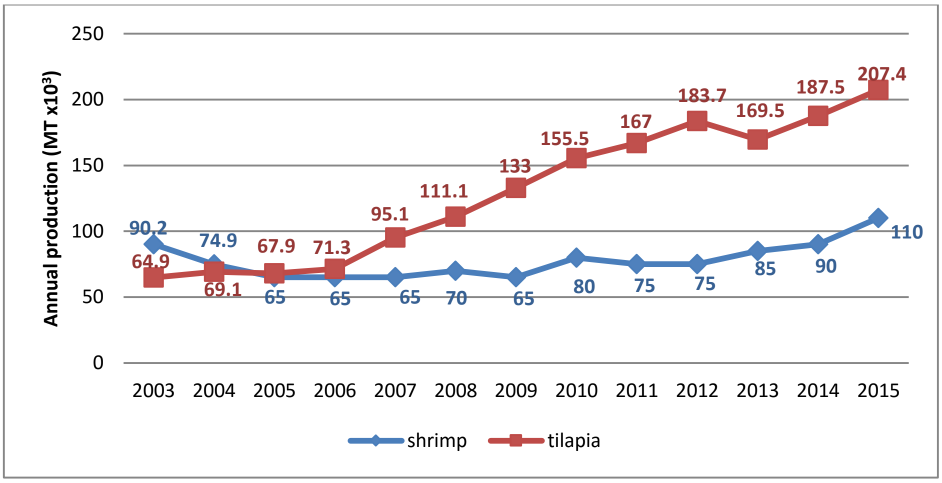


Figure 8: Annual shrimp (*L. vannamei*) and Nile Tilapia production in Brazil. Source: Adapted from Nunes & Rocha (2015).

Table 7: Native Species - Fish

Popular name	Maturity age/size	Spawing (times/ year)	Slaughter age/ weight	Mean weight gain	OBS (FCR, etc)
Tambaqui	4-5yr/55 cm	2	2-3 kg	-	Widely used in crossbreeding
Pirarucu	5 yr/ 40-45kg	1	-	10-14kg/year	Carcass yield 57%/ Can reach 250kg
Pintado/ Surubin	50-65 cm			1.2-2kg/year	Widely used in hybrids production
Cachara	2yr/37 cm	1			Often used in crossbreeds with Pintado/Can reach 20 kg
Dourado					High meat quality and market value.
Jundiá da Amazônia					High filet income. Widely used in crossbreeding with Pintado

Pacu	3-4 years	1.0-1.5kg/year	Widely used in crossbreeding to hybrid produces
Hybrids			
Pintado da Amazônia	Cachara+ Jundiá		Smaller head, e.g. better carcass yield
Tambacu	Tambaqui+ Pacu		
Tambaqui	Tambaqui+ Pirapitinga		

Currently, there are many projects aimed at the development of aquaculture in Brazil, and initiatives targeted at native species development are starting to appear (Appendix I: Programmes). These projects focus on the development of technologies with subsequent transfer to the commercial sector. An example is the Aquabrasil project, which was based on breeding and genetics as the supporting structure of further development of aquaculture in Brazil. The project was coordinated by Embrapa, the Brazilian Agricultural Research Corporation, which is a state-owned research company affiliated with the Brazilian Ministry of Agriculture, Livestock and Food Supply (MAPA). One of the goals of this project was to establish and consolidate a national breeding programme for aquatic species in the country. The native species involved were tambaqui (*Colossoma macropomum*) in the Amazon Basin and Pintado (*Pseudoplatystoma spp*) in Mato Grosso do Sul (Embrapa Pantanal e UFMS). The exotic species were Tilápia GIFT (*Oreochromis niloticus* genetically improved line), and the *Litopenaeus vannamei* shrimp. The project has already been completed and the main outcomes were realized in Tilapia GIFT. The most prominent results were approximately 4 percent or genetic annual gain to weight dairy gain (Embrapa Meio Norte, 2011). This is not surprising since the technology to select tilapia is already well established.

There is another important project, also from Embrapa, in partnership with Sebrae and MPA (Fisheries and Aquaculture Ministry), under development in the Amazon region with a native species called Pirarucu (*Arapaima gigas*). Pirarucu is one of the biggest freshwater fish in the world and is known for its high quality flesh. However, this indigenous species still needs to adapt to breeding and farming in captivity. This scientific research, called “Amazon’s Pirarucu: Research actions and technology transfer”, includes genetics and reproductive investigation, amongst other aspects of Pirarucu production (EMBRAPA, 2013). Another government initiative involving aquaculture in Brazil is being implemented by SEBRAE (Brazilian Micro and Small

Business Support Service) in the Northeast region of Brazil, and is called AquiNordeste. This project aims to modify the current scenario and boost aquaculture in the region by developing farming practices and achieving productivity gains in both fish (Tilapia) and native oyster species of the region, *C. brasiliana* and *C.rhizophora*. There are some important private initiatives in the city of Sorriso, Mato Grosso state (Amazonic Bain, Mid-west region), with native species. These privately owned initiatives, some of them in partnership with Embrapa through the project Aquabrasil, work with genetic improvement of hybrids from native species, such as Pintado da Amazônia, tambacu and tambatinga.

Despite of the high growth rates of the native species currently farmed, these species are in general very late maturing, and reproduce later in life. This is an issue in breeding programmes for tambaqui, for instance, which takes at least 3.5 years to be able to reproduce, meaning a long generation interval and slower rates of genetic gain. On the other hand, there are several early maturing native species that can be used, such as Pintado and Pacu, which are slow growing species in general, but are able to reproduce and grow in captivity. Also, it is possible to capture wild brood fish to use as breeder stock, but there are regulations, mainly in the case of Pirarucu fish.

There is a larger programme for Pirarucu in Amazonia, which regulates fishing and capturing by local fishermen. This means that, currently Pirarucu can be captured (i.e. harvested) in nature, but just as adult fish, when they are greater than 1.55m in length, both for use as brood fish or to slaughter.

Pintado is also under regulation laws for capture in the wild, as are all of the other native species. So, it is possible to manage the genetic variability in these native captive species, but there are no well-established programmes and tools to quantify the levels of inbreeding in captive populations, or in wild populations.

With the exception of Nile Tilapia and *L.vannamei*, the genetic improvement of aquatic species in Brazil is still in the very early stages, with fewer research initiatives in the area. The absence of programmes is likely due to the low level of structure in the industry and because of this the industry currently depends almost entirely on government resources. Even with significant support from the governmental agencies for aquaculture, especially by the Fisherie and Aquaculture Departament (Ministério da Pesca e Aquicultura – MPA) who, through MAPA (Brazilian Ministry of Agriculture, Levestok and Food Supply)[3] are the main authority for the management and development of fisheries and aquaculture in Brazil, the licensing procedure is slow because of bureaucracy. Licenses are frequently cancelled and there is no stability to the aquaculture business. This explains the lack of investment in aquaculture in the country. Investors have no interest in operating under this fragile institutional structure where everything depends on public investment. The public resources are largely targeted at universities, with few public policies focusing on the real (i.e. feasible, objective and profitable) goals. There is an opportunity for private businesses to identify traits for selection which are of economic importance since, to date, genetic improvement tools such as breeding objectives and selection indexes are absolutely non-existent.

4. Description of an approach between Brazil and New Zealand companies to improve the aquaculture value chain through genetics

In this chapter is described a case for cooperation in the aquaculture sector between Brazilian and New Zealand, companies such as Mar & Terra, NATIV and AbacusBio Ltd, combining agribusiness and specialized animal genetic improvement.

4.1. Assessment of the business opportunities.

A brief analysis of the Brazilian aquaculture supply chain and its genetic improvement status (chapter 1, section 3) and a report on the possible gains obtained around the world in aquaculture with genetic improvement strategies (chapter 1, section 2), has highlighted an opportunity to establish a relationship between the companies mentioned above.

Brazil has natural resources and the potential to develop aquaculture, and there’s a need to adopt technologies and expertise in breeding and genetics in order to optimize aquaculture businesses. There is opportunity to use sustainable genetic improvement principles to promote authentic high quality brand presence in the market through improved quality of fish and higher productivity in aquaculture.

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[3] MPA was dissolved as Ministry in October 2015 and now integrate MAPA. There is no further information about it.

Business initiatives such as Mar & Terra and NATIV, supplying aquaculture species in the form of differentiated new products, highly appreciated by consumers, could use a genetic selection strategy to improve eating quality, make a positive impact on the conservation of native species, and demonstrate stewardship of the environment. It is possible to optimize production and support marketing through breeding and genetics, transforming business profitability and brand positioning in the market. Based on professional experience, it is realistic to expect that a 5% increase in revenue and a 5% reduction in costs can be achieved by an efficient and sustainable genetic improvement program.

4.1.1. Choose one target company

AbacusBio has been working with New Zealand King Salmon (NZKS) since the implementation of its breeding programme in the late 90's.

The target company in Brazil should have a similar profile to NZKS, and have a structure, which would enable the implementation of a genetic improvement programme, or the company should at least have an interest in developing a new structure. Fortunately, Mar & Terra and NATIV, for example, have the necessary profile and also have a basic traceability system for identification of the brood stock animals.

It is important to understand that the process of implementing genetic improvement programmes is long and if developed from a low base, is also expensive. Because of this, at first, AbacusBio needs to target an operating company that could prompt realize the benefits of such a programme.

4.1.2. Contacting the company

The first contact was made through New Zealand Trade and Enterprise (NZTE), the New Zealand government's international business development agency, to introduce AbacusBio to Mar & Terra and NATIV.

The next step, given the interest from both companies, was for AbacusBio to interact directly, in order to understand the businesses, before preparing a proposal:

a. *<u>Detect the main problems</u>*: The main problems appear to be a lack of structure to increase fingerling production and the cost of feed. There also appears to be a problem with the stability of demand for products in the market.

b. *Select which problems could be solved by use of genetic improvement program:* All the problems identified in the previous item could be partially solved by genetic improvement. Firstly, by selecting for increase growth, and then by selecting for reduced feed intake

   The last one could be solved through development of differentiated products using selection for eating quality traits.

c. *Understanding the technologies already used which would underpin the genetic improvement programme*: Traceability systems applied to the brood stock should allow collection of data to be used in the genetic improvement programme. The domestication process of the native species is complete in both companies. Particularly, reproduction in captivity is well established, and so there is an opportunity to implement selection to improve production.

d. *Detect the opportunities to increase production and add value to products based on genetic improvement*: There are opportunities to increase production and add value to the native fish species, especially by producing high quality differentiated products.

4.1.3. Attracting the attention of the companies' boards

To attract the attention of both Brazilian companies' boards, a brief summary of the concept was sent to the board members. This summary was based on results achieved by aquaculture businesses in New Zealand, as described at section 2. A version of the document sent is in Appendix II, and it was elaborated to contain the following items:

4.1.4. Basic approach used to elaborate the first introductory document to potential partner companies.

a) Introductory presentation: vision, summary of AbacusBio services and products and brief proposition;
b) Track record: describing current clients achievements;
c) Market opportunity: clear definition of where the main opportunities are;

d) Problems and current solutions: describe the potential current problems that might affect these businesses and respective solutions;
e) Business model and revenue streams: opportunities for all parties involved;
f) Next steps to proceed with the proposition.

All these elements were fundamental to any proposal and/or strategic document to be sent to potential partners. For each one, the document was elaborated in a way that prioritizes the needs of these businesses.

4.2. Interpreting feedback to inform the next steps

Feedback has been received from the board of one of the companies since the first approach. There is an expectation of further discussions on the options to develop these business opportunities.

There would be need to acquire a better understanding of the company's operations and, together with them, carry out the development of a programme plan. The plan should consider important matters such as objectives, goals, and timeframes, as well as necessary investment and expected returns, current infrastructure and systems to be developed, and an overview of the practical implementation of the programme.

5. Final considerations

Brazilian natural conditions and market are promising to aquaculture but the production is below the potential. The country can be as competitive as it is at grains and other meats sectors in aquaculture. However, there are many factors that need to be undergoing first, one of particular relevance is the lack of investments in technology.

Genetic improvement has been shown as a technological solution to address low productivity in Tilapia and shrimp *L. vannamei* in Brazilian aquaculture. And some other native species have been standing out among others and present great sales potential in the domestic and international market. As such, there is opportunity to apply genetic improvement in Brazilian native fish species used in commercial production.

Around the world, aquaculture businesses have been successfully applying genetic improvement tools to develop commercial production systems. The financial gains arising from aquaculture supply chains that have implemented genetic improvement programmes are apparent. These gains come from improvements in productivity and product value, leading to increased profits. In New Zealand, NZKS is an example of this.

The government development targets plan to the sector are going through more quality and health products control to physically restructure equipment acquisition and input, to prepare human resources, to promote, disclose and certificate the products in the national and international trade (SEBRAE, 2014). But without technology investments the development process becomes extremely slow. To accelerate the aquaculture development, Brazil is intensifying the knowledge share through benchmarking and cooperation agreements internationally and looking for private initiative approaching. New Zealand companies have an opportunity to offer knowledge and systems, based on genetic improvement, to aquaculture industries in other countries. Brazil has the profile of a country that could benefit from this knowledge transfer.

CHAPTER 2 – Article: Genetic parameters for lamb growth and carcass scanning traits recorded in breeder flocks in Brazil – Souza, M. L., Santos, B.F.S., Amer, P. R.

1. Abstract

Genetic parameters were estimated for growth and carcass predictor traits, as well as (co) variances for the direct and maternal genetic effects using data from two Brazilian sheep breeding flocks. Data were collected between 2003 and 2015 and the traits evaluated were birth weight (BWT), pre-weaning weight daily gain (PreWG), post-weaning weight daily gain (PostWG), as well as eye muscle area (EMA) and Fat depth (FAT) measured using ultrasonography. BWT heritability was low (0.10) when compared to the other growth traits which had heritabilities of moderate to high magnitude (0.38 and 0.28 for PreWG and PostWG, respectively). For EMA and FAT the average heritabilities were low, 0.09 and 0.15 respectively. The estimates of heritabilities and genetic variances of PostWG, EMA and FAT were consistently different in magnitude between the two flocks. The two growth traits were negatively correlated while maternal effects were estimated to be zero. These observations may be explained by the lambs' creep-feeding supplementation during the suckling phase, reducing their dependence on ewe's milk. In these conditions, the structure of the data was insufficient to allow partitioning of maternal genetic effects and maternal permanent environmental effects from direct genetic effects, and also insufficient to estimate genetic correlations accurately.

Keywords: Sheep; Genetic parameters; Growth traits; Carcass traits.

2. Introduction

The Brazilian sheep industry has developed a structure that allows increased productivity and profitability of sheep farming. This has been motivated by the high price of ovine meat in the domestic market, which is largely driven by demand from a large human population exceeding supply from a small sheep population. In Brazil, the sheep production sector has emerged as an exploratory economic alternative for medium and small livestock farmers (Viana et. al, 2015). However, there are many inefficiencies across the sheep production value chain and one of the reasons for this is that there is a lack of genetic improvement underlying the breeding structure of the industry. The absence of a well-established breeding structure is a lost opportunity for gains in industry efficiency and productivity and currently there are only very limited results of genetic parameter studies, or overall productivity information, for the national sheep flock.

Countries such as New Zealand and Australia, with developed sheep industries, rely largely on genetic improvement programs, which focus on economically important traits to ensure profitability of their value chains (Garrick, Blair, & Clarke, 2000; Brown et al., 2007). Genetic improvement programmes in sheep are present in many places of the world with the intent to improve productivity, e.g. South Africa (Schoeman et al., 2010), US (Notter, 1998), Europe (Croston et al., 1980) and Norway (Eikje et al., 2008). Well-designed breeding programmes, based on genetic evaluation, could help to drive the development of the sheep value chain in Brazil towards higher productivity and increased profitability. Traits such as lamb growth and carcass traits are important to sheep farming operations because they are measures that are directly related to the income of the sheep business and selection for traits associated with growth and carcass yield are key for profitable meat production. However, knowledge of genetic variation and covariation among traits is required for the design of effective sheep breeding programs and accurate prediction of genetic progress (Safari & Fogarty, 2003).

The aim of this study was to estimate direct and maternal genetic parameters for growth and carcass traits, as well as genetic and phenotypic (co) variances among them. Data from two Brazilian sheep breeding flocks were used to estimate these parameters. The hypothesis was that there is an opportunity for selection (through genetic variation, heritabilities and correlations) within these flocks and therefore application of selection based on breeding values would be feasible. The intention was to present genetic parameters which can support establishment of breeding strategies that could help the development of the Brazilian sheep industry.

3. Material and methods

Data from two typical but different sheep breeding flocks were analyzed. These were Dorper (Flock A) and Texel (Flock B) breed flocks from Paraná and São Paulo states respectively. Both flocks focus on meat production, managing about 1,000 breeding ewes, and are influential in many other breeder flocks through ram sales. In both flocks, animals are exposed to rotational grazing throughout the year, as well as being fed concentrate and forage based supplement during the dry period of the year (generally during the winter months, between June to September). Ewes receive supplements from the final third of the gestation period through until lambs are weaned, and lambs are supplemented with concentrate via creep-feeding up to weaning.

Data were collected between 2003 and 2015. All of the traits were measured in lambs and include growth traits such as birth weight (BWT), pre-weaning daily gain (PreWG) and post-weaning daily gain (PostWG), eye muscle area (EMA) and Fat depth (FAT). To accommodate regular weighing, and a spread of lambing dates, pre weaning daily gain phenotypes used in the analysis were obtained separately for each animal by fitting a regression line through all of its weights available up until weaning (approximately 90 days of age) including birth weight. Similarly, post weaning daily gain phenotypes used were obtained by fitting a regression line through all of an individual animal’s weights between its weaning and scanning dates (approximately 150 days). The measures of EMA and FAT were collected via ultrasonic scanning between the 12th and 13th vertebrae.

Parentage information has been collected since the start of the recording process in both flocks. Lambs were tagged at birth and records of birth rank, birth weight and date, dam and any lambing difficulty were then included in the database. Records of matings were associated with birth information to build up the pedigree containing dams and sires of all lambs born.

3.1. Statistical analyses

General linear models were initially applied to the data using the Proc GLM function of SAS (9.4 version) to inform the models used in the subsequent genetic analyses. The model fitted to the data included a series of adjustment effects, such as age of dam at lambing, lamb year of birth, birth rank (litter size) and rearing rank, sex of the lamb, management mobs at birth, weaning and scanning. Interactions between sex and lamb weight in the scanning day were also considered as adjustment factors. Variance analysis (ANOVA) and Least Square Means (LS-Means) were used to assess the interactions between fixed effects and trait means. Table 8 presents a summary of data used in this analysis for each flock.

Table 8: Number of observations (N), Mean, Standard Deviation (SD), Minimum value (Min), Maximum value (Max) and Coefficient of Variation (CV) of the trait (variable) in each flock.

Variable	Flock	*N*	Mean	SD	Min	Max	CV%
BWT(kg)	**A**	*1494*	3.61	1.05	2.00	6.10	29.14
	B	*1581*	3.19	0.65	2.00	7.00	20.44
PreWG (g/day)	**A**	*1453*	263.36	84.77	54.86	492.77	32.19
	B	*1044*	320.71	87.38	109.02	600.00	27.25
PostWG (g/day)	**A**	*946*	164.92	86.54	51.02	500.00	52.47
	B	*496*	121.40	66.49	50.00	500.00	54.77
EMA (cm^2)	**A**	*499*	11.59	3.04	1.54	20.23	26.21
	B	*1595*	11.38	2.87	2.40	22.11	25.21
FAT (mm)	**A**	*496*	3.64	1.64	1.00	9.00	45.08
	B	*1594*	3.04	1.11	1.00	9.00	36.70

A multi-trait mixed model with direct, maternal and permanent environmental effects was used to estimate variance components for each of the growth and carcass traits. These variance components were then used to derive genetic and phenotypic parameters including the heritability for each trait, along with genetic and phenotypic correlations. The model assumed year of birth, age of dam at lambing, lamb year of birth, birth rank, rearing rank, sex of the lamb and management mob at birth, weaning and scanning and their interaction as fixed effects. Effects of animal, maternal and permanent environmental effects were fitted as random effects. The model used for genetic analysis had the following structure:

$$\mathbf{y}_i = \mathbf{Xb} + \mathbf{Zu} + \mathbf{Zm} + \mathbf{Zp} + \mathbf{e}$$

where **y** is the dependent variable or observation vector for the different i traits (BWT, PreWG, PostWG, EMA and FAT), **b** is the vector of fixed effects, **u** is the vector of direct additive genetic effects, **m** is the maternal additive genetic effects vector, **p** is the vector of maternal permanent environmental effects, **e** is the residual effects vector. The incidence matrix of fixed effects is **X** and **Z** is the incidence matrix relating observations to animals.

Heritabilities and correlations (genetic and phenotypic) were calculated from the (co)variances estimated using ASReml (Gilmour et al., 2009). Specific analyses were performed for each flock and for each group of traits, i.e. growth and carcass traits. The heritability and variances of the different flocks were weighted by the respective standard errors in order to generate average trait parameters. Additionally, genetic and phenotypic correlations were estimated between growth traits and between carcass traits within flocks.

A pedigree file was generated for each flock, containing sire, dam and animal ID, as well as year and flock of birth of each animal born since 2003. The information contained in the pedigree file was used to form the relationship matrix used in the calculations.

4. Results

The results of the analyses of variance which measured the significance of fixed effects and their interactions for the different traits are presented in Table 9. The factors that resulted in significant effects for the trait were incorporated into the final model. The age of the dam was significant only for flock A for all of the growth traits, whilst birth rank was significant for birth weight and pre-weaning growth rate, but not for post-weaning growth, in both flocks. The sex of the lamb had significant effects for all growth and carcass traits for both flocks, with the exception of Fat depth in flock B. The effect of year of birth was statistically significant for all of the traits in both flocks. Rearing rank (rr) was not significant for any trait.

Table 9: Variance Analysis results (F values) and tests of significance for fixed effects on traits: Birth Weight (BWT) Pre-weaning weight daily gain (PreWG); Post-weaning weight daily gain (PostWG), Eye muscle area (EMA); Fat depth (FAT).

VS	Flock	aod	br	sex	yob	rr	mobbirth	mobscan	sex*scanlw	CV %	R^2
BWT	A	8.49**	71.73**	24.45**	27.73**	-	-	-	-	23.51	0.36
	B	1.59^{ns}	45.01**	5.58*	84.69**	-	6.81**			18.09	0.22
PreWG	A	7.04**	22.13**	16.6**	18.81**	1.44 ^{ns}	-	-	-	28.22	0.25
	B	2.34 ^{ns}	13.12**	50.17**	236.30**	3.09 ^{ns}	2.09 ^{ns}			20.31	0.45
PostWG	A	3.39*	2.33 ^{ns}	23.55**	23.82**	0.26 ^{ns}	-	-	-	45.31	0.27
	B	0.19 ^{ns}	2.78 ^{ns}	15.69**	12.52**	0.83 ^{ns}	0.01 ^{ns}			52.27	0.11
EMA	A	-	-	8.29**	4.92**	-	-	18.99**	3.97**	16.74	0.75
	B	-	-	44.26**	182.77**	-		3.99*	5.5**	15.48	0.68
FAT	A	-	-	40.65**	7.75**	-	-	61.51**	1.58**	35.04	0.63
	B	-	-	3.21 ^{ns}	25.77**	-	-	0.86 ^{ns}	2.68**	30.98	0.40

VS = variation source; ** ($p<0.01$); * ($p<0.05$); ns=no significance; Environmental effects: aod=age of dam; br=birth rank; yob=lamb year of birth; rr=rearing rank; mobbirth=mob where born; mobscan=scanning mob; scanlw=lamb weight at scanning day. Traits with “-“does not have the factor in the model. R^2=Coefficient of determination of the model. CV%=Coefficient of variation of the model.

Table 10 presents the least square means for factor effects on growth and carcass traits. Overall, lambs from older ewes had higher PreWG in flock A, birth weight was higher in small litters of both flocks and females were born with lower weight than males, and also gained less weight before and after weaning.

Table 10: Least squares means and standard error of fixed effects on traits Birth Weight (BWT), Pre-weaning weight daily gain (PreWG); Post-weaning weight daily gain (PostWG); Eye muscle area (EMA) and Fat depth (FAT).

LSMeans±SE							
GROWTH		**BWT (kg)**		**PreWG (g/day)**		**PostWG (g/day)**	
Flock		A	B	A	B	A	B
aod	1	2.4±*0.2*a	2.8±*0.2*ab	181.4±*12.6*a	270.5±*29.2*a	151.3±*15.3*ab	101.1±*21.7*
	2	2.7±*0.1*b	3.0±*0.1*a	184.6±*12.7*a	324.6±*18.1*bc	162.7±*15.4*ab	111.9±*9.3*
	3	2.8±*0.1*bc	2.9±*0.1*ab	206.9±*12.4*b	309.2±*17.6*ab	146.9±*14.6*a	95.9±*9.9*
	4	2.8±*0.1*c	2.8±*0.1*b	200.8±*11.9*b	335.0±*17.2*c	167.2±*14.7*b	103.4±*8.2*
br	1	3.3±*0.1*a	3.2±*0.1*a	237.2±*9.7*ab	307.3±*7.4*a	170.2±*10.7*a	105.7±*6.4*ac
	2	2.5±*0.1*b	3.0±*0.1*b	177.6±*10.9*b	281.3±*8.5*b	145.7±*10.7*b	119.1±*7.9*b
	3	2.2±*0.1*b	2.5±*0.1*c	165.5±*26.6*a	340.9±*49.8*ab	155.1±*36.1*ab	84.5±*20.1*bc
sex	F	2.5±*0.1*a	2.8±*0.1*a	184.8±*11.6*a	297.2±*18.1*a	144.9±*14.1*a	92.1±*9.8*a
	M	2.8±*0.1*b	2.9±*0.1*b	202.1±*12.3*b	322.5±*18.2*b	169.1±*14.5*b	114.1±*9.1*b
rr	1	-	-	189.7±*12.3*	347.7±*2.8*a	151.3±*15.3*	119.2±*3.6*
	2	-	-	204.0±*12.6*	322.1±*2.8*b	156.8±*15.9*	119.1±*5.5*
	3	-	-	186.6±*16.5*	298.7±*38.9*ab	163.0±*20.8*	87.7±*45.9*
CARCASS		**EMA (cm^2)**		**FAT (mm)**			
Flock		A	B	A	B		
sex	F	11.9±*0.4*a	11.0±*0.2*a	3.8±*0.2*a	2.9±*0.1*a		
	M	11.3±*0.4*b	12.1±*0.2*b	2.8±*0.3*b	3.1±*0.1*b		

Means with different letters in the column are statistically different ($P<0.05$). Factor: aod=age of dam; br=birth rank; rr=rearing rank; sex (M=male, F= female).

4.1. Heritabilities and variance components

The estimates of heritabilities and variance components are presented in Table 11 for each flock for the various traits. Moderate estimates of direct heritabilities were found for growth and scanning traits in flock A and relatively lower heritabilities were found in flock B. Maternal heritability estimates were very low or nil for most of the traits and flocks.

Estimates of genetic variances for all of the traits varied considerably between flocks. These differences were particularly large for BWT, PostWG, EMA and FAT. The differences between flocks for phenotypic variances were smaller, especially for BWT, EMA and FAT. Between flocks, differences in phenotypic variance were large for PreWG and PostWG.

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Table 11: Heritability (h^2), genetic and phenotypic variances and standard errors (±SE) of growth and carcass traits of Dorper and Texel sheep flocks in Brazil.

	Flock	**BWT (kg)**		**PreWG (g/day)**		**PostWG (g/day)**		**EMA (cm^2)**		**FAT (mm)**	
h^2 a ±SE	**A**	0.19	*±0.19*	0.42	*±0.07*	0.42	*±0.08*	0.27	*±0.11*	0.27	*±0.09*
	B	0.08	*±0.04*	0.33	*±0.09*	0.10	*±0.10*	0.03	*±0.03*	0.09	*±0.04*
	Average	**0.10**	***±0.12***	**0.38**	***±0.08***	**0.28**	***±0.09***	**0.09**	***±0.07***	**0.15**	***±0.07***
h^2m±SE	**A**	0.03	*±0.05*	0.00	*±0.00*	0.00	*±0.00*	0.00	*±0.05*	0.00	*±0.00*
	B	0.00	*±0.00*	0.08	*±0.04*	0.00	*±0.00*	0.02	*±0.04*	0.00	*±0.00*
	Average	**0.01**	***±0.02***	**0.04**	***±0.02***	**0.00**	***±0.00***	**0.01**	***±0.04***	**0.00**	***±0.00***
σ^2g ±SE	**A**	0.15	*±0.05*	2426.92	*±469.42*	2428.61	*±517.83*	1.12	*±0.47*	0.42	*±0.15*
	B	0.03	*±0.01*	1375.32	*±405.70*	436.92	*±408.34*	0.09	*±0.11*	0.08	*±0.04*
	Average	**0.05**	***±0.03***	**1862.83**	***±437.56***	**1315.04**	***±463.08***	**0.28**	***±0.29***	**0.15**	***±0.10***
σ^2p ±SE	**A**	0.75	*±0.03*	5778.00	*±282.40*	5765.00	*±322.80*	4.09	*±0.28*	1.54	*±0.11*
	B	0.33	*±0.01*	4203.00	*±209.60*	4192.00	*±282.30*	3.21	*±0.11*	0.90	*±0.03*
	Average	**0.45**	***±0.02***	**4873.98**	***±246.00***	**4925.86**	***±302.55***	**3.47**	***±0.20***	**1.05**	***±0.07***
σ^2m±SE	**A**	0.02	*±0.04*	0.00	*±0.00*	0.00	*±0.00*	0.02	*±0.20*	0.00	*±0.00*
	B	0.00	*±0.00*	35.03	*±152.31*	0.00	*±0.00*	0.05	*±0.08*	0.00	*±0.00*
	Average	**0.01**	***±0.02***	**0.00**	***±76.16***	**0.00**	***±0.00***	**0.04**	***±0.14***	**0.00**	***±0.00***
σ^2pe±SE	**A**	0.08	*±0.04*	875.78	*±200.41*	343.79	*±210.91*	0.00	*±0.00*	0.03	*±0.06*
	B	0.01	*±0.01*	0.00	*±0.00*	157.01	*±365.14*	0.00	*±0.00*	0.00	*±0.00*
	Average	**0.02**	***±0.02***	**0.00**	***±100.20***	**275.40**	***±288.03***	**0.00**	***±0.00***	**0.01**	***±0.03***

[1] BWT = Birth Weight; PreWG = Pre Weaning Weight daily gain; PostWG = Post Weaning Weight daily gain; EMA = Eye muscle area; FAT = Fat Depth

[2] h^2=direct heritability σ^2g=genetic variability; σ^2p=phenotypic variability; σ^2m=genetic maternal variability; h^2m=genetic maternal heritability; σ^2pe= maternal permanent environment variability.

4.2. Correlations

Genetic and phenotypic correlations are presented in Table 12. Moderate to high negative estimates of genetic correlations between BWT and PreWG, and BWT and PostWG were obtained. These negative genetic correlations normally are not expected for traits that reflect body size and growth rate. All phenotypic correlations were low, except between PreWG and PostWG in flock B. The correlations between EMA and FAT were positive and moderate to high (genetic), whilst phenotypic correlations were moderate.

Table 12: Within flock genetic correlations (below diagonal) and phenotypic correlations (above diagonal) and its respective Standard error (±SE).

Growth Traits[1]	Flock	BWT		PreWG		PostWG	
BWT	**A**	-		0.05	±0.03	0.07	*±0.04*
	B	-		-0.07	*±0.01*	0.02	*±0.04*
PreWG	**A**	-0.21	*±0.17*	-		-0.05	*±0.04*
	B	-0.37	*±0.26*	-		-0.35	*±0.05*
PostWG	**A**	0.10	*±0.18*	-0.06	*±0.15*	-	
	B	-0.61	*±0.43*	-0.28	*±0.34*	-	
Scanning Traits[2]		**EMA**		**FD**			
EMA	**A**	-		0.14	*±0.05*		
	B	-		0.16	*±0.02*		
FAT	**A**	0.86	*±0.19*	-			
	B	0.26	*±0.49*	-			

[1] BWT = Birth Weight; PreWG = Pre Weaning Weight daily gain; PostWG = Post Weaning Weight daily gain;

[2] EMA = Eye muscle area; FAT = Fat depth

[3] Standard Error (±SE)

5. Discussion

In this study, birth weight direct heritability was low (0.10) but within the range found in the literature, especially considering studies that used models which accounted for maternal effects (Boujenane et al., 2015; Gholizadeh & Ghafouri-Kesbi, 2015; Mohammadi et al., 2012). It also sits within the range of birth weight heritabilities published in Safari & Fogarty (2003) literature review (0.05 to 0.39) for meat breeds. Selection for birth weight traits as recorded in these two flocks is unlikely to be effective with such low heritabilities. The heritabilities of the other growth traits, such as PreWG (0.38) and PostWG (0.28) were of moderate to high magnitude in this study. Ono (2011) reported lower heritability for PreWG (0.20) in Brazilian flocks of the same regions in similar production systems. Maxa et.al. (2007) also founded lower heritability (0.14) for PreWG in Texel flocks from Denmark with data collected between 1980 and 2004. The authors also reported low to moderate maternal heritability for the same population. El Fadili et.al, (2000) reported high heritability for PreWG (0.42) and low maternal heritability (0.08), similarly to the findings of this where data were from flocks where ewes and lambs also received concentrate supplementation prior to weaning of lambs. The maternal heritabilities evaluated for PreWG in this study for both flocks are very low or non-existent. This suggests that almost all of the additive genetic inheritance is due to direct genetic effects and that maternal effects make minimal contribution to the trait’s variability under these feeding systems.

On average, the heritabilities for PostWG found in our study are similar to those presented by (Zishiri et al., 2013) in South African Dorper flocks of 0.27, and to those presented by Safari et al. (2005) which reported similar values to meat and dual-purpose breeds of 0.28 and 0.22, respectively. Ono (2011) found a lower heritability of 0.15 for PostWG for Brazilian sheep flocks in the same region and production system, but their data did not include records from the Dorper breed. On the other hand, the heritabilities found in this study are different between the flocks. The Dorper breed flock (Flock A) had the higher heritability for PostWG (0.42), while the Texel flock had a much lower heritability of 0.10 for the same trait. While sampling error may have contributed to the different results for the two flocks, different breed and different population structure could also be contributing factors.

This study found low heritabilities for EMA (0.09) and FAT (0.15) when estimates were averaged between the flocks relative to findings from other studies reported in the literature. The heritabilities of EMA and FAT reported by Ono (2011) for similar Brazilian sheep flocks were 0.18 and 0.10, respectively. However, the heritabilities of both EMA and FAT reported in this study for flock A (0.27) were closer to the heritabilities reported by Karamichou et al. (2007) of 0.38 for EMA and 0.30 for FAT. As well as PostWG, EMA and FAT heritabilities were higher in the Dorper flock and lower in the Texel flock, reinforcing the large differences in genetic parameter estimates between the flocks.

The magnitude of phenotypic variation was similar for both flocks for all traits. Thus, the differences in heritability observed were due to differences in the magnitudes of genetic variances. The amount of genetic variation estimated for both flocks for growth and carcass traits means that selection should be effective for both, however, higher heritabilities and genetic variances of flock A are likely to result in faster genetic gain comparing to flock B. The similarities in management and farming conditions are not enough to offset the differences in the genetic makeup of the flocks.

Moderate to high negative genetic correlations were found between BWT and PreWG, (-0.21 and -0.37 in flocks A and B respectively). Ono (2011) founded positive correlations between these traits in his study (0.79), and Safari et al. (2005) found an average genetic correlation of 0.45 between weaning weight and birth weight in a review of a large number of studies from the literature. The genetic correlations between pre and post weaning growth found in our study were also negative. In contrast, the review of Safari et al. (2005) reported positive genetic correlations between BWT and PostWG (0.28) and between PreWG and PostWG (0.85). Within flocks in this study, contrasting genetic correlations among traits were estimated. In flock A, the low correlations between growth traits show that these traits minimally influence each other. In contrast, corresponding estimates of correlations in Flock B were stronger and negative which could suggest that animals with low birth weight would have high PreWG and PostWG, but also that animals with high PreWG would have low PostWG. The opposite could also be true, assuming that lambs eating large amounts of concentrate during the lactation period are less likely to rely on their mothers' milk ability, and are probably already adapted to high concentrate diets when weaned. However, the standard errors of the genetic correlations in both flocks are very high and perhaps the quantity of data in each flock wasn´t sufficiently robust to detect and quantify the extent of lambs' milk dependence during lactation, and consequently, to measure these genetic correlations accurately.

Genetic and phenotypic correlations for carcass traits show that EMA and FAT will increase in the same direction when selection is carried out for these traits. Safari et al. (2005) reported a high positive correlation between EMA and FAT measured by ultrasound scanning (0.40), similar to Ono (2011) and Gilmour et al. (1994), which found a genetic correlation of 0.37 between these traits, suggesting that selection for EMA will increase FAT and vice-versa.

In this study, maternal effects were not significantly different from zero for most of the traits. For lambs which are receiving creep feeding at this early age, during lactation, maternal effects may not be present, because any deficiencies in, for example, milk production of ewes will be offset by the lambs that are drinking less milk consuming more concentrate. Ghafouri-Kesbi & Eskandarinasab (2008) evaluating maternal effects in growth detected that lambs receiving a limited supply of ewe's milk may be encouraged to start eating creep feeding earlier and in such situations the importance of milk decreased more rapidly when compared to lambs that weren't offered concentrate, leading to a smaller estimate of maternal heritability at weaning. This is similar to the findings of this study. In both flocks, the reliance on creep-feeding supplements might explain the negative correlations among growth traits, and the absence of maternal effects.

In the context of the Brazilian sheep production chain, there will be an absence of records of maternal performance of the ewes when performance recording flocks have high rates of creep feeding simultaneously as lambs are suckling. To allow selection on maternal weaning gain, it might therefore be necessary to feed less concentrates to lambs. Barros et al., (2009) argue that rearing lambs in creep feeding systems in Brazil is not viable, but never-the-less, it is a common practice among Brazillian sheep farmers who enjoy relatively high prices for lamb. It is more economical to supplement lambs, rather than the lactating ewes (Neiva et al., 2003), and when forage for lactating ewes is limited in availability, farmers are reluctant to depend on milk production for growth of lambs.

The Brazilian sheep industry is currently based on production systems for meat production. Sheep farming needs to be supported by well-designed genetic improvement programs that involve production traits such as growth, carcass and reproduction, to increase meat quality and productivity. Phenotypic selection for growth and visual predictions of carcass traits has typically been relied on for genetic progress in the Brazilian sheep industry. While this is likely inefficient compared with selection based on estimated breeding values, it is also likely to have limited improvements in other important traits such as reproduction, survival and resistance to diseases. There is a risk of perpetuation of an undeveloped industry if selection continues to be based only on morphological or phenotypic criteria, without appropriated technical justification. Therefore, the genetic parameters estimated in this study can be used to provide more accurate selection tools, such as estimated breeding values, to all rams and ewes available to the market.

6. Conclusion

It is possible to identify genetic variation for growth and carcass predictor traits in performance recording sheep breeding flocks in Brazil. However, the genetic variation in maternal traits appears to be masked by the high rates of creep feeding. Also the magnitude of heritabilities observed differed substantially between the two studied flocks that were of different breeds. Based on the results of this study, in which phenotypically similar flocks are genetically different, it is important to highlight the need to evaluate genetic parameters in order to obtain accurate genetic evaluations and improve selection effectiveness.

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APPENDIX

1. Appendix I: Programmes

1.1. Summary of the main programmes and public research institutes:

- Pirarucu da Amazônia – Research Actions and Technology Transfer – EMBRAPA

This important project is already under development in the Amazon region with native species Pirarucu (*Arapaima gigas*) since February 2013. The project is expected to end in January 2016 (EMBRAPA, 2013). This scientific research project includes genetics and reproductive investigation, as well as nutrition, health and overall farming practices.

Contacts

Project Leader: Adriana Ferreira Lima
E-mail: adriana.lima@embrapa.br

- Mapping of Tambaqui (Colossoma macropomum) Genome – INPA (Amazon National Research Institute)

Responsible researcher: Vera Val/ Jorge Porton (INPA)/ Sérgio Nozawa (UniNilton Lins).

- AquiNordeste (SEBRAE)

Amongst a number of other areas, genetic improvement of oyster is part of this project, which intends to promote the breeding of the native oyster species, *C. brasiliana and C.rhizophora,* and stimulate the oyster seed production.

This project is coordinated by Sebrae in eight states (Sergipe, Bahia, Alagoas, Paraíba, Ceará, Rio Grande do Norte, Piaui e Maranhão). It prioritizes small holding farmers, artisanal fisherman and entrepreneurs within the supply chain. The project has also proposed to establish demonstration units for breeding of oyster, Tilapia and Tambaqui (SEBRAE, 2015)

- AQUABRASIL Project (Embrapa)

Project Leader: Emiko Kawakami de Resende

The general goal of this large project was "produce the technical and scientific basis for the development of aquaculture agribusiness in a sustainable basis, from selected species".

The project was based in four important action plans:

I. Genetic improvement program to GIFT Tilapia and dissemination of the breed lines. **Execution: Maringá Estate UniversityParaná state.Responsible researcher: Ricardo P. Ribeiro/ Emiko K. de Resende/ Julio Queiroz.**

II. Genetic improvement of Tambaqui at Amazon Basin**. Execution: Fish production station of Balbina Hydroeletric – Amazônia (North). Responsible researcher: Ricardo P. Ribeiro/ Roger Crescencio/ Marcos Tucunduva/ Angela P Legat (UEM).**

III. Initial stage of genetic improvement of Pintado for increased growth rate. **Execution: Experimental Aquaculture Station of Mato Grosso do Sul Federal University (Midwest), in partnership with private owned initiative "Projeto Pacu", "Mar e Terra" and "Piraí Piscicultura". Responsible researcher: Celso Benites/ Ricardo Ribeiro/ Emiko K. de Resende/ Hamilton Hisano/ Angela P. Legat.**

IV. Genetic improvement program of the *Litopenaeus vannamei* shrimp forresistance**. Execution: Embrapa Meio Norte in partnership with Northeastern university's such as UEC, UFRP and UFRN. Responsible reasearcher: Angela P. Legat/ Rodrigo Maggioni/ Wagner F. Molina/ Maria Raquel M. Coimbra/ Atiliene L. Pereira.**

This was the first initiative towards genetic improvement of aquatic species in Brazil. Among other outcomes from the project, the most prominent results were obtained on GIFT Tilapia: 28% increase in growth rate and consequent 17 days decrease in the average cultivating time on floating cages was achieved. This project has already finished, but the group PeixeGen, in the Maringá University (UEM) in Paraná, led by Ricardo Pereira Ribeiro still works with Genetic Improvement of GIFT Tilapia in the same line of research.

1.2. Summary of the main farming private operations and corporates operating in aquaculture in Brazil

- NATIV – Indústria de pescados Amazônicos Ltda.

NATIV is a privately owned company located in Sorriso, Mato Grosso state (Midwest region). The company has about 200 ha of water surface where species such as Pintado, Suribin, Tambaqui and Tilápia are farmed(NATIV, 2015). The company has established their own hatchery lab, where they produce Pintado da Amazônia to supply their own operation and associated farmers. The whole system is based on electronic identification of the parent fish.

NATIV works in a vertically integrated supply chain, which includes farming, processing and distribution. Their processing plant is still understocked and the company is therefore focusing in the integration of other producers in the region(NATIV, 2015).

NATIV has received about US$60 million from a private equity fund, administrated by Global Equity, which buy holdings in companies. In 2013 annual income was estimated about US$ 10 million (Valor Econômico, 2013). The company aims on achieving a turnover of U$ 200 M by 2019.

Technologies currently used:

- Brood-stock caught from the wild with permit of responsible environmental agencies;
- Receive identification chip;
- Crossbreeding between Cachara and Jundiá:

Cachara (calm fish) X Jundiá (does not eat other fish) =
Amazon Pintado (Hybrid with small head, calm and less aggressive)

- Weekly monitoring of breeding females – egg quality analysis;
- Vertically integrated supply chain: farming, processing and distribution
- There is a reproduction unity in the farm with 83 excavated ponds to fingerling production.
- Traceability system in reproduction sector using software to record:
    - Time of fingerling production;
    - Parentage;
    - Growth;
    - Feeding;
    - Slaughter age;
    - Production;
    - Client specification.

Contacts

http://www.nativpescados.com.br/nativ2009/Default.aspx
Founder: Pedro Furlan Uchoa Cavalcanti
Controler: Global Equity
E-mail: snac@nativpescados.com.br

Slaughter/processing plant address
Avenida Attílio Fontana, nº 471 - Distrito Industrial Novo Tempo
CEP: 78890-000 - Sorriso - MT (Caixa postal 1064)
Phone: 55-66-3545-4300

Tecnological center address
Rodovia Estrada MT 404 A 35 KM da BR 163 + 4KM a direita, S/N
CEP: 78890-000 - Zona Rural - Sorriso – MT

- Delicious Fish – Indústria e Comécio de pescados Ltda.

Delicious Fish is part of the Gaspar Group, also in Sorriso city. Its total production is about 3,000 ton of fish per year. As NATIV, Delicious Fish has its own hatchery and slaughter/processing plant. The plant processes the groups own production and the production of more than 30 partners. Delicious Fish also produces the feed used in the aquaculture farms.

Species raised in the farm are Pintado da Amazônia, Tambacu e Tambatinga, and the company is currently considering to work with Pirarucu. In partnership with Embrapa, Delicious Fish was part of the Aquabrasil project, aiming to have access to genetic improvement in the long term.(Delicious Fish, 2015)

Technologies currently used:

- Base of Embrapa (Aquabrasil) experiments since 2008.
- Fingerling reproduction lab (60 hatcheries and 40 boxes just for Aquabrasil Tambaqui and Cachara projects).
- Brood-stock caught in the wild to be multiplied at laboratory.
- Start Pirarucu fingerling captive production in 2009.
- Semen cryopreservation.
- Families separation structure
- Electronic microchip for individual identification of fish.
- Embrapa coordenates the breeding programmes for native species such as Tambaqui (Colossoma macropomum) and Cachara (Pseudoplatystoma reticulatum).
- Selection of animals based on growth EBV’s.
- In 2013 there were 64 Tambaqui families and 71 Cachara families formed using genetic material exchange between many partners of the project spread across the country.
- Molecular genetics technology used to evaluate the genetic variance of selected brood-stock.
- (Oliveira & Ribeiro, 2012)
- The program is finished, and there’s fewer information available on the currently situation of the program.
- Currently, Delicious Fish receives technical assistance of a private consultancy company called Genetic Fish Rise (http://geneticfish.com.br), coordinated by the same researchers leading the Aquabrasil project.

Contact

http://www.deliciousfish.com.br/
Founder: João Pedro da Silva
E-mail: deliciousfish@deliciousfish.com.br
Address: Rod BR 163, km 702, Distrito de Primavera do Norte
CEP: 78890-000.
Sorriso – MT - Brasil

- Colpani

Similarly to NATIV and Delicious Fish, COLPANI is a fully integrated supply chain, but based in São Paulo state. Besides their hatcheries, fish feed industry, slaughter and process plants, the company also own a fast-food franchise called Colpani Fish Grill.

COLPANI the unique in the country with permit to export Pirarucu. The company also produces other species such as Tilapia, Dourado and Pintado. (Colpani, 2015)

Technologies currently used:

- Fingerling production laboratory (total control of all farming phases until distribution)
- Technology applied in production and reproduction of main migrating fish species;
- Development of Pirarucu production and reproduction methodologies
- Multiplication of genetically improved Tilapia (acquiring brood-stock of families improved in Maringá University).

Contacts
http://www.colpanipescados.com.br/
Founder: Martinho Colpani and Thiago Colpani (Family business)
Responsible for Tilapia Genetic Improvement: Pedro Claudio Azevedo.
E-mail: contato@grupoaguasclaras.com.br
Address: Estr. Dr. Gentil Ferreira da Silva - Mococa - SP, CEP:13733-340
Phone: (19) 3665-6911

- Mar & Terra

The company is a vertically integrated operation located at Mato Grosso do Sul state (Midwest Brazil). With investments from international groups, the company exporting significant amounts of fish to USA, Japan and Europe. The company has its own multiplication programme, which is probably limited to identification of parent fish, phenotypic selection and multiplication of juveniles to their operations and to the market. The company has received considerable investments from Axial, a venture capital fund that specializes in promoting investments in sustainability and monitoring the management of innovative business. The company Tilabras is a new company formed by the association of Axial Holding (represented by Mar e Terra in Brazil) with Regal Springs.

Technologies currently used:

- Total traceability across entire production process.
- All breeding stock is identified by microchips
- Reproduction laboratory to increase fingerlings production, with highlight to Pirarucu and Pintado fingerling production. (400 females of Pintado and 130 females of Pirarucu).
- Development of alternative techniques to control diseases, like probiotics and vaccines.
- Development of balanced diets according to phases of breeding.
- Enable to export Pirarucu fingerlings.

Contacts

http://www.mareterra.com.br/site/empresa.asp?lang=in
http://www.axialpar.com.br/index_view.asp?lang=en

- Aquabel

Aquabel produces and distributes Nile Tilapia fingerlings across Brazil. They are based in Rolândia, Paraná state but own five productions units distributed in the country. During ten years they were in a partnership with GenoMar ASA (http://www.genomar.no/) and today they hold their own Tilapia line called “Tilapia Premium Aquabel”.

Currently, Aquabel maintains a partnership with the Chilean company Aquainnovo (http://www.aquainnovo.net/), and together they built the new unit of research and development aiming genetic improvement of fish in Brazil.

Technologies currently used:

- Artificial incubation of the eggs and 100% sexual reversion technology applied in the fingerlings
- Greenhouse utilization to produce fingerlings during winter
- Utilization of genetic selected brood-stock
- Traceability by DNA
- Responsible for importation of several lines and breeds of fish to the country

Contacts

http://www.aquabel.com.br/
Aquabel Piscicultura
Phone 55 (43) 3255-1555
e-mail: aquabel@aquabel.com.br
Adress: Caixa Postal 08 - Cep. 86600-000
Rolândia - Paraná

- Rio doce Piscicultura.

With base in Aguaí SP, they produce fingerlings, juveniles and adults of several species such as Nile Tilapia, Tambaqui, Tambacu, Curimbatá, Lambari, Pintado, Pirarucu and another source of species used in Brazilian freshwater aquaculture.

Technologies currently used:

- Environmental control in the reproduction and growth structure to fingerlings.

Contacts

Phone: 55 (19) 3633-2044/3633-8587
Skype: riodocepiscicultura
e-mail: contatos@riodocepiscicultura.com.br
contatos@riodocespeixes.com.br
web site: http://www.riodocepiscicultura.com.br/

- Aquatec Ltda

Aquatec Ltda is the main company in Brazil responsible to provide post-larvae shrimp (*Litopenaeus vannamei*). Operating since 1989, this company has helped the development of shrimp industry in the country. In 1998 they stablished a genetic improvement program to *L. vannamei* in Brazil. Currently they have special lines of shrimp available in the market, free of pathogens and fast growth.

Production capacity is around 300 million post-larvae units per month in the base structure in Barra da Cunhaú, Canguaretam, Rio Grande do Norte state.

Since 2006 they have a filial called Genearch Aquaculture Ltda with special focus on research of genetic improved lines of shrimp. http://www.genearch.com.br/.

Technologies currently used:

- High control of the parentage to reduce inbreeding in their shrimp farms and their clients.
- Three differentiated products (lines) of shrimp in the market
- Environmental controll of brood-stck production to avoid pathogens in the whole production (high control and sanitary monitoring).
- Own fleet with all the equipment needed to delivery of the products.
- Pedigree control of the founder families

Contacts

Adress: Av. do Pontal S/N - Barra de Cunhau - Canguaretama, RN, 59190-000
Phone: (84) 3241-5200
Web site: http://aquatec.com.br/
How genetic improvement can be a valuable tool and product for aquaculture supply chain development

2. Appendix II: Approaching document sent to Mar & Terra

“To Mar & Terra

Arno Soares Seerig (Production Manager) and the company’s board

The Issue: Opportunity cost of non-optimal production and disconnected breeding programme

The Solution: A programme to optimize production and support marketing through breeding and genetics

Scale of Benefit: Fully integrated system to transform business profitability and brand positioning in the market

Our proposition

There is opportunity to use sustainable genetic improvement principles to promote authentic high quality brand presence in the market through improved quality of fish and higher productivity in aquaculture. AbacusBio is seeking a partnership with a leading privately owned company in Brazil to explore this substantial opportunity, considering the country’s environmental conditions for aquaculture and its market potential.

Business initiatives such as Mar & Terra, supplying aquaculture species in the form of differentiated new products, highly appreciated by consumers, could use a genetic selection strategy to improve eating quality, make a positive impact on the conservation of native species, and demonstrate stewardship of the environment.

Based on our experience, it is realistic to expect that a 5% increase in revenue and a 5% reduction in costs can be achieved by an efficient and sustainable genetic improvement program.

Our track record

AbacusBio works in partnership with companies to add value to their business through genetic improvement. Ōra King is a case where this concept has proven successful. The brand is owned by New Zealand King Salmon (NZKS, http://www.kingsalmon.co.nz/). The business produced 7,000 tonnes of saleable product in 2014, with an average market value of U$ 17 per kg. The company´s selective breeding has created a genetically distinct breed which has become its strongest proposition (i.e. Ōra King, http://orakingsalmon.co.nz/our-story/) and main vehicle connecting NZKS with premium menus around the world. The program supports the story about New Zealand in general, and its values highlight the great quality of products, the landscape where it is farmed, and the clean-and-green concept. AbacusBio has been working with the NZKS breeding programme since its inception in the late 1990’s in the development, implementation and monitoring of the breeding programme. We have also developed a system that allows selection of superior brood-stock through integration, in multiple levels, of real time key information on fish performance, pedigree (i.e. family formation) and harvest statistics.

AbacusBio also works with other aquaculture businesses to establish well-structured breeding programmes enabling high economic returns for vertically integrated value chains of aquatic species in New Zealand. Hapuku and King Fish are examples of cases in which small breeding programmes support these native marine species of fin fish for domestication and efficient farming production. This work is being led by the National Institute for Water and Atmospheric Research (NIWA) in New Zealand. The biggest challenge, in these cases, was to balance the trade-off between appropriate rates of genetic progress whilst maintaining genetic diversity. These fish are large at maturity, and infrastructural demands make existing programmes used for commercial breeding of smaller species such as salmon, completely unrealistic. A cornerstone of these emerging industries is their successful breeding programmes, which enhance business profitability in the short, medium and long term by properly selecting, preserving and promoting these native species. The Hapuku and King Fish are fledgling emerging industries expected to improve returns on exports and targeted to introduce great products to high end consumers around the world.

The opportunity

Mar & Terra operates a fully integrated value chain of different native fish species, from the farm to the end consumer. Mar & Terra stands out for marketing products with high standards of quality, in an economically viable, socially just and environmentally conscious way, meeting the requirements of the most demanding markets in the world. This demands proper strategies to overcome production issues and achieve higher profitability, enabling better control of the process and higher quality of produce. In spite of the company’s leading position in the market and its well-structured business, there might be technical issues faced by Mar & Terra that influence the whole operation:

1- Exploitation and management of genetic resources of native fish species, supporting full expression of production potential as well as controlling non-desirable levels of inbreeding and sub-optimal productivity rates.
2- Connection between available genetic resources and aspects of value to the market. There is need to appropriately define breeding objectives which connect farming and economics principles to the market expectations through genetics.
3- Need to associate principles of genetic improvement with the sustainability story and tell the story to the market. High quality native species produce, farmed in an environmentally friendly production system, attending the demand of high-end consumers, is a story that should be underpinned by breeding tools and systems, in vertically integrated aquaculture value chains.
4- Use data generated from appropriate identification of the best individuals and families, capable of generating increased farming production, which is directly connected with trait measurements and pedigree records.
5- Feed conversion is the most important trait of selection in fish, and probably the principal cost component of the production system. However, its relationship with other traits has to be balanced through the breeding programme, increasing performance in desirable traits by 5% per year while minimising detrimental changes in antagonistic traits.

The practice of electronic tagging in fish allows tracking and reliable identification of brood-stock, and these systems are present in the current structure of Mar & Terra. The identification of individual fish forms the basis to associate genetic relationships and trait performance, which combined through their economic values can be used to predict progress in productivity. The definition of the breeding objective underlies the design of the breeding programme and encompasses the main issues faced by other aquaculture industries around the world. The most appropriate solutions are frequently associated with approaches that involve the overall efficiency of vertically integrated value chains.

AbacusBio is interested in working with Mar & Terra and adding value to the remarkable work developed by the company to date, through our technology and expertise. Our scientific expertise and our understanding of Brazilian agribusiness will lead to the development of a high standard breeding program in conjunction with Mar & Terra.

Considering the estimated Mar & Terra volume sold and market price, based on our experience, it is reasonable to predict an average 5% increase in sale value due to brand strengthening around sustainable breed conservation and enhancement, and a 5% reduction in costs of production, on an annual basis. Genetic improvement results are long-term and benefits are cumulative, both important aspects to understand how an investment of this nature might pay off.

Next steps

AbacusBio is interested to further discuss options to develop these business opportunities. There would be need to acquire better understanding of your company’s operations and, together with Mar & Terra, carry out the development of an underlying programme plan. The plan should consider important matters such as objectives, goals, and timeframes, as well as necessary investment and expected returns, current infrastructure and systems to be created, and an overview of the practical implementation of the programme.

Bruno Santos, David Band, Marina Souza and Peter Amer

AbacusBio Limited

Dunedin, 23rd September 2015

www.abacusbio.co.nz”